

THE EXPERT'S VOICE® IN COBOL

Beginning COBOL for Programmers

*A TUTORIAL AND MODULAR REFERENCE
ON COBOL FOR ESTABLISHED
PROGRAMMERS*

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CHAPTER 1



Introduction to COBOL

When, in 1975, Edsger Dijkstra made his comment that “The use of COBOL cripples the mind; its teaching should, therefore, be regarded as a criminal offence,¹” he gave voice to, and solidified, the opposition to COBOL in academia. That opposition has resulted in fewer and fewer academic institutions teaching COBOL so that now it has become difficult to find young programmers to replace the aging COBOL workforce.²⁻³ This scarcity is leading to an impending COBOL crisis. Despite Dijkstra’s comments and the claims regarding COBOL’s imminent death, COBOL remains a dominant force in the world of enterprise computing, and attempts to replace legacy COBOL systems have been shown to be difficult, dangerous, and expensive.

In this chapter, I discuss some of the reasons for COBOL’s longevity. You’re introduced to the notion of an application domain and shown the suitability of COBOL for its target domain. COBOL is one of the oldest computer languages, and the chapter gives a brief history of the language and its four official versions. Later, the chapter presents the evidence for COBOL’s dominance in enterprise computing and discusses the enigma of its relatively low profile.

An obvious solution to the scarcity of COBOL programmers is to replace COBOL with a more fashionable programming language. This chapter exposes the problems with this approach and reveals the benefits of retaining, renovating, and migrating the COBOL code.

Finally, I discuss why learning COBOL and having COBOL on your résumé could be useful additions to your armory in an increasingly competitive job market.

What Is COBOL?

COBOL is a high-level programming language like C, C#, Java, Pascal, or BASIC, but it is one with a particular focus and a long history.

COBOL’s Target Application Domain

The name COBOL is an acronym that stands for **Common Business Oriented Language**, and this expanded acronym clearly indicates the target domain of the language. Whereas most other high-level programming languages are general-purpose, domain-independent languages, COBOL is focused on business, or enterprise, computing. You would not use COBOL to write a computer game or a compiler or an operating system. With no low-level access, no dynamic memory allocation, and no recursion, COBOL does not have the constructs that facilitate the creation of these kinds of program. This is one of the reasons most universities do not teach COBOL. Because it cannot be used to create data structures such as linked lists, queues, or stacks or to develop algorithms like Quicksort, some other programming language has to be taught to allow instruction in these computer science concepts. The curriculum is so crowded nowadays that there is often no room to introduce two programming languages, especially when one of them seems to offer little educational benefit.

Although COBOL's design may preclude it from being used as a general-purpose programming language, it is well suited for developing long-lived, data-oriented business applications. COBOL's forte is the processing of data transactions, especially those involving money, and this focus puts it at the heart of the mission-critical systems that run the world. COBOL is found in insurance systems, banking systems, finance systems, stock dealing systems, government systems, military systems, telephony systems, hospital systems, airline systems, traffic systems, and many, many others. It may be only a slight exaggeration to say that the world runs on COBOL.

COBOL's Fitness for Its Application Domain

What does it mean to say that a language is well suited for developing business applications? What are the requirements of a language working in the business applications domain? In a series of articles on the topic, Professor Robert Glass⁴⁻⁷ concludes that such a programming language should exhibit the following characteristics:

- *It should be able to declare and manipulate heterogeneous data.* Unlike other application domains, which mainly manipulate floating-point or integer numbers, business data is a heterogeneous mix of fixed and variable-length character strings as well as integer, cardinal, and decimal numbers.
- *It should be able to declare and manipulate decimal data as a native data type.* In accounting, bank, taxation, and other financial applications, there is a requirement that computed calculations produce *exactly* the same result as those produced by manual calculations. The floating-point calculations commonly used in other application domains often contain minute rounding errors, which, taken over millions of calculations, give rise to serious accounting discrepancies.

■ **Note** The requirement for decimal data, and the problems caused by using floating-point numbers to represent money values, is explored more fully later in this book.

- *It should have the capability to conveniently generate reports and create a GUI.* Just as calculating money values correctly is important for a business application, so is outputting the results in the format normally used for such business output. GUI screens, with their interactive charts and graphs, although a welcome addition to business applications, have not entirely eliminated the need for traditional reports consisting of column headings, columns of figures, and a hierarchy of subtotals, totals, and final totals.
- *It should be able to access and manipulate record-oriented data masses such as files and databases.* An important characteristic of a business application programming language is that it should have an external, rather than internal, focus. It should concentrate on processing data held externally in files and databases rather than on manipulating data in memory through linked lists, trees, stacks, and other sophisticated data structures.

In an analysis of several programming languages with regard to these characteristics, Professor Glass⁶ finds that COBOL is either strong or adequate in all four of these characteristics, whereas the more fashionable domain-independent languages like Visual Basic, Java, and C++ are not. This finding is hardly a great surprise. With the exception of GUIs and databases, these characteristics were designed into COBOL from the outset.

Advocates of domain-independent languages claim that the inadequacies of such a language for a particular application domain can be overcome by the use of function or class libraries. This is partly true. But programs written using bolted-on capabilities are never quite as readable, understandable, or maintainable as programs where these capabilities are an intrinsic part of the base language. As an illustration of this, consider the following two programs: one program is written in COBOL (Listing 1-1), and the other is written in Java (Listing 1-2).

Listing 1-1. COBOL Version

```

IDENTIFICATION DIVISION.
PROGRAM-ID. SalesTax.
WORKING-STORAGE SECTION.
01 beforeTax    PIC 999V99 VALUE 123.45.
01 salesTaxRate PIC V999  VALUE .065.
01 afterTax     PIC 999.99.
PROCEDURE DIVISION.
Begin.
  COMPUTE afterTax ROUNDED = beforeTax + (beforeTax * salesTaxRate)
  DISPLAY "After tax amount is " afterTax.

```

Listing 1-2. Java Version (from http://caliberdt.com/tips/May03_Java_BigDecimal_Class.htm)

```

import java.math.BigDecimal;
public class SalesTaxWithBigDecimal
{
    public static void main(java.lang.String[] args)
    {
        BigDecimal beforeTax    = BigDecimal.valueOf(12345, 2);
        BigDecimal salesTaxRate = BigDecimal.valueOf(65, 3);
        BigDecimal ratePlusOne  = salesTaxRate.add(BigDecimal.valueOf(1));
        BigDecimal afterTax     = beforeTax.multiply(ratePlusOne);
        afterTax = afterTax.setScale(2, BigDecimal.ROUND_HALF_UP);
        System.out.println( "After tax amount is " + afterTax);
    }
}

```

The programs do the same job. The COBOL program uses native decimal data, and the Java program creates data-items using the bolted-on `BigDecimal` class (itself an acknowledgement of the importance of decimal data for this application domain). The programs are presented without explanation (we'll revisit them in Chapter 12; and, if you need it, you can find an explanation there). I hope that, in the course of trying to discover what the programs do, you can agree that the COBOL version is easier to understand—even though you do not, at present, know any COBOL but are probably at least somewhat familiar with syntactic elements of the Java program.

History of COBOL

Detailed histories of COBOL are available elsewhere. The purpose of this section is to give you some understanding of the foundations of COBOL, to introduce some of the major players, and to briefly describe the development of the language through the various COBOL standards.

Beginnings

The history of COBOL starts in April 1959 with a meeting involving computer people, academics, users, and manufacturers to discuss the creation of a common, problem-oriented, machine-independent language specifically designed to address the needs of business⁸. The US Department of Defense was persuaded to sponsor and organize the project. A number of existing languages influenced the design of COBOL. The most significant of these were AIMACO (US Air Force designed), FLOW-MATIC (developed under Rear Admiral Grace Hopper) and COMTRAN (IBM's COMmercial TRANslator).

The first definition of COBOL was produced by the Conference on Data Systems Languages (CODASYL) Committee in 1960. Two of the manufacturer members of the CODASYL Committee, RCA and Remington-Rand-Univac, raced to produce the first COBOL compiler. On December 6 and 7, 1960, the same COBOL program (with minor changes) ran on both the RCA and Remington-Rand-Univac computers.⁸

After the initial definition of the language by the CODASYL Committee, responsibility for developing new COBOL standards was assumed by the American National Standards Institute (ANSI), which produced the next three standards: American National Standard (ANS) 68, ANS 74, and ANS 85. Responsibility for developing new COBOL standards has now been assumed by the International Standards Organization (ISO). ISO 2002, the first COBOL standard produced by this body, defines the object-oriented version of COBOL.

COBOL Standards

Four standards for COBOL have been produced, in 1968, 1974, 1985, and 2002. As just mentioned, the most recent standard (ISO 2002) introduced object orientation to COBOL. This book mainly adheres to the ANS 85 standard; but where this standard departs from previous standards, or where there is an improvement made in the ISO 2002 standard, a note is provided.

The final chapter of the book previews ISO 2002 COBOL. In that chapter, I discuss why object orientation is desirable and what new language elements make it possible to create object-oriented COBOL programs.

COBOL ANS 68

The 1968 standard resolved incompatibilities between the different COBOL versions that had been introduced by various producers of COBOL compilers since the language's creation in 1960. This standard reemphasized the *common* part of the COBOL acronym. The idea, contained in the 1960 language definition, was that the language would be the same across a range of machines.

COBOL ANS 74 (External Subprograms)

The major development of the 1974 standard was the introduction of the CALL verb and external subprograms. Before ANS 74 COBOL, there was no real way to partition a program into separate parts, and this resulted in the huge monolithic programs that have given COBOL such a bad reputation. In these programs, which could be many tens of thousands of lines long, there was no modularization, no functional partitioning, and totally unrestricted access to any variable in the Data Division (more on divisions in Chapter 2).

COBOL ANS 85 (Structured Programming Constructs)

The 1985 standard introduced structured programming to COBOL. The most notable features were the introduction of explicit scope delimiters such as END-IF and END-READ, and contained subprograms. In previous versions of COBOL, the period (full stop) was used to delimit scope. Periods had a visibility problem that, taken along with the fact that they delimited all open scopes, was the cause of many program bugs. Contained subprograms allowed something approaching procedures to be used in COBOL programs for the first time.

COBOL ANS 2002 (OO Constructs)

Object orientation was introduced to COBOL in the ISO 2002 standard. Whereas previous additions had significantly increased the huge COBOL reserved word list, object orientation was introduced with very few additions.

The Argument for COBOL (Why COBOL?)

As you’ve seen, COBOL is a language with a 50-year history. Many people regard it as a language that has passed its sell-by date—an obsolete language with no relevance to the modern world. In the succeeding pages, I show why, despite its age, programmers should take the time to learn COBOL.

Dominance of COBOL in Enterprise Computing

One reason for learning COBOL is its importance in enterprise computing. Although the death of COBOL has been predicted time and time again, COBOL remains a dominant force at the heart of enterprise computing. In 1997, the Gartner group published a widely reported estimate that of the 300 billion lines of code in the world, 240 billion (80%) were written in COBOL.⁹ Around the same time, Capers Jones¹⁰ identified COBOL as the major programming language in the United States, with a software portfolio of 12 million applications and 605 million function points. To put this in perspective, in the same study he estimated that the combined total for C and C++ was 4 million software applications and 261 million points. According to Jones, each function point requires about 107 lines of COBOL; so, in 1996, the software inventory for the United States contained about 64 billion lines of COBOL code. Extrapolating for the world, the Gartner estimate does not seem outside the realms of possibility.

Of course, the 1990s were a long time ago, and in 1996/97, Java had just been created. You might have expected that as Java came to the fore, COBOL would be eclipsed. This did not happen to any significant extent. Much new development has been done in Java, but the existing inventory of COBOL applications has largely remained unaffected. In an OVUM report in 2005,¹¹ Gary Barnett noted, “Cobol remains the most widely deployed programming language in big business, accounting for 75% of all computer transactions” and “90% of all financial transactions.” In that report, Barnett estimated that there “are over 200 billion lines of COBOL in production today, and this number continues to grow by between three and five percent a year.”

Even today, COBOL’s position in the domain of business computing does not seem to be greatly eroded. In a survey of 357 IT professionals undertaken by *ComputerWorld* in 2012,^{2, 12} 54% of respondents said that more than half of all their internal business application code was written in COBOL. When asked to quantify the extent to which languages were used in their organization, 48% said COBOL was used frequently, while only 39% said the same of Java. And as the 2005 OVUM report¹¹ predicted, new COBOL development is still occurring; 53% of responders said that COBOL was still being used for new development in their organization. Asked to quantify what proportion of new code was written in COBOL 27% said that it was used for more than half of their new development.

Although only tangentially relevant to the issue of COBOL’s importance in business computing, one other item of interest came out of the *ComputerWorld* survey.^{2, 12} Responders were asked to compare Visual Basic, C#, C++, and Java to COBOL for characteristics such as batch processing, transaction processing, handling of business-oriented features, runtime efficiency, security, reporting, development cost, maintenance cost, availability of programmers, and agility. In every instance except the last two, COBOL scored higher than its more recent counterparts.

Finally, in a May 2013 press release, IBM noted that nearly 15% of all new enterprise application functionality is written in COBOL and that there are more than “200 billion lines of COBOL code being used.”¹³

Danger, Difficulty, and Expense of Replacing Legacy COBOL Applications

The custodians of legacy systems come under a lot of pressure to replace their legacy COBOL code with a more modern alternative. The high cost of maintenance, obsolete hardware, obsolete software, the scarcity of COBOL programmers, the need to integrate with newer software and hardware technologies, the relentless hype surrounding more modern languages—these are all pressures that drive legacy system modernization in general and language replacement in particular. How is it then that the COBOL software inventory seems largely unchanged?

When a legacy system is considered for modernization, a number of alternatives might be considered:

- Replacement with a commercial off-the-shelf (COTS) package
- Complete rewrite

- Automatic language conversion
- Wrapping the legacy system to present a more modern interface
- Code renovation
- Migration to commodity hardware and software

The problem is, experience shows that most modernization attempts that involve replacing the COBOL code fail. Some organizations have spent millions of dollars in repeated attempts to replace their COBOL legacy systems, only to have each attempt fail spectacularly.

Replacement with a COTS Package

Replacement is much harder than it seems. Many legacy COBOL systems implement functionality such as payroll, stock control, and accounting that today would be done by a COTS system. Replacing such a legacy system with a standard COTS package might seem like an attractive option, and in some cases it might be successful; but in many legacy systems, so many proprietary extensions have been added to the standard functionality that replacement is no longer a viable option. Attempting to replace such a legacy system with a COTS package will fail—either completely, causing the replacement attempt to be abandoned; or partially, leading to cost and time overruns and failures in functionality fit.

I know of one instance where a university attempted to replace a COBOL-based Student Record System with a bought-in package as a solution to the Y2K problem. Around September 1999, the school realized that, due to database migration difficulties, the package solution would not be ready in time for the millennium changeover. A successful Y2K remediation of the existing COBOL legacy system was then done, and this bought sufficient time for the new package to be brought on line. Even then, the package only implemented about 80% of the functionality formerly provided by the legacy system.

Complete Rewrite

A complete rewrite in another language is often seen as a viable modernization option. Again, in a restricted set of circumstances, this might be the case. When the documentation created for original legacy system is still available, there is no reason the rewritten replacement should not be as successful as the original. Unfortunately, this happy circumstance is not the case with most legacy systems.

These systems often represent the first parts of the organization to be computerized. They embody the core functionality of the organization; its mission-critical operations; its beating heart. When these systems were created, they replaced the existing manual systems. In the intervening years, the requirements, system architecture, and other documentation have long since been lost. The people who operated the manual system and knew how it worked have either retired or moved on. The rewrite cannot be treated as a greenfield site would be treated, where the requirements could be elicited from stakeholders. For all sorts of legal, customer, and employee reasons, the functionality of the new system must match that of the old. The only source of information about how the system works is embedded in the COBOL code itself. Extracting the business rules from existing legacy code, in order to specify the requirements of the new system, is a very difficult task. The failure rates for most legacy system rewrites are very high.

Automatic Language Conversion

Automatic language conversion is often touted as a solution to the lack of architectural and functional documentation in legacy systems. You don't have to know how the system works, goes the mantra; you can just automatically convert it into a more modern language. But converting legacy COBOL code is a much more difficult task than people realize.¹⁴ Even if the functionality can be reproduced (and this is highly problematic),³ the resulting code is likely to be an unmaintainable, unreadable mess. It is likely to consist of many more lines of code than the original¹⁵ and

to retain the idiom or flavor of COBOL. Although such converted software may be written in the syntax of the target language, it will not look like any kind of a program that a programmer in that language would normally produce. Such automatically produced programs¹⁴ will be so foreign to those who have to maintain them that they are likely to be received with some hostility.

Some organizations advertise their ability to convert legacy COBOL to another language. This is a given; the questions are: how faithful is the conversion and how maintainable is the converted code? Few if any case studies (where they exist at all) mentioned by these organizations address the maintainability problems that may be expected of code produced by automatic language conversion. Although such conversions may alleviate the shortage of COBOL programmers, they probably cause an increase in maintenance costs. It is doubtful if any of these conversions can be deemed a success.

Approaches to legacy system modernization that involve replacing the COBOL code have not been very successful. They either fail completely and have to be abandoned, fail in terms of cost and deadline overruns, or fail in terms of not delivering on maintainability promises.

Wrapping the Legacy System

Most successful modernization efforts retain the COBOL code. Wrapping the legacy code solves interfacing problems but does not address the cost of maintenance, or hardware or software obsolescence problems. On the other hand, it is cheap, it is safe, and it provides an obvious, and immediate, return on investment (ROI).

Code Renovation

Code renovation addresses the cost-of-maintenance problem but none of the others. It is safe and has very good tool support from both COBOL vendors and third parties, but it does not provide an obvious ROI.

Migration to Commodity Hardware and Software

Migration involves moving the legacy COBOL code to modern commodity hardware and software. This approach has some risks, because the COBOL code may have to be changed to accommodate the new hardware and software. However, there is significant tool support to assist migration, and this greatly mitigates the risk of failure. Many case studies point to the success of the migration approach, as borne out by a 2010 report from the Standish Group.¹⁶ This report found that migration and enhancement “stands out as having the highest chance of success and the lowest chance of failure” with the new software development project “six times more likely” and the package replacement project “twice as likely” to fail as migration and enhancement.

Migration solves many of the problems with legacy systems. Obsolescence is addressed by moving to more modern hardware and software. General costs are addressed through the elimination of licensing fees and other costs (in one case study, replacing printed reports with online versions saved \$22,000 per year).¹⁷⁻¹⁸ Maintenance costs are often also addressed because code renovation usually precedes a migration. However, interfacing with modern technologies might still be a problem, and there remains the problem of the scarcity of COBOL programmers.

Shortage of COBOL Programmers: Crisis and Opportunity

A major issue that prompts companies to attempt replacement of their legacy COBOL with some other alternative is the perceived scarcity of COBOL programmers. Harry Sneed states this baldly: “The reason for this conversion is that there are no COBOL programmers available. Otherwise the whole system could have been left in COBOL.”³ He comments that COBOL “is no longer taught in the technical high schools and universities. Therefore, it is very difficult to recruit COBOL programmers. In Austria it is almost impossible to find programmers with knowledge of COBOL. Those few that are left are all close to retirement.” Because of their seniority, they are also more expensive than cheap, young Java programmers.

However, the problem is not that there are no COBOL programmers. Capers Jones estimated that there were 550,000 COBOL programmers in the United States to deal with the Y2K problem.¹⁰ Even now, Scott Searle of IBM estimates that the current worldwide population of COBOL programmers is about two million programmers, with about 50,000 of these in India.¹⁹ The real problem is that most of the population of COBOL programmers are nearing retirement age. This is a crisis in the making. As already discussed, it is dangerous and expensive to attempt to replace COBOL legacy systems; but when these COBOL programmers retire, who will maintain the legacy systems?

Legacy system stakeholders are gradually waking up to the problem. Since 2008, there has been a gradual increase in awareness of the need to do something about it. COBOL vendors have encouraged academic training of a new crop of COBOL developers. Micro Focus does this through its Micro Focus Academic Program and Academic Alliance programs, and an IBM initiative in this area has resulted in COBOL being taught in 400 colleges and universities around the world.¹⁹ In addition, the training companies and in-house training groups that traditionally were the main source of COBOL developers are once more starting to take up the strain. For example, the US Postal Service will start its own COBOL training program as its COBOL programmers retire,²⁰ and the Social Security Administration (SSA)²⁰ in the United States is going the same route. Manta Technologies is reported to be developing a COBOL training series consisting of nine or ten courses.²¹ The company hopes to complete the series by the end of 2013. Some COBOL vendors like Veryant²² are also providing training courses.

Motivational speakers are often heard to say that the Chinese word for crisis is composed of two characters that represent *danger* and *opportunity*. Although there seems to be some doubt about the veracity of this claim, there is no doubt that in the coming years the crisis caused by the tsunami of retiring programmers represents a golden opportunity for those who can grasp it. The number of students earning computing degrees fell sharply after the year 2000, and this led to a programmer shortfall that has made it a seller's market for computer skills. But student numbers are recovering; and as the job market gets more competitive, having COBOL on your résumé may be a very useful differentiating skill—especially if it is combined with knowledge of Java.

COBOL: The Hidden Asset

The numbers supporting the dominance of COBOL in the business application domain sound incredible. Certainly, a lot of skepticism has been voiced about them on the Internet and elsewhere. But much of the skepticism comes from those who have little or no knowledge of the mainframe arena, an area in which COBOL is strong, if not supreme. You can gain an appreciation for the opposing points of view by reading Jeff Atwood's post "COBOL: Everywhere and nowhere" and the associated comments. His comment that "I have never, in my entire so-called 'professional' programming career, met anyone who was actively writing COBOL code²³" is indicative of the problem programmers often have when presented statistics regarding the importance of COBOL. Many of the comments that followed Atwood's post reflected that disbelief; but as one commentator remarked, "You want to see COBOL? Go look at a company that processes payroll, or handles trucking, food delivery, or shipping. Look at companies that handle book purchase orders or government disbursements or checking account reconciliation. There's a huge ecosystem of code out there that's truly invisible to those of us who work in and around the Internet."²⁴

Many programmers with a conspiracy-theory bent attempt to prove the impossibility of the COBOL statistics by pointing to the number of lines of code that could be produced by programmers in the given time frame, or by pointing to the impossibility of maintaining the claimed number of lines with the estimated number of COBOL programmers. There are a number of answers to these points.

One answer is that the COBOL code inventory has been hugely bulked out by fourth-generation languages (4GLs) and other COBOL-generating software.²⁵ 4GLs were all the rage between the 1970s and 1990s, and many produced COBOL code instead of machine code. This was done to give buyers confidence that if the 4GL vendor failed, they would not be left high and dry. In many cases, the vendors did fail, and only the COBOL code was left. In other cases, the programmers took to maintaining the COBOL code directly, and it is now so divorced from the 4GL that there is no point in trying to return to the 4GL code.

Another answer is that programmer productivity seems high because many programs are simply near-copies of existing work. In a legacy system, the enterprise data is often trapped in a variety of storage technologies, from various kinds of database to direct access files and flat files. Nearly every user request to get at that data requires a COBOL program to be written. But these programs are not written from scratch. A programmer creates the program by using

the copy, paste, and amend method. The programmer simply copies a similar program, make a few changes, and voilà: a new COBOL program and a big boost to apparent programmer productivity.

If the number of bugs found in legacy systems approached that found in newly minted systems, 2 million programmers might find it very difficult to maintain upwards of 200 billion lines of code. The fact is, though, that unless an environmental change or a user request forces a modification of a legacy system, not much maintenance is required. When a system has been in production for many tens of years, only the blue-moon bugs remain. There is an old joke that goes, “What’s the difference between computer hardware and computer software?” The answer is, “If you use hardware long enough, it breaks. But if you use software long enough, it works.” A real-world manifestation of David Brin’s²⁶ practice effect, perhaps?

■ **Note** *Blue-moon bugs* are bugs that manifest themselves only as a result of the coincidence of an unusual set of circumstances.

A considerable amount of evidence points to the relatively bug-free status of legacy systems. For instance, when an inventory of software systems was taken in preparation for the Y2K conversion, it was discovered that it had been so long since some of the programs in the inventory had been modified that the source code had been lost. In the opinion of Chris Verhoef, “about 5% of the object code lacks its source code.”²⁷

In his paper “Migrating from COBOL to Java,”¹⁵ Harry Sneed mentions that 5 COBOL programmers were responsible for 15,486 function points of legacy COBOL whereas 25 Java developers were responsible for 13,207 function points of Java code. Although it might suit COBOL advocates to believe that COBOL developers are five times more efficient than Java developers, a more realistic explanation is that the legacy system had settled into a largely bug-free equilibrium while the newly minted Java code was still awash with them.

COBOL definitely has a visibility problem. The hype that surrounds some computer languages would have you believe that most of the production business applications in the world are written in Java, C, C++, or Visual Basic and that only a small percentage are written in COBOL. In reality, COBOL is arguably the major programming language for business applications.

One reason for COBOL’s low profile lies in the difference between the vertical and horizontal software markets. To use a clothing analogy, an application created for the vertical software market is like a tailored, bespoke suit, whereas an application created for the horizontal software market is like a commodity, off-the-rack suit.

Advantages of Bespoke Software

Why should a company spend millions of dollars to create a bespoke application when it could buy a COTS package? One reason is that because a bespoke application is specifically designed for an organization’s particular requirements, it can be tailored to fit in exactly with the way the business or organization operates. Another reason is that it can be customized to interface with other software the company operates, providing a fully integrated IT infrastructure across the whole organization. Yet another reason is that because the company “owns” the software, the company has control over it. But the primary reason for creating a bespoke application is that it can offer an enterprise a competitive advantage over its rivals. Because a bespoke application can incorporate the business processes and business rules that are specific to the company and that do not exist in any packaged solution, it can offer a considerable advantage over competing companies. Owens and Minor²⁸⁻²⁹ refer to the specific business rules and processes embedded in their bespoke applications as their “secret sauce.”

An example of the effectiveness of bespoke software is the software that first allowed an airline to offer a frequent-flyer program (air miles). That software conferred such an advantage on the airline that competitors were forced to catch up, and frequent-flyer programs are now almost ubiquitous.

Characteristics of COBOL Applications

Software produced for the vertical software market has characteristics that distinguish it from the commodity software you are probably more familiar with. This section examines some characteristics of COBOL applications that you may find surprising.

COBOL Applications Can Be Very Large

Many COBOL applications consist of more than 1 million lines of code, and applications consisting of 6 million lines or more are not considered unusually large in many programming shops:

- In “Revitalizing modifiability of legacy assets,”³⁰ Niels Veerman mentions a banking company that had “one large system of 2.6 million LOC in almost 1000 programs.”
- The Irish Life Group, Ireland’s leading life and pensions company, is reported³¹ to have completed a legacy system migration project to rehost 3 million lines of COBOL code.
- A Microsoft case study reported that Simon & Schuster had a code inventory of some 5 million lines of COBOL code.³²
- The Owens and Minor case study mentioned earlier reported that “the company ran its business on 10 million lines of custom COBOL/CICS code.”²⁹
- In his paper “A Pilot Project for Migrating COBOL Code to Web Services,” Harry Sneed reported a “legacy life insurance system with more than 20 million lines of COBOL code running under IMS on the IBM mainframe.”³³
- The authors of “Industrial Applications of ASF+SDF” talk about a large suite of mainframe-based COBOL applications that consist of 25,000 programs and 30 million lines of code.³⁴
- An audit report by the Office of the Inspector General in 2012 noted that as of June 2010, the US SSA had a COBOL code inventory of “over 60 million lines of COBOL code.”³⁵
- The Bank of New York Mellon is quoted as having a software inventory of 112,500 Cobol programs consisting of 343 million lines of code.²
- Kwiatkowski and Verhoef report a case study where “a Cobol software portfolio of a large organization operating in the financial sector” consisted of over “18.2 million physical lines of code (LOC).”²⁵

COBOL Applications Are Very Long-Lived

The huge investment in creating a software application consisting of millions of lines of COBOL code means the application cannot simply be discarded when a new programming language or technology appears. As a consequence, business applications between 10 and 30 years old are common, and some have been in existence for around 50 years.

A Microsoft case study on the Swedish company Stockholmshem noted that its computer system “was created in 1963 and had been expanded over the years to include roughly 170 online Customer Information Control System (CICS)/COBOL programs and 370 batch COBOL programs.”³⁶

Kwiatkowski and Verhoef²⁵ published a version log (reproduced in Figure 1-1) for a module in the software portfolio of a large financial organization that illustrates the longevity of COBOL programs. Each line of the log is a comment that shows a version number, the name of a programmer, and the date the software was modified. The log shows that maintenance of this module started in 1975. Nor was this the oldest module found. That honor belonged to a program that had been written in 1967. For some readers of this book, the software in this portfolio started life long before they were born.

clauses, sentences, sections, and divisions. As it happens, this design goal was not realized. Managers and users nowadays do not read COBOL programs. Computer programs are just too complex for most nonprofessionals to understand them, however familiar the syntactic elements. But the design goal and its effect on COBOL syntax had one important side effect: it made COBOL the most readable, understandable, and self-documenting programming language in use today. It also made it the most verbose.

It is easy for programmers unused to the business programming paradigm, where programming with a view to ease of maintenance is very important, to dismiss the advantage of COBOL's readability. Not only does this readability generally assist the maintenance process, but the older a program gets, the more valuable readability becomes.

When programs are new, both the in-program comments and the external documentation accurately reflect the program code. But over time, as more and more revisions are applied to the code, it gets out of step with the documentation until the documentation is actually a hindrance to maintenance rather than a help. The self-documenting nature of COBOL means this problem is not as severe with COBOL as it is with other languages.

Readers who are familiar with C, C++, or Java might want to consider how difficult it becomes to maintain programs written in these languages. C programs you wrote yourself are difficult enough to understand when you return to them six months later. Consider how much more difficult it would be to understand a program that was written 15 years previously, by someone else, and which had since been amended and added to by so many others that the documentation no longer accurately reflected the program code. This is a nightmare awaiting maintenance programmers of the future, and it is already peeking over the horizon.

COBOL Is Stable

As a computer language, COBOL evolves with near-glacial slowness. The designers of COBOL do not jump on the bandwagon of every new, popular fad. Changes incorporating new ideas are made to the language only when the new idea has proven itself.

Since its creation in 1960, only four COBOL standards have been produced:

- *ANS 68 COBOL*: Resolved incompatibilities between different COBOL versions
- *ANS 74 COBOL*: Introduced the CALL verb and external subprograms
- *ANS 85 COBOL*: Introduced structured programming and internal subprograms
- *ISO 2002 COBOL*: Introduced object orientation to COBOL

Enterprises running mission-critical applications are unsurprisingly suspicious of change. Many of these organizations stay one version behind the very slow leading edge of COBOL. It is only now that the 2002 version of COBOL has been specified that many will start to move to the 1985 standard. This is one reason this book mainly adheres to the ANS 85 standard.

Conscious of the long life of COBOL applications, backward compatibility has been a major concern of the ANSI COBOL Committee. Very few language elements have been dropped from the language. As a result, programs I wrote in the 1980s for the DEC VAX using VAX COBOL compile, with little or no alteration, on the Micro Focus Visual COBOL compiler. Java, although only created in 1995, is now on its seventh version and already has a very long list of obsolete, deprecated, and removed features. In the years since its creation, Java has removed more language features than COBOL has in the whole of its 50-year history.

COBOL Is Simple

COBOL is a simple language (until the most recent version, it had no pointers, no user-defined functions, and no user-defined types). It encourages a simple, straightforward programming style. Curiously enough, though, despite its limitations, COBOL has proven itself well suited to its target problem domain (business computing). Most COBOL programs operate in a domain where the program complexity lies in the business rules that have to be encoded rather than in the sophistication of the data structures or algorithms required. In cases where sophisticated algorithms are needed, COBOL usually meets the need with an appropriate verb such as SORT or SEARCH.

Earlier in this book, I noted that the limitations of COBOL meant it could not be used to teach computer science concepts. And in the previous paragraph, I noted that COBOL is a simple language with a limited scope of function. These comments pertain to versions of COBOL prior to the ANS 2002 version. With the introduction of OO COBOL, everything has changed. OO COBOL retains all the advantages of previous versions but now includes the following:

- User-defined functions
- Object orientation
- National characters (Unicode)
- Multiple currency symbols
- Cultural adaptability (locales)
- Dynamic memory allocation (pointers)
- Data validation using the new VALIDATE verb
- Binary and floating-point data types
- User-defined data types

COBOL Is Nonproprietary

The COBOL standard does not belong to any particular vendor. It was originally designed to be a “machine independent common language⁸” and to be ported to a wide range of machines. This capability was demonstrated by the first COBOL compilers when the same program was compiled and executed on both the RCA and the Remington-Rand-Univac computers.⁸ The ANSI COBOL committee, and now the ISO, define the non-vendor-specific syntax and semantic language standards. COBOL has been ported to virtually every operating system, from every flavor of Windows to every flavor of Unix; from IBM’s VM, zOS, and zVSE operating systems, to MPE, MPE-iX, and HP-UX on HP machines; from the Wang VS to GCOS on Bull machines. COBOL runs on computers you have probably never heard of, such as the Data General Nova, SuperNova, and Eclipse MV series; the DEC PDP-11/70 and VAX; the Univac 9000s and the Unisys 2200s; and the Hitachi EX33 and the Bull DPX/20.

COBOL Is Maintainable

COBOL has a 50-year proven track record for application production, maintenance, and enhancement. The indications from the Y2K problem that COBOL applications were cheaper to fix than applications written in more recent languages (\$28 per function point versus \$35 for C++ and \$65 for PL/1) have been supported by the 2012 *ComputerWorld* survey¹² and the 2011/12 CRASH Report.⁴⁰ When comparing COBOL maintenance costs to those of Visual Basic, C#, C++, and Java, the *ComputerWorld* survey reported that 72% of respondents found that COBOL was just as good (29%) as these languages or better (43%). Similarly, the CRASH Report found that COBOL had the lowest technical debt (defined in the report as “the effort required to fix problems that remain in the code when an application is released”) of any mainstream language, whereas Java-EE, averaging \$5.42 per LOC, had the highest.

One reason for the maintainability of COBOL programs was mentioned earlier: the readability of COBOL code. Another reason is COBOL’s rigid hierarchical structure. In COBOL programs, all external references, such as references to devices, files, command sequences, collating sequences, the currency symbol, and the decimal point symbol, are defined in the Environment Division.

When a COBOL program is moved to a new machine, has new peripheral devices attached, or is required to work in a different country, COBOL programmers know that the parts of the program that will have to be altered to accommodate these changes will be isolated in the Environment Division. In other programming languages, programmer discipline might ensure that the references liable to change are restricted to one part of the program but they could just as easily be spread throughout the program. In COBOL programs, programmers have no choice. COBOL’s rigid hierarchical structure ensures that these items are restricted to the Environment Division.

Summary

Unfortunately, the leaders of the computer science community have taken a very negative view of COBOL from its very inception and therefore have not looked carefully enough to see what good ideas are in there which could be further enlarged, expanded or generalized.

Jean Sammet, “The Early History of COBOL,”
ACM Sigplan Notices 13(8), August 1978

The problem with being such an old language is that COBOL suffers from 50 years of accumulated opprobrium. Criticism of COBOL is often based—if it is based on direct experience at all—on programs written 30 to 50 years ago. The huge monolithic programs, the tangled masses of spaghetti code, and the global data are all hallmarks of COBOL programs written long before programmers knew better. They are not characteristic of programs written using more modern versions of COBOL.

Critics also forget that COBOL is a domain-specific language and criticize it for shortcomings that have little relevance to its target domain. There is little acknowledgement of how well suited COBOL is for that domain. The performance of COBOL compared to other languages in recent surveys underlines its suitability. The 2012 *ComputerWorld* survey¹² compared COBOL with Visual Basic, C#, C++, and Java and reported that, among other things, respondents found it better in terms of batch processing, transaction processing, handling business-oriented features, and maintenance costs. Nor is this a one off: similar results have been reported by other surveys.

There is enormous pressure to replace COBOL legacy systems with systems written in one of the more fashionable languages. The many failures that have attended replacement attempts, however, have given legacy system stakeholders pause for thought. The well-documented dangers of the replacement approach and the relative success of COBOL system migration is leading to a growing reassessment of options. Keeping the COBOL codebase is now seen as a more viable, safer, cheaper alternative to replacement. But this reassessment reveals a problem. Keeping, and even growing, the COBOL codebase requires COBOL programmers, and the COBOL workforce is aging and nearing retirement.

For some years now, programmers have luxuriated in a seller’s market. The demand for programmers has been far in advance of the supply. But student numbers in computer science courses around the world are recovering from the Y2K downturn. As these graduates enter the job market, it will become more and more competitive. In a competitive environment, programmers may find that having a résumé that includes COBOL is a useful differentiator.

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CHAPTER 2



COBOL Foundation

This chapter presents some of the foundational material you require before you can write COBOL programs. It starts by identifying some elements of COBOL that programmers of other languages find idiosyncratic and it explains the reasons for them. You're then introduced to the unusual syntax notation (called *metalanguage*) used to describe COBOL verbs and shown some examples.

COBOL programs have to conform to a fairly rigid hierarchical structure. This chapter introduces the structural elements and explains how each fits into the overall hierarchy. Because the main structural element of a COBOL program is the division, you spend some time learning about the function and purpose of each of the four divisions.

COBOL programs, especially in restrictive coding shops, are required to conform to a number of coding rules. These rules are explained and placed in their historical context.

The chapter discusses the details of name construction; but because name construction is about more than just the mechanics, you also learn about the importance of using descriptive names for both data items and blocks of executable code. The importance of code formatting for visualizing data hierarchy and statement scope is also discussed.

To whet your appetite for what is coming in the succeeding chapters, the chapter includes a number of small example programs and gives brief explanations. The chapter ends by listing the most important COBOL compilers, both free and commercial, available for Windows and UNIX.

COBOL Idiosyncrasies

COBOL is one of the oldest programming languages still in use. As a result, it has some idiosyncrasies, which programmers used to other languages may find irritating. One of the design goals of COBOL was to assist readability by making the language as English-like as possible.¹ As a consequence, the structural concepts normally associated with English prose, such as division, section, paragraph, sentence, verb, and so on, are used in COBOL programs. To further aid readability, the concept of *noise words* was introduced. Noise words are words in a COBOL statement that have no semantic content and are used only to enhance readability by making the statement more English-like.

One consequence of these design decisions is that the COBOL reserved-word list is extensive and contains many hundreds of entries. The reserved words themselves also tend to be long, with words like UNSTRING, EVALUATE, and PERFORM being typical. The English-like structure, the long reserved words, and the noise words makes COBOL programs seem verbose, especially when compared to languages such as C.

When COBOL was designed, today's tools were not available. Programs were written on coding forms (see Figure 2-1), passed to punch-card operators for transfer onto punch cards (see Figure 2-2), and then submitted to the computer operator to be loaded into the computer using a punch-card reader. These media (coding sheets and punch cards) required adherence to a number of formatting restrictions that some COBOL implementations still enforce today, long after the need for them has gone. This book discusses these coding restrictions but doesn't adhere to them. You should be aware, though, that depending on the coding rules in a particular coding shop, you might be obliged to abide by these archaic conventions.

The final COBOL irritant is that although many of the constructs required to write well-structured programs have been introduced into modern COBOL (ANS 85 COBOL and OO-COBOL), the need for backward compatibility means some language elements remain that, if used, make it difficult and in some cases impossible to write good programs. ALTER verb, I'm thinking of you.

COBOL Syntax Metalanguage

COBOL syntax is defined using a notation sometimes called the COBOL *metalanguage*. In this notation

- Words in uppercase are reserved words. When underlined, they are mandatory. When not underlined, they are noise words, used for readability only, and are optional.
- Words in mixed case represent names that must be devised by the programmer (such as the names of data items).
- When material is enclosed in curly braces { }, a choice must be made from the options within the braces. If there is only one option, then that item is mandatory.
- When material is enclosed in square brackets [], the material is optional and may be included or omitted as required.
- When the ellipsis symbol . . . (three dots) is used, it indicates that the preceding syntactic element may be repeated at your discretion.
- To assist readability, the comma, semicolon, and space characters may be used as separators in a COBOL statement, but they have no semantic effect. For instance, the following statements are semantically identical:

```
ADD Num1 Num2 Num3 TO Result
ADD Num1, Num2, Num3 TO Result
ADD Num1; Num2; Num3 TO Result
```

In addition to the metalanguage diagrams, syntax rules govern the interpretation of metalanguage. For instance, the metalanguage for PERFORM. . VARYING (see Figure 2-3) implies that you can have as many AFTER phrases as desired. In fact, as you will discover when I discuss this construct in Chapter 6, only two are allowed.

$$\begin{array}{l}
 \underline{\text{PERFORM}} \left[\text{1stProc} \left[\left\{ \begin{array}{l} \underline{\text{THRU}} \\ \underline{\text{THROUGH}} \end{array} \right\} \text{EndProc} \right] \right] \left[\text{WITH TEST} \left\{ \begin{array}{l} \underline{\text{BEFORE}} \\ \underline{\text{AFTER}} \end{array} \right\} \right] \\
 \underline{\text{VARYING}} \left\{ \begin{array}{l} \text{Counter1\#i} \\ \text{IndexName1} \end{array} \right\} \underline{\text{FROM}} \left\{ \begin{array}{l} \text{StartValue\#il} \\ \text{IndexName2} \end{array} \right\} \\
 \underline{\text{BY}} \text{ StepValue\#il } \underline{\text{UNTIL}} \text{Condition1} \\
 \left[\underline{\text{AFTER}} \left\{ \begin{array}{l} \text{Counter2\#i} \\ \text{IndexName3} \end{array} \right\} \underline{\text{FROM}} \left\{ \begin{array}{l} \text{StartValue 2\#il} \\ \text{IndexName4} \end{array} \right\} \right] \dots \\
 \quad \underline{\text{BY}} \text{ StepValue2\#il } \underline{\text{UNTIL}} \text{Condition2} \\
 \left[\text{StatementBlock } \underline{\text{END - PERFORM}} \right]
 \end{array}$$

Figure 2-3. *PERFORM. . VARYING metalanguage*

Some Notes on Syntax Diagrams

As mentioned in the previous section, the interpretation of the COBOL metalanguage is modified by syntax rules. Because it can be tedious to wade through all the rules for each COBOL construct, this book uses a modified form of the syntax diagram. In this modified diagram, special operand suffixes indicate the type of the operand; these are shown in Table 2-1.

Table 2-1. *Special Metalanguage Operand Suffixes*

Suffix	Meaning
\$i	Uses an alphanumeric data item
\$il	Uses an alphanumeric data item or a string literal
#i	Uses a numeric data item
#il	Uses a numeric data item or numeric literal
\$\$i	Uses a numeric or an alphanumeric data item

Example Metalanguage

As an example of how the metalanguage for a COBOL verb is interpreted, the syntax for the COMPUTE verb is shown in Figure 2-4. I'm presenting COMPUTE here because, as the COBOL arithmetic verb (the others are ADD, SUBTRACT, MULTIPLY, DIVIDE) that's closest to the way things are done in many other languages, it will be a point of familiarity. The operation of COMPUTE is discussed in more detail in Chapter 4.

```

COMPUTE {Result#i [ ROUNDED ]} ... = Arithmetic Expression
      [ { ON SIZE ERROR
        { NOT ON SIZE ERROR } StatementBlock END-COMPUTE } ]
  
```

Figure 2-4. *COMPUTE metalanguage syntax diagram*

The COMPUTE verb assigns the result of an arithmetic expression to a variable or variables. The interpretation of the COMPUTE metalanguage is as follows:

- A COMPUTE statement must start with the keyword COMPUTE.
- The keyword must be followed by the name of a numeric data item that receives the result of the calculation (the suffix #i indicates that the operand must be the name of a numeric data item [variable]).
- The equals sign (=) must be used.
- An arithmetic expression must follow the equals sign.
- The square braces [] around the word ROUNDED indicate that rounding is optional. Because the word ROUNDED is underlined, the word must be used if rounding is required.
- The ellipsis symbol (...) indicates that there can more than one Result#i data item.
- The ellipsis occurs outside the curly braces {}, which means each result field can have its own ROUNDED phrase.

In other words, you could have a COMPUTE statement like

```
COMPUTE Result1 ROUNDED, Result2 = ((9 * 9) + 8) / 5
```

where Result1 would be assigned a value of 18 (rounded 17.8) and Result2 would be assigned a value of 17 (truncated 17.8), assuming both Result1 and Result2 were defined as PIC 99.

Structure of COBOL Programs

COBOL is much more rigidly structured than most other programming languages. COBOL programs are hierarchical in structure. Each element of the hierarchy consists of one or more subordinate elements. The program hierarchy consists of divisions, sections, paragraphs, sentences, and statements (see Figure 2-5).

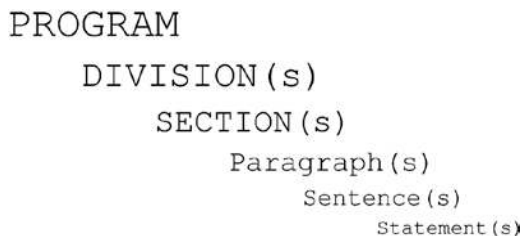


Figure 2-5. Hierarchical COBOL program structure

A COBOL program is divided into distinct parts called divisions. A division may contain one or more sections. A section may contain one or more paragraphs. A paragraph may contain one or more sentences, and a sentence one or more statements.

■ **Note** Programmers unused to this sort of rigidity may find it irksome or onerous, but this layout offers some practical advantages. Many of the programmatic items that might need to be modified as a result of an environmental change are defined in the ENVIRONMENT DIVISION. External references, such as to devices, files, collating sequences, the currency symbol, and the decimal point symbol are all defined in the ENVIRONMENT DIVISION.

Divisions

The division is the major structural element in COBOL. Later in this chapter, I discuss the purpose of each division. For now, you can note that there are four divisions: the IDENTIFICATION DIVISION, the ENVIRONMENT DIVISION, the DATA DIVISION, and the PROCEDURE DIVISION.

Sections

A section is made up of one or more paragraphs. A section begins with the section name and ends where the next section name is encountered or where the program text ends.

A section name consists of a name devised by the programmer or defined by the language, followed by the word *Section*, followed by a period (full stop). Some examples of section names are given in Example 2-1.

In the first three divisions, sections are an organizational structure defined by the language. But in the PROCEDURE DIVISION, where you write the program's executable statements, sections and paragraphs are used to identify blocks of code that can be executed using the PERFORM or the GO TO.

Example 2-1. Example Section Names

```
SelectTexasRecords SECTION.
FILE SECTION.
CONFIGURATION SECTION.
INPUT-OUTPUT SECTION.
```

Paragraphs

A paragraph consists of one or more sentences. A paragraph begins with a paragraph name and ends where the next section name or paragraph name is encountered or where the program text ends.

In the first three divisions, paragraphs are an organizational structure defined by the language (see Example 2-2). But in the PROCEDURE DIVISION, paragraphs are used to identify blocks of code that can be executed using PERFORM or GO TO (see Example 2-3).

Example 2-2. ENVIRONMENT DIVISION Entries Required for a File Declaration

```
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT ExampleFile ASSIGN TO "Example.Dat"
        ORGANIZATION IS SEQUENTIAL.
```

Example 2-3. PROCEDURE DIVISION with Two Paragraphs (Begin and DisplayGreeting)

```
PROCEDURE DIVISION.
Begin.
    PERFORM DisplayGreeting 10 TIMES.
    STOP RUN.

DisplayGreeting.
    DISPLAY "Greetings from COBOL".
```

Sentences

A sentence consists of one or more statements and is terminated by a period. There must be at least one sentence, and hence one period, in a paragraph. Example 2-4 shows two sentences. The first sentence also happens to be a statement; the second consists of three statements.

Example 2-4. Two Sentences

```
SUBTRACT Tax FROM GrossPay GIVING NetPay.

MOVE .21 TO VatRate
COMPUTE VatAmount = ProductCost * VatRate
DISPLAY "The VAT amount is - " VatAmount.
```

Statements

In COBOL, language statements are referred to as *verbs*. A statement starts with the name of the verb and is followed by the operand or operands on which the verb acts. Example 2-5 shows three statements.

Example 2-5. Three Statements

```
DISPLAY "Enter name " WITH NO ADVANCING
ACCEPT  StudentName
DISPLAY "Name entered was " StudentName
```

In Table 2-2, the major COBOL verbs are categorized by type. The arithmetic verbs are used in computations, the file-handling verbs are used to manipulate files, the flow-of-control verbs are used to alter the normal sequential execution of program statements, the table-handling verbs are used to manipulate tables (arrays), and the string-handling verbs allow such operations as character counting, string splitting, and string concatenation.

Table 2-2. Major COBOL Verbs, Categorized by Type

Arithmetic	File Handling	Flow of Control	Assignment & I-O	Table Handling	String Handling
COMPUTE	OPEN	IF	MOVE	SEARCH	INSPECT
ADD	CLOSE	EVALUATE	SET	SEARCH ALL	STRING
SUBTRACT	READ	PERFORM	INITIALIZEACCEPT	SET	UNSTRING
MULTIPLY	WRITE	GO TO	DISPLAY		
DIVIDE	DELETE	CALL			
	REWRITE	STOP RUN			
	START	EXIT PROGRAM			
	SORT				
	RETURN				
	RELEASE				

The Four Divisions

At the top of the COBOL hierarchy are the four divisions. These divide the program into distinct structural elements.

Although some of the divisions may be omitted, the sequence in which they are specified is fixed and must be as follows. Just like section names and paragraph names, division names must be followed by a period:

IDENTIFICATION DIVISION. Contains information about the program

ENVIRONMENT DIVISION. Contains environment information

DATA DIVISION. Contains data descriptions

PROCEDURE DIVISION. Contains the program algorithms

IDENTIFICATION DIVISION

The purpose of the IDENTIFICATION DIVISION is to provide information about the program to you, the compiler, and the linker. The PROGRAM-ID paragraph is the only entry required. In fact, this entry is required in every program. Nowadays all the other entries have the status of comments (which are not processed when the program runs), but you may still find it useful to included paragraphs such as AUTHOR and DATE-WRITTEN.

The PROGRAM-ID is followed by a user-devised name that is used to identify the program internally. This name may be different from the file name given to the program when it was saved to backing storage. The metalanguage for the PROGRAM-ID is

```
PROGRAM-ID. UserAssignedProgramName.
[IS [COMMON] [INITIAL] PROGRAM].
```

The metalanguage items in square braces apply only to subprograms, so I will reserve discussion of these items until later in the book.

When a number of independently compiled programs are combined by the linker into a single executable run-unit, each program is identified by the name given in its PROGRAM-ID. When control is passed to a particular program by means of a CALL verb, the target of the CALL invocation is the name given in the subprogram's PROGRAM-ID for instance:

```
CALL "PrintSummaryReport".
```

Example 2-6 shows an example IDENTIFICATION DIVISION. Pay particular attention to the periods — they are required.

Example 2-6. Sample IDENTIFICATION DIVISION

```
IDENTIFICATION DIVISION.
PROGRAM-ID. PrintSummaryReport.
AUTHOR. Michael Coughlan.
DATE-WRITTEN. 20th June 2013.
```

ENVIRONMENT DIVISION

The ENVIRONMENT DIVISION is used to describe the environment in which the program works. It isolates in one place all aspects of the program that are dependent on items in the environment in which the program runs. The idea is to make it easy to change the program when it has to run on a different computer or one with different peripheral devices or when the program is being used in a different country.

The ENVIRONMENT DIVISION consists of two sections: the CONFIGURATION SECTION and the INPUT-OUTPUT SECTION. In the CONFIGURATION SECTION, the SPECIAL-NAMES paragraph allows you to specify such environmental details as what alphabet to use, what currency symbol to use, and what decimal point symbol to use. In the INPUT-OUTPUT SECTION, the FILE-CONTROL paragraph lets you connect internal file names with external devices and files.

Example 2-7 shows some example CONFIGURATION SECTION entries. A few notes about the listing:

- In some countries the meaning of the decimal point and the comma are reversed. For instance, the number 1,234.56 is sometimes written 1.234,56. The DECIMAL-POINT IS COMMA clause specifies that the program conforms to this scheme.
- The SYMBOLIC CHARACTERS clause lets you assign a name to one of the unprintable characters. In this example, names for the escape, carriage return, and line-feed characters have been defined by specifying their ordinal position (not value) in the character set.
- The SELECT and ASSIGN clauses let you connect the name you use for a file in the program with its actual name and location on disk.

Example 2-7. CONFIGURATION SECTION Examples

```

IDENTIFICATION DIVISION.
PROGRAM-ID. ConfigurationSectionExamples.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SPECIAL-NAMES.
    DECIMAL-POINT IS COMMA.
    SYMBOLIC CHARACTERS    ESC  CR  LF
                          ARE 28  14 11.

INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT StockFile ASSIGN TO "D:\DataFiles\Stock.dat"
    ORGANIZATION IS SEQUENTIAL.

```

DATA DIVISION

The DATA DIVISION is used to describe most of the data that a program processes. The obvious exception to this is literal data, which is defined *in situ* as a string or numeric literal such as “Freddy Ryan” or -345.74.

The DATA DIVISION is divided into four sections:

- The FILE SECTION
- The WORKING-STORAGE SECTION
- The LINKAGE SECTION
- The REPORT SECTION

The first two are the main sections. The LINKAGE SECTION is used only in subprograms, and the REPORT SECTION is used only when generating reports. The LINKAGE and REPORT sections are discussed more fully when you encounter the elements that require them later in the book. For now, only the first two sections need concern you.

File Section

The FILE SECTION describes the data that is sent to, or comes from, the computer’s data storage peripherals. These include such devices as card readers, magnetic tape drives, hard disks, CDs, and DVDs.

Working-Storage Section

The WORKING-STORAGE SECTION describes the general variables used in the program. The COBOL metalanguage showing the general structure and syntax of the DATA DIVISION is given in Figure 2-6 and is followed by a fragment of an example COBOL program in Example 2-8.

DATA DIVISION.

```
[ FILE SECTION. ]
  file section entries ]
```

```
—
[ WORKING-STORAGE SECTION. ]
  working storages entries ]
```

```
[ LINKAGE SECTION. ]
  linkage section entries ]
```

```
[ REPORT SECTION. ]
  report section entries ]
```

Figure 2-6. DATA DIVISION metalanguage**Example 2-8.** Simple Data Declarations

```
IDENTIFICATION DIVISION.
PROGRAM-ID. SimpleDataDeclarations.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 CardinalNumber          PIC 99      VALUE ZEROS.
01 IntegerNumber          PIC S99     VALUE -14.
01 DecimalNumber          PIC 999V99  VALUE 543.21.
01 ShopName                PIC X(30)  VALUE SPACES.
01 ReportHeading          PIC X(25)   VALUE "=== Employment Report ===".
```

Data Hierarchy

All the data items in Example 2-8 are independent, elementary, items. Although data hierarchy is too complicated a topic to deal with at this point, a preview of hierarchical data declaration is given in BirthDate (see Example 2-9).

Example 2-9. Example of a Hierarchical Data Declaration

```
01 BirthDate.
   02 YearOfBirth.
      03 CenturyOB          PIC 99.
      03 YearOB             PIC 99.
   02 MonthOfBirth         PIC 99.
   02 DayOfBirth           PIC 99.
```

In this declaration, the data hierarchy indicated by the level numbers tells you that the data item `BirthDate` consists of (is made up of) a number of subordinate data items. The immediate subordinate items (indicated by the 02 level numbers) are `YearOfBirth`, `MonthOfBirth`, and `DayOfBirth`. `MonthOfBirth` and `DayOfBirth` are elementary, atomic, items that are not further subdivided. However, `YearOfBirth` is a data item that *is* further subdivided (indicated by the 03 level numbers) into `CenturyOB` and `YearOB`.

In typed languages such as Pascal and Java, understanding what is happening to data in memory is not important. But understanding what is happening to the data moved into a data item is critical in COBOL. For this reason, when discussing data declarations and the assignment of values to data items, I often give a model of the storage. For instance, Figure 2-7 gives the model of the storage for the data items declared in Example 2-9 and shows what happens to the data when you execute the statement - `MOVE "19451225" TO BirthDate`.

BirthDate							
YearOfBirth				MonthOfBirth		DayOfBirth	
CenturyOB		YearOB					
1	9	4	5	1	2	2	5

Figure 2-7. Memory model for the data items declared in Example 2-9

PROCEDURE DIVISION

The PROCEDURE DIVISION is where all the data described in the DATA DIVISION is processed and produced. It is here that you describe your algorithm. The PROCEDURE DIVISION is hierarchical in structure. It consists of sections, paragraphs, sentences, and statements. Only the section is optional; there must be at least one paragraph, one sentence, and one statement in the PROCEDURE DIVISION.

Whereas the paragraph and section names in the other divisions are defined by the language, in the PROCEDURE DIVISION they are chosen by you. The names chosen should reflect the function of the code contained in the paragraph or section.

In many legacy COBOL programs, paragraph and section names were used chiefly as labels to break up the program text and to act as the target of `GO TO` statements and, occasionally, `PERFORM` statements. In these programs, `GO TO`s were used to jump back and forward through the program text in a manner that made the program logic very difficult to follow. This programmatic style was derisively labeled *spaghetti code*.

In this book, I advocate a programming style that eschews the use of `GO TO`s as much as possible and that uses `performs` and paragraphs to create single-entry, single-exit, open subroutines. Although the nature of an open subroutine is that control can drop into it, adherence to the single-entry, single-exit philosophy should ensure that this does not happen.

Shortest COBOL Program

COBOL has a very bad reputation for verbosity, but most of the programs on which that reputation was built were written in ANS 68 or ANS 74 COBOL. Those programs are 40 years old. In modern versions of the language, program elements are not required unless explicitly used. For instance, in the `ShortestProgram` (see Listing 2-1), no entries are required for the ENVIRONMENT and DATA DIVISIONS because they are not used in this program. The IDENTIFICATION DIVISION is required because it holds the mandatory `PROGRAM-ID` paragraph. The PROCEDURE DIVISION is also required, there must be at least one paragraph in it (`DisplayPrompt`), and the paragraph must contain at least one sentence (`DISPLAY "I did it".`). `STOP RUN`, a COBOL instruction to halt execution of the program, would normally appear in a program but is not required here because the program will stop when it reaches the end of the program text.

- The actual program text starts in column 8. The four positions from 8 to 11 are known as Area A, and the positions from 12 to 72 are called Area B.
- The area from position 73 to 80 is the identification area; it was generally used to identify the program. This again was disaster insurance. If two stacks of cards were dropped, the identification allowed the cards belonging to the two programs to be identified.

When a COBOL compiler recognizes the Areas A and B, all division names, section names, paragraph names, file-description (FD) entries, and 01 level numbers must start in Area A. All other sentences must start in Area B.

In some COBOL compilers, it is possible to set a compiler option or include a compiler directive to free you from these archaic formatting conventions. For instance, the Micro Focus Net Express COBOL uses the compiler directive - \$ SET SOURCEFORMAT"FREE". Although modern compilers may free you from formatting restrictions, it is probably still a good idea to position items according to the Area A and Area B rule.

Name Construction

COBOL has a number of different user-devised names, such as data names (variable names), paragraph names, section names, and mnemonic names. The rules for name construction are given here along with some advice which all programmers should embrace.

All user-defined names in COBOL must adhere to the following rules:

- They must contain at least 1 character and not more than 30 characters.
- They must contain at least one alphabetic character and must not begin or end with a hyphen.
- They must be constructed from the characters *A* to *Z*, the numbers 0 to 9, and the hyphen. Because the hyphen can be mistaken for the minus sign, a word cannot begin or end with a hyphen.
- Names are not case-sensitive. SalesDate is the same as salesDate or SALESDATE.
- None of the many COBOL reserved words may be used as a user-defined name. The huge number of reserved words is one of the annoyances of COBOL. One strategy to avoid tripping over them is to use word doubles such as using I terCount instead of Count.

Here are some examples of user-defined names:

```
TotalPay
Gross-Pay
PrintReportHeadings
Customer10-Rec
```

Comments about Naming

Data-item names are used to identify variables. In COBOL, all variable data is defined in the DATA DIVISION rather than throughout the program as is done in many other languages. In the PROCEDURE DIVISION, section names and paragraph names are devised by you and are used to identify blocks of executable code.

The proper selection of data-item, section, and paragraph names is probably the most important thing you can do to make your programs understandable. The names you choose should be descriptive. Data-item names should be descriptive of the data they contain; for instance, it is fairly clear what data the data items TotalPay, GrossPay, and NetPay hold. Section and paragraph names should be descriptive of the function of the code contained in the paragraph or section; for instance, these seem fairly descriptive: ApplyValidInsertion, GetPostage, and ValidateCheckDigit. Difficulty in assigning a suitably descriptive name to a block of code should be taken as a sign that the program has been incorrectly partitioned and is likely to offend the Module Strength/Cohesion guidelines³⁻⁶.

Authors writing about other programming languages often make the same point: programmers should choose descriptive names. But in many of these languages, where succinctness appears to be a highly lauded characteristic, the ethos of the language seems to contradict this advice. In COBOL, the language is already so verbose that the added burden of descriptive names is not likely to be a problem.

Comments about Program Formatting

In COBOL, hierarchy is vitally important in the declaration of data. Proper indentation is a very useful aid to understanding data hierarchy (more on this later). Misleading or no indentation is often a source of programming errors. Good programmers seem to understand this instinctively: when student programs are graded, those that correctly implement the specification are often found to have excellent formatting, whereas those with programming errors are often poorly formatted. This is ironic, because the programmers who are most in need of the aid of a well-formatted program seem to be those who pay formatting the least attention. Weak programmers never appear to understand how a poorly formatted program conspires against them and makes it much more difficult to produce code that works.

Proper formatting is also important in the PROCEDURE DIVISION. Even though the scope of COBOL verbs is well-signaled using END delimiters, indentation is still a very useful aid to emphasize scope.

This discussion brings me to an important piece of advice for COBOL programmers. This advice is a restatement of the Golden Rule promulgated by Jesus, Confucius, and others:

Write your programs as you would like them written if you were the one who had to maintain them.

Comments about Programming Style

As noted earlier, data names and reserved words are not case sensitive. The reserved words PROCEDURE DIVISION can be written as uppercase, lowercase, or mixed case. My preference, developed during years of reading program printouts, is to put COBOL reserved words in uppercase and user-defined words in mixed case with capitals at the beginning of each word. Sometimes, for clarity, the words may be separated by a hyphen. This is the style I have chosen for this book because I believe it is the best for a printed format.

I want to stress, though, that this stylistic scheme is a personal preference. Programmers in other languages may be more used to a different scheme, and as long as the scheme is consistently used, it should present no problem. It is worth mentioning that when you start to work in a programming shop, a naming scheme may be forced on you. So perhaps it is not a bad thing to get some practice fitting in with someone else's scheme.

Example Programs

This section provides some example programs to whet your appetite and give you a feel for how a full COBOL program looks. In particular, they give advance warning about how variables (data items) are declared in COBOL. This differs so much from other languages such as C, Java, and Pascal that it is likely to be a matter of some concern, if not consternation. These programs also introduce some of the more interesting and useful features of COBOL.

The COBOL Greeting Program

Let's start with the program you last saw in the COBOL coding sheet (see Figure 2-1). In Listing 2-2 it has been modernized a little by introducing lowercase characters. This basic program demonstrates simple data declaration and simple iteration (looping). The variable `IterNum` is given a starting value of 5, and the `PERFORM` executes the paragraph `DisplayGreeting` five times:

Listing 2-2. The COBOL Greeting Program

```
IDENTIFICATION DIVISION.
PROGRAM-ID. CobolGreeting.
*>Program to display COBOL greetings
DATA DIVISION.
WORKING-STORAGE SECTION.
01 IterNum    PIC 9 VALUE 5.

PROCEDURE DIVISION.
BeginProgram.
    PERFORM DisplayGreeting IterNum TIMES.
    STOP RUN.

DisplayGreeting.
    DISPLAY "Greetings from COBOL".
```

The DoCalc Program

The `DoCalc` program in Listing 2-3 prompts the user to enter two single-digit numbers. The numbers are added together, and the result is displayed on the computer screen.

Listing 2-3. The DoCalc Example Program

```
IDENTIFICATION DIVISION.
PROGRAM-ID. DoCalc.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 FirstNum    PIC 9    VALUE ZEROS.
01 SecondNum  PIC 9    VALUE ZEROS.
01 CalcResult  PIC 99   VALUE 0.
01 UserPrompt  PIC X(38) VALUE
    "Please enter two single digit numbers".

PROCEDURE DIVISION.
CalculateResult.
    DISPLAY UserPrompt
    ACCEPT FirstNum
    ACCEPT SecondNum
    COMPUTE CalcResult = FirstNum + SecondNum
    DISPLAY "Result is = ", CalcResult
    STOP RUN.
```

The program declares three numeric data items (variables): `FirstNum` for the first number input, `SecondNum` for the second, and `CalcResult` to hold the result of the calculation. It also declares a data item to hold the string used to prompt the user to enter two single-digit numbers.

Data declarations in COBOL are very different from the type-based declaration you might be used to in other languages, so some explanation is required. In COBOL, every data-item declaration starts with a level number. Level numbers are used to represent data hierarchy. Because all the items in this example program are independent, elementary data items, they have a level number of 01.

Following the level number is the name of the data item, and this in turn is followed by a storage declaration for the data item. The storage declaration defines the type and size of the storage required. To do this, COBOL uses a kind of “declaration by example” strategy. An example, or picture (hence PIC), is given of the maximum value the data item can hold. The symbols used in the picture declaration indicate the basic type of the item (numeric = 9, alphanumeric = X, alphabetic = A), and the number of symbols used indicates the size.

Consider the following declarations in `DoCalc`:

```
01 FirstNum      PIC 9  VALUE ZEROS.
01 SecondNum    PIC 9  VALUE ZEROS.
```

These indicate that `FirstNum` and `SecondNum` can each hold a cardinal number with a value between 0 and 9. If these data items were required to hold an integer number, the pictures would have to be defined as `PIC S9` (signed numeric).

In this program, the picture clauses (which is what they are called) are followed by `VALUE` clauses specifying that `FirstNum` and `SecondNum` start with an initial value of zero. In COBOL, unless a variable is explicitly given an initial value, its value is undefined.

■ **Bug Alert** Numeric data items must be given an explicit numeric starting value by means of the `VALUE` clause, using the `INITIALIZE` verb, or by assignment. If a numeric data item with an undefined value is used in a calculation, the program may crash. Of course, a data item with an undefined value may *receive* the result of a calculation because in that case any non-numeric data is overwritten with the calculation result.

The `CalcResult` data item is defined as follows:

```
01 CalcResult    PIC 99 VALUE 0.
```

This indicates that `CalcResult` can hold a cardinal number between 0 and 99. It too is initialized to zero, but in this case the value 0 is used rather than the word `ZEROS`. The word `ZEROS` is a special COBOL data item called a *figurative constant*. It has the effect of filling the data item with zeros. I have chosen to initialize this variable with the value 0 to make two points. First, numeric values can be used with the `VALUE` clause. Second, the figurative constant `ZEROS` should be used in preference to the numeric value because it is clearer than 0, which in some fonts can easily be mistaken for an O.

The `UserPrompt` data item is defined as follows:

```
01 UserPrompt    PIC X(24) VALUE
                 "Please enter two single digit numbers".
```

This indicates that it can hold an alphanumeric value of up to 24 characters. It has been initialized to a starting string value.

■ **COBOL Detail** `UserPrompt` should have been defined as a constant, but COBOL does not allow constants to be created. The nearest you can get to a user-defined constant in COBOL is to assign an initial value to a data item and then not change it. This is a serious deficiency that has finally been addressed in the ISO 2002 version of COBOL by means of the `CONSTANT` clause.

COBOL PUZZLE

Given the description of `BirthDate` in Example 2-10, what do you think would be displayed by the COBOL code in Example 2-11?

Example 2-10. `BirthDate` Data Description

```
01 BirthDate.
  02 YearOfBirth.
    03 CenturyOB      PIC 99.
    03 YearOB         PIC 99.
  02 MonthOfBirth    PIC 99.
  02 DayOfBirth      PIC 99.
```

Example 2-11. Code That Manipulates `BirthDate` and Its Subordinate Items

```
MOVE 19750215 TO BirthDate
DISPLAY "Month is = " MonthOfBirth
DISPLAY "Century of birth is = " CenturyOB
DISPLAY "Year of birth is = " YearOfBirth
DISPLAY DayOfBirth "/" MonthOfBirth "/" YearOfBirth
MOVE ZEROS TO YearOfBirth
DISPLAY "Birth date = " BirthDate.
```

The answer is at the end of the chapter.

The Condition Names Program

The final example program for this chapter previews COBOL condition names and the `EVALUATE` verb. A condition name is a Boolean item that can only take the value `true` or `false`. But it is much more than that. A condition name is associated (via level 88) with a particular data item. Rather than setting the condition name to `true` or `false` directly, as you might do in other languages, a condition name automatically takes the value `true` or `false` depending on the value of its associated data item.

Listing 2-4 accepts a character from the user and displays a message to say whether the character entered was a vowel, a consonant, or a digit. When `CharIn` receives a character from the user, the associated condition names are all set to `true` or `false` depending on the value contained in `CharIn`.

The `EVALUATE` verb, which is COBOL's version of `switch` or `case`, is shown here at its simplest. It is immensely powerful, complicated to explain, but intuitively easy to use. In this program, the particular `WHEN` branch executed depends on which condition name is `true`. See anything familiar, Ruby programmers?

Listing 2-4. Using the EVALUATE Verb

```

IDENTIFICATION DIVISION.
PROGRAM-ID. ConditionNames.
AUTHOR. Michael Coughlan.
* Using condition names (level 88's) and the EVALUATE
DATA DIVISION.
WORKING-STORAGE SECTION.
01 CharIn          PIC X.
   88 Vowel        VALUE "a", "e", "i", "o", "u".
   88 Consonant     VALUE "b", "c", "d", "f", "g", "h"
                   "j" THRU "n", "p" THRU "t", "v" THRU "z".
   88 Digit         VALUE "0" THRU "9".
   88 ValidCharacter VALUE "a" THRU "z", "0" THRU "9".
PROCEDURE DIVISION.
Begin.
  DISPLAY "Enter lower case character or digit. Invalid char ends."
  ACCEPT CharIn
  PERFORM UNTIL NOT ValidCharacter
    EVALUATE TRUE
      WHEN Vowel     DISPLAY "The letter " CharIn " is a vowel."
      WHEN Consonant DISPLAY "The letter " CharIn " is a consonant."
      WHEN Digit     DISPLAY CharIn " is a digit."
    END-EVALUATE
  ACCEPT CharIn
  END-PERFORM
  STOP RUN.

```

Chapter Exercise

Write a version of the ConditionNames program in your favorite language. See if you can convince yourself that your version is as clear, concise, readable, and maintainable as the COBOL version.

Where to Get a COBOL Compiler

Now that you've seen the basics of COBOL, it's time to get the software. A couple of years ago, the question of where to get a free COBOL compiler would have been difficult to answer. The policies of COBOL vendors, who were locked into mainframe thought patterns and pricing structures, made it very difficult for interested students to get access to a COBOL compiler. In very recent years, though, and probably in response to the shortage of COBOL programmers, a number of options have become available.

Micro Focus Visual COBOL

Micro Focus COBOL is probably the best-known version of COBOL for Windows PCs. Micro Focus Visual COBOL is the company's most recent version of COBOL. It implements the OO-COBOL standard and integrates either with Microsoft Visual Studio (where it acts as one of the standard .NET languages) or with Eclipse. It is available on Windows, Linux (Red Hat and SuSE) and Unix (Aix, HP-UX, and Solaris).

A personal edition of Visual COBOL is available that is free for non-commercial use. The Visual Studio version can be installed even if Visual Studio is not available, because in that case the Visual Studio Shell edition is installed.

www.microfocus.com/product-downloads/vcpe/index.aspx

OpenCOBOL

OpenCOBOL is an open source COBOL compiler. The OpenCOBOL web site claims to implement a substantial part of the [ANS 85](#) and [ANS 2002](#) COBOL standards as well as many of the extensions introduced by vendors such as Micro Focus and IBM.

OpenCOBOL translates COBOL into C. The C code can be compiled using the native C compiler on a variety of platforms including Windows, Unix/Linux, and Mac OS X.

The compiler is free and is available from www.opencobol.org/.

Raincode COBOL

Raincode is a supplier of programming-language analysis and transformation tools. The company has a version of COBOL available that integrates with Microsoft Visual Studio and generates fully managed .NET code. The COBOL compiler is free from www.raincode.com/mainframe-rehosting/.

Compileonline COBOL

An online COBOL compiler is available at compileonline.com. Its data input is somewhat problematic, which limits its usefulness, but it can be handy if you just want a quick syntax check. See www.compileonline.com/compile_cobol_online.php.

Fujitsu NetCOBOL

Fujitsu NetCOBOL is a very well-known version of COBOL for Windows. NetCOBOL implements a version of the OO-COBOL standard, compiles on the .NET Framework, and can interoperate with other .NET languages such as C# and VB.NET.

A number of other versions of this COBOL are available, including a version for Linux. A trial version is available for download but there is no free version: www.netcobol.com/product/netcobol-for-net/.

Summary

This chapter explored part of the foundational material required to write COBOL programs. Some of the material covered was informational, some practical, and some advisory. You saw how COBOL programs are organized structurally and learned the purpose of each of the four divisions. You examined COBOL metalanguage diagrams and the COBOL coding and name construction rules. I offered advice concerning name construction and the proper formatting of program code. Finally, you examined some simple COBOL programs as a preview of the material in coming chapters.

The next chapter examines how data is declared in COBOL. This chapter is only an introduction, though. Data declaration in COBOL is complicated and sophisticated because COBOL is mainly about data manipulation. COBOL data declarations offer many data-manipulation opportunities. Later chapters explore many advanced data-declaration concepts such as condition names, table declarations, the USAGE clause, and data redefinition using the REDEFINES clause.

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COBOL PUZZLE ANSWER

Given the description of BirthDate in Listing 2-5, what do you think would be displayed by the COBOL code in Listing 2-6?

Listing 2-5. BirthDate data description

```
01 BirthDate.
  02 YearOfBirth.
    03 CenturyOB      PIC 99.
    03 YearOB         PIC 99.
  02 MonthOfBirth    PIC 99.
  02 DayOfBirth      PIC 99.
```

Listing 2-6. Code manipulating BirthDate and its subordinate items

```
MOVE 19750215 TO BirthDate
DISPLAY "Month is = " MonthOfBirth
DISPLAY "Century of birth is = " CenturyOB
DISPLAY "Year of birth is = " YearOfBirth
DISPLAY DayOfBirth "/" MonthOfBirth "/" YearOfBirth
MOVE ZEROS TO YearOfBirth
DISPLAY "Birth date = " BirthDate.
```

COBOL Puzzle Answer

```
Month is = 02
Century of birth is = 19
Year of birth is = 1952
15/02/1952
Birth date = 00000215
```

CHAPTER 3



Data Declaration in COBOL

As you explore the COBOL language, you will notice many differences between it and other programming languages. Iteration, selection, and assignment are all done differently in COBOL than in languages like C, Java, and Pascal. But on the whole, these differences are fairly minor—more a question of nuance than a radical departure. When you are familiar with how iteration and selection work in other languages, COBOL's implementation requires only a small mental adjustment. Assignment might create more of a hiccup, but there is nothing too radical even in that. The real difference between COBOL and these other languages lies in how data is declared.

This chapter explores the different categories of data used in COBOL. It demonstrates how you can create and use items of each category. Because COBOL's approach to data declaration affects assignment in COBOL, that topic is also examined in this chapter.

Categories of Program Data

COBOL programs basically use three categories of data:

- Literals
- Figurative constants
- Data items (variables)

Unlike other programming languages, COBOL does not support user-defined constants.

COBOL Literals

A literal is a data item that consists only of the data item value itself. It cannot be referred to by a name. By definition, literals are constants in that they cannot be assigned a different value.

There are two types of literal:

- Alphanumeric (text/string) literals
- Numeric literals

Alphanumeric Literals

Alphanumeric literals are enclosed in quotes and consist of alphanumeric characters. Here are some examples:

```
"William Murphy", "1528", "-1528", "1528.95"
```

■ **Note** Enclosing the text in quotes defines the item as an alphanumeric literal even though the literal value may be entirely numeric.

Numeric Literals

Numeric literals may consist of numerals, the decimal point, and the plus or minus sign. Numeric literals are not enclosed in quotes. Here are some examples:

1528, 1528.95, -1528, +1528

Data Items (Variables)

A data item can be defined as a named location in memory in which a program can store a data value and from which it can retrieve the stored value. A **data name**, or identifier, is the name used to identify the area of memory reserved for a data item.

In addition to the data name, a data item must also be described in terms of its basic type (alphabetic, alphanumeric, numeric) and its size. Every data item used in a COBOL program must have a description in the DATA DIVISION.

Data Type Enforcement

Languages such as Pascal, Java, and C# may be described as *strongly typed* languages. In these languages, there are a number of different data types, and the distinction between them is rigorously enforced by the compiler. For instance, if a variable is defined as a float, the compiler will reject a statement that attempts to assign a character value to that variable.

In COBOL, there are only three types of data: numeric, alphanumeric (text/string), and alphabetic. The distinction between these data types is only weakly enforced by the compiler. In COBOL, it is possible to assign a non-numeric value to a data item that has been declared to be numeric.

The problem with this lax approach to data typing is that COBOL programs crash (halt unexpectedly) if they attempt to do computations on numeric data items that contain non-numeric data. In COBOL, therefore, it is the responsibility of the *programmer* to ensure that non-numeric data is never assigned to a numeric data item intended for use in a calculation. Programmers who use strongly typed languages do not need to have this level of discipline because the *compiler ensures* that a variable of a particular type can only be assigned an appropriate value.

■ **Bug Alert** Attempting to perform computations on numeric data items that contain non-numeric data is a frequent cause of program crashes for beginning COBOL programmers. This can easily happen if the data item has not been initialized to a valid starting value.

Figurative Constants

Unlike most other programming languages, COBOL does not provide a mechanism for creating user-defined, named constants. This is a serious deficiency. Named constants make a program more readable and more maintainable.

For instance, although a literal value of .06 (representing the current sales tax rate of 6%) could be used throughout a program whenever the sales tax rate was required, the program would be more readable if the value was assigned to the named constant `SalesTaxRate`. Similarly, using a named constant would make maintenance easier. If the actual sales tax rate changed, only the constant definition would have to be updated instead of all the places in the program where the literal sales tax rate value was used.

In COBOL, a data item can be assigned a value, but there is no way to ensure that, somewhere in the program, some maintenance programmer has not assigned a different value to the data item.

■ **ISO 2002** Although this book adheres to the ANS 85 standard, you may be interested to know that this deficiency has been addressed in ISO 2002 COBOL standard by means of the `CONSTANT` clause entry.

Code example:

```
01 SalesTaxRate  CONSTANT AS .06.
```

Although COBOL does not allow user-defined named constants, it does have a set of special constants called *figurative constants*. Figurative constants are special constant values that may be used wherever it is legal to use a literal value. However, unlike a literal, when a figurative constant is assigned to a data item, it fills the entire item, overwriting everything in it. Figurative constants are often used to initialize data items. For instance, `MOVE SPACES TO CustomerName` fills the whole data item with spaces, and `MOVE ZEROS TO FinalTotal` fills that data item with zeros. Table 3-1 shows the COBOL figurative constants.

Table 3-1. *Figurative Constants*

Figurative Constant	Behavior
ZERO ZEROS ZEROES	Behaves like one or more instances of the literal value 0. The constants ZERO, ZEROS, and ZEROES are all synonyms. Whichever is used, the effect is exactly the same.
SPACE SPACES	Behaves like one or more instances of the <i>space</i> character. SPACE and SPACES are synonyms.
HIGH-VALUE HIGH-VALUES	Behaves like one or more instances of the character in the highest ordinal position in the current collating sequence (usually the ASCII character set). HIGH-VALUE and HIGH-VALUES are synonyms.
LOW-VALUE LOW-VALUES	Behaves like one or more instances of the character in the lowest ordinal position in the current collating sequence (the null character [hex 00] in the ASCII character set). LOW-VALUE and LOW-VALUES are synonyms.
QUOTE QUOTES	Behaves like one or more instances of the quote character. However, it cannot be used to bracket a non-numeric literal instead of the actual quote character. For instance, <code>QUOTE Freddy QUOTE</code> cannot be used in place of "Freddy". QUOTE and QUOTES are synonyms.
ALL literal	Allows an ordinary literal character to behave as if it were a figurative constant.

Elementary Data Items

An *elementary item* is the equivalent of a variable in other languages. It is an atomic data item that is not further subdivided. The type and size of an elementary data item are the type and size specified in its PICTURE clause.

In COBOL, an elementary data item declaration consists of a line of code containing the following mandatory items:

- A level number
- A data-name or identifier
- A PICTURE clause

The declaration may also take a number of optional clauses. The most common optional clause is the VALUE clause, which assigns an initial, or starting, value to a data item.

Elementary data items that are not a subdivision of a group item must use a level number of 01 or 77. This book uses 01 for these items. A discussion of the role of level 77s is reserved for later in this chapter.

■ **Note** A data item declaration may also take a number of other optional clauses such as USAGE, BLANK WHEN ZERO, and JUSTIFIED.

Declaring Elementary Data Items

In typed languages, the data type specified is important because the type determines the range of values that the item can store and governs the operations that can be applied to it. For instance, a Java `int` data item can store values between -2,147,483,648 and 2,147,483,647 and can only be used in operations that expect an operand of that, or a compatible, type. From the type of the item, the compiler can establish how much memory to set aside for storing its values.

COBOL is not a *typed* language, so it employs a very different mechanism for describing its data items. COBOL uses what could be described as a “declaration by example” strategy. In effect, you provide the system with an example, or template, or *picture* of the size and type (alphabetic, numeric, alphanumeric) of the item. From this PICTURE clause, the compiler derives the information necessary to allocate the item.

PICTURE Clause Symbols

To create the required picture, you use a set of symbols. The most common symbols used in standard PICTURE clauses are shown in Table 3-2.

Table 3-2. Common Symbols Used in Standard PICTURE Clauses

Symbol	Meaning
A	Indicates an occurrence of any alphabetic character (<i>a</i> to <i>z</i> plus blank) at the corresponding position in the picture: 01 ThreeLetterAcronym PIC AAA VALUE "DNA".
X	Indicates an occurrence of any character from the character set at the corresponding position in the picture: 01 Salutation PIC XXX VALUE "Mr.".
9	Indicates the occurrence of a digit at the corresponding position in the picture: 01 CardinalValue PIC 9(4) VALUE 1234.
V	Indicates the position of the decimal point in a numeric value. It is often referred to as the <i>assumed decimal point</i> because it is not part of the value but is rather <i>information</i> about the value: 01 TotalSales PIC 9(5)V99 VALUE ZEROS.
S	Indicates the presence of a sign, and can only appear at the beginning of a picture: 01 IntegerValue PIC S9(4) VALUE -1234.

■ **Note** There are many more picture symbols than those listed in Table 3-2. Most of the remaining symbols will be introduced when you explore edited pictures in Chapter 9.

PICTURE Clause Notes

Although the word PICTURE can be used when defining a PICTURE clause, it is normal to use the abbreviation PIC. The recurring symbols in a PICTURE clause can become difficult to count, especially at a glance, so it is normal practice to specify recurring symbols by using a *repeat* factor inside brackets. For instance:

PIC 9(8) is equivalent to PICTURE 99999999.

PIC 9(7)V99 is equivalent to PIC 9999999V99.

PICTURE X(15) is equivalent to PIC XXXXXXXXXXXXXXXX.

PIC S9(5)V9(4) is equivalent to PIC S99999V9999.

PICTURE 9(18) is equivalent to PIC 999999999999999999.

The repeat factor in brackets is normally used for any picture string with more than three symbols. For instance, a three-digit data item might be described as PIC 999, but a four-digit item would be PIC 9(4).

Numeric values can have a maximum of 18 digits, whereas the limit on string values (PIC X) is usually system dependent.

■ **ISO 2002** In the 2002 standard, the maximum number of digits in a numeric literal or PICTURE clause was increased from 18 digits to 31 digits.

Example Declarations

In typed languages, because the memory required is defined by a variable's data type, a picture of what is happening to the data in the memory is not useful. In COBOL, however, knowing what is happening to the data in memory is very important for a proper understanding of how data declaration and data movement work. For this reason, many of the examples in this book are accompanied by an illustration that attempts to show what is happening to the data.

Consider the examples that follow. A simplified version of what is happening in memory is shown in Example 3-1. Later examples use more granular illustrations that show each character of storage. One thing you can already note from even this simple example is that although `TaxRate` is given an initial value of `.35`, what is actually in memory is `35`. The `V` in the `PICTURE` clause tells COBOL to treat this item as if it had a decimal point in the leftmost character position. Example 3-1 also reveals that the values in alphanumeric data items are left aligned and space filled (the example shows the space character as `*`), whereas numeric data items seem to be right aligned (they aren't—see the "MOVE Rules" section later in this chapter) and zero filled.

Example 3-1. Data Items and Memory Representation

WORKING-STORAGE SECTION			
Num1	Num2	TaxRate	CustomerName
000	015	35	Mike*****

DATA DIVISION.

WORKING-STORAGE SECTION.

```
01 Num1          PIC 999  VALUE ZEROS.
01 Num2          PIC 999  VALUE 15.
01 TaxRate       PIC V99  VALUE .35.
01 CustomerName PIC X(15) VALUE "Mike".
```

Assignment in COBOL

In typed languages, the assignment operation is simple because assignment is only allowed between items with compatible types. The simplicity of assignment in these languages is achieved at the cost of having a large number of data types.

In COBOL, there are only three basic data types:

- Alphabetic (PIC A)
- Alphanumeric (PIC X)
- Numeric (PIC 9)

But this simplicity is achieved at the cost of having a complex assignment statement.

The MOVE Verb

Assignment in COBOL is achieved using the `MOVE` verb. The `COMPUTE` verb, which assigns the result of an arithmetic expression to a data item, should never be used to assign the value of one item to another. Similarly, the `SET` verb, which can be used to set a condition name to `TRUE` or to change the value in a table index, should only be used for these specialized purposes. All ordinary assignments should use `MOVE`.

MOVE Syntax

The MOVE metalanguage makes the verb seem simple but its operation is complicated by a set of governing rules. The metalanguage for MOVE is as follows:

MOVE Source\$#i1 TO Destination\$#i...

MOVE copies data from the source identifier (or literal) to one or more destination identifiers. The source and destination identifiers can be group or elementary data items.

In most programming languages, the data movement in an assignment statement is from right to left. That is, data is copied from the source item on the right to the destination item on the left (for example, $Dest := Source$ ^{Modula-2} or $Dest = Source$ ^{Java}). COBOL does things differently. In COBOL, the MOVE verb copies data from the source item on the left to the destination item(s) on the right. Almost all the COBOL verbs conform to this pattern of data movement. The COMPUTE verb, which has its destination data item on the left, is the one exception.

MOVE Rules

The major rules for the MOVE verb are given here. As with all the other verbs, you need to consult your COBOL manual for the more esoteric rules:

- The source and destination identifiers can be either elementary or group data items.
- When data is copied into a destination item, the contents of the destination item are completely replaced. The contents of the source item are undisturbed.
- If the number of characters in the source item is *too few* to fill the destination item, the rest of the destination item is filled with zeros or spaces.
- If the number of characters in the source item is *too many* to fit in the destination item, the characters that cannot fit are lost. This is known as *truncation*.
- When the destination item is alphanumeric or alphabetic (PIC X or A), data is copied into the destination area from left to right, with space-filling or truncation on the right.
- When the destination item is numeric or edited numeric, data is *aligned along the decimal point* with zero-filling or truncation as necessary.
- When the decimal point is not explicitly specified in either the source or destination item(s), the item is treated as if it had an assumed decimal point immediately after its rightmost character.

MOVE Combinations

Although COBOL is much less restrictive in this respect than many other languages, certain combinations of sending and receiving data types are not permitted (even by COBOL) and will be rejected by the compiler. The valid and invalid MOVE combinations are shown in Figure 3-1.

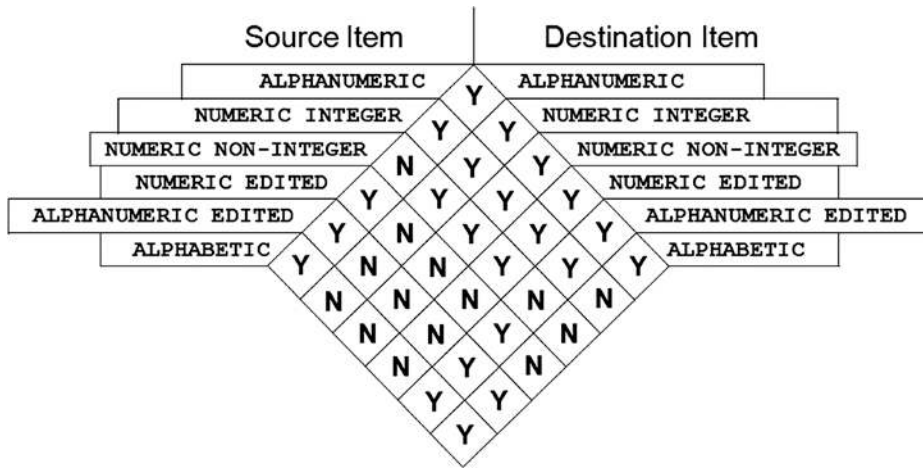


Figure 3-1. Valid and invalid MOVE combinations

Source: J.M. Triance, *Structured COBOL Reference Summary*, National Computing Centre Limited, N.C.C Publications, 1984, page 48.

MOVE Examples

Having a dusty set of rules is all very well, but the operation of the MOVE verb can only be appreciated by examining some examples. The examples in this section only feature elementary data items. Things get a lot more exciting when MOVE is used with a group item; you will see some examples of group item moves at the end of the chapter.

Alphanumeric MOVES

Remember the following rule for alphanumeric MOVES: when the destination item is alphanumeric or alphabetic (PIC X or A), data is copied into the destination area from *left to right* with space-filling or truncation on the right.

In Example 3-2, the data item Surname is described as having sufficient storage for eight alphanumeric characters. It has been assigned an initial value of "COUGHLAN".

Example 3-2. Alphanumeric Moves with Truncation and Space Filling

```
01 Surname      PIC X(8) VALUE "COUGHLAN".
MOVE "SMITH" TO Surname
MOVE "FITZWILLIAM" TO Surname
```

Surname							
C	O	U	G	H	L	A	N
S	M	I	T	H	*	*	*
F	I	T	Z	W	I	L	L

When the first move is executed, "SMITH" is copied into Surname from left to right. Because "SMITH" has too few characters to fill Surname, the rest of the data item is filled with spaces.

The second move copies "FITZWILLIAM" into Surname from left to right. Because the literal is too large to fit into Surname, the last three letters (IAM) are truncated.

Numeric MOVES

Remember the following rule for numeric MOVES: when the destination item is numeric or edited numeric, data is aligned along the decimal point with zero-filling or truncation as necessary. An edited numeric data item is one that contains symbols such as \$ and , and . that format data for output. They are not numeric items, and they can't be used in calculations (except as the receiving field), but they do obey the decimal-point alignment and zero-filling rules. Edited numeric data items are discussed in Chapter 9.

When the decimal point is not explicitly specified in either the source or destination item(s), the item is treated as if it had an assumed decimal point immediately after its rightmost character.

Example Set 1

In Example 3-3, SalePrice is a data item described as PIC 9(4)V99: that is, a decimal number with four digits before the decimal point and two after it. For each MOVE statement, a diagram showing the contents of the SalePrice data item is given. Each diagram shows the actual data moved in black, the filled zeros in grey, and the truncated digits outside the memory area. The position of the assumed decimal point is indicated with an arrow.

When the figurative constant ZEROS (or ZERO or ZEROES) is moved to SalePrice, the data item is filled with zeros.

When the numeric literal 25.5 is moved to SalePrice, there is alignment along the decimal point of the literal and the assumed decimal point in SalePrice, with the result being zero-filling on both the left and right sides.

When 7.553 is moved to SalePrice, there is alignment of the decimal points, with the result being zero-filling on the left and truncation of the digit 3 on the right. In the diagram the truncated digit is shown outside the memory area.

When 93425.158 is moved to SalePrice, there is alignment of the decimal points, with the result that the most significant digit is truncated on the left and the least significant on the right.

The literal value 128 contains no decimal point, so it is treated as if it had a decimal point in the rightmost position. This decimal point is aligned with assumed decimal point in SalePrice, with the result that there is zero filling on the left and right.

Example 3-3. Numeric MOVES with Alignment Along the Decimal Point, Truncation, and Zero-Filling

01 SalePrice	PIC 9(4)V99.	
MOVE ZEROS TO SalePrice		
MOVE 25.5 TO SalePrice		
MOVE 7.553 TO SalePrice		
MOVE 93425.158 TO SalePrice	9	
MOVE 128 TO SalePrice		

SalePrice					
0	0	0	0	0	0
0	0	2	5	5	0
0	0	0	7	5	5
3	4	2	5	1	5
0	1	2	8	0	0

↑
•

Inadvertent truncation is obviously not desirable; but unfortunately, for MOVE operations at least, there is no protection against it. It is up to you to ensure that the data item is large enough to take the data moved into it. Inadvertent truncation is much more likely when calculations are involved. When a number of values are multiplied together, you might not realize that in some cases the result will be too large for the receiving data item. For computations, you can protect against inadvertent truncation by means of the ON SIZE ERROR clause. When this clause is used, it acts like a specialized exception handler. Chapter 4 discusses ON SIZE ERROR when you examine the operation of the COBOL arithmetic verbs.

Example Set 2

In Example 3-4, NumOfEmployees is described as a cardinal number capable of holding a value between 0 and 999. Salary is a decimal number data item with four digits before the decimal point and two after it. CountyName is an alphanumeric data item nine characters long.

The literal value 6745 has no decimal point, so it is treated as if the number has a decimal point in the rightmost position (6745.). NumOfEmployees also contains no explicit decimal point, so it is treated as if the data item has an assumed decimal point specified in the rightmost position:

```
01 NumOfEmployees PIC 999V
```

When the literal 6745 is moved to NumOfEmployees, there is alignment along these decimal points. The result is truncation of the most significant digit.

When NumOfEmployees (treated as if defined as 01 NumOfEmployees PIC 999V) is moved to Salary, which does have an explicit decimal point, there is alignment along the decimal points, with the result being zero-filling on both the left and right.

When the literal value 12.4 is moved to NumOfEmployees (treated as if defined as 01 NumOfEmployees PIC 999V), there is alignment along the decimal points with truncation of the digit 4 on the right and zero-filling on the left.

When the literal "Galway" is moved to CountyName, the data movement starts filling the data item from the left. When the value does not entirely fill the data item, the remaining character positions are space-filled.

When the figurative constant ALL and its associated character literal are moved to a data item, the data item is entirely filled with the character specified. In this example, the character specified after ALL is the hyphen, so CountyName is filled with hyphens.

Example 3-4. Numeric and Alphanumeric MOVES

```
01 NumOfEmployees PIC 999.
```

```
MOVE 12.4 TO NumOfEmployees
```

```
MOVE 6745 TO NumOfEmployees
```

NumOfEmployees				
0	1	2	4	0
6	7	4	5	0

↑

•

```
01 Salary PIC 9999V99.
```

```
MOVE NumOfEmployees TO Salary
```

Salary					
0	7	4	5	0	0

↑

•

```
01 CountyName PIC X(9).
```

```
MOVE "GALWAY" TO CountyName
```

```
MOVE ALL "@" TO CountyName
```

CountyName								
G	A	L	W	A	Y	*	*	*
@	@	@	@	@	@	@	@	@

Structured Data

In COBOL, the term *elementary item* describes an ordinary data item or variable. An elementary item is a data item that is *atomic*: it has not been further subdivided. Every elementary item must have a PICTURE clause. The PICTURE clause specifies the type and size of the storage required for the data item.

Group Data Items

Sometimes when you are manipulating data it is convenient to treat a collection of elementary items as a single group. For instance, you might want to group the data items `Forename`, `MiddleInitial`, and `Surname` as the group `EmployeeName`. Alternatively, you might want to group the `YearOfBirth`, `MonthOfBirth`, `DayOfBirth` data items as the group `DateOfBirth`. In addition, you might want to collect both these group items and some elementary items in an employee record description.

In COBOL, you can easily create groups like these using *group items*. A group item in COBOL is a data item that is a collection of elementary and/or group data items. It is a heterogeneous data structure. In languages like Pascal and Modula-2, group items are referred to as *records*. In C and C++, they are called *structs*. Java has no real equivalent.

The constituent parts of a group item may be elementary items or other group items. But ultimately, every group item must be defined in terms of its subordinate elementary items. Because a group item is ultimately defined in terms of elementary items, it *cannot* have a `PICTURE` clause, and its size is the sum of the sizes of its subordinate elementary items. A group item is simply a convenient name that you give to a collection of (ultimately) elementary items. Using that name, you can manipulate the collection.

In a group item, the hierarchical relationship between the various subordinate items of the group is expressed using level numbers. The higher the level number, the lower the item is in the hierarchy and the more atomic it is. If a group item is the highest item in a data hierarchy, it is referred to as a *record* and uses the level number 01.

The type of a group item is always assumed to be alphanumeric (`PIC X`, even if it contains only numeric data items) because a group item may have several different data items and types subordinate to it, and an alphanumeric picture is the only one that can support such collections.

Level Numbers

Level numbers 01 through 49 are the general level numbers used to express data hierarchy. There are also special level numbers such as 66, 77, and 88:

- Level 66 is used with the `RENAMES` clause. The `RENAMES` clause allows you to apply a new name to a data-name or group of contiguous data-names. It is similar to the `REDEFINES` clause; but because of the maintenance problems associated with it, the `RENAMES` clause has largely fallen into disuse and in some programming shops is banned. You learn more about the operation and shortcomings of the `RENAMES` clause when the `REDEFINES` clause is examined later in the book.
- Level 77 is used to identify a noncontiguous, single data item in the `WORKING-STORAGE` or `LINKAGE` sections; it cannot be subdivided, and it cannot be part of a group item. In the past, 77s were used for efficiency purposes (77s used less memory than the same items defined as a level 01). Nowadays level 01 is often used instead of 77. Some programming shops take the view that, instead of declaring large numbers of indistinguishable 77s, it is better to collect the individual items into named groups for documentation purposes even if the group, as a group, has no practical purpose. For instance, you might group individual totals such as `ShopTotal`, `CityTotal`, `StateTotal`, and `CountryTotal` under the group item `Totals` for documentation purposes. You could not create such a grouping if the items were declared using level 77s.
- Level 88 is used to implement condition names. Whereas level 66 and level 77 are not used in modern COBOL, level 88s and condition names are very important, useful, and unique weapons in COBOL's armory. Chapter 5 provides a detailed examination of the declaration and use of level 88s and condition names.

Data Hierarchy

Level numbers are used to express data hierarchy. The best way to understand the data hierarchy and the data-manipulation opportunities afforded by this organization is by means of an example.

Suppose you want to store information about students. You can create a data item called `StudentRec` and describe it as follows:

```
01 StudentRec    PIC X(44).
```

You can load some data into `StudentRec` using this statement:

```
MOVE "1205621William Fitzpatrick 19751021LM051385" TO StudentRec.
```

Once you have done this, the `StudentRec` area of storage is instantiated with the data as shown in Example 3-5.

Example 3-5. StudentRec as an Elementary Data Item

WORKING-STORAGE SECTION.

```
01 StudentRec    PIC X(44).
```

StudentRec																																												
1	2	0	5	6	2	1	W	I	L	L	I	A	M			F	I	T	Z	P	A	T	R	I	C	K			1	9	7	5	1	0	2	1	L	M	0	5	1	3	8	5

You can see that the data in `StudentRec` consists of a number of pieces of information: the student's ID, the student's name, the date of birth, the course ID, and the student's grade point average (GPA). But because you have defined `StudentRec` as an elementary item (an undifferentiated string of characters), you have no easy way of getting at the individual pieces of data. You can move or display the contents of the entire string, but you cannot easily, for instance, display only the date of birth or the student's name.

What you need to do is to describe `StudentRec` as a group item that is subdivided into `StudentId`, `StudentName`, `DateOfBirth`, `CourseId`, and `GPA`. The revised `StudentRec` description and the way it appears in storage are shown in Example 3-6.

Example 3-6. StudentRec as a Group Data Item

WORKING-STORAGE SECTION.

```
01 StudentRec.
   02 StudentId      PIC 9(7).
   02 StudentName    PIC X(21).
   02 DateOfBirth    PIC X(8).
   02 CourseId       PIC X(5).
   02 GPA            PIC 9V99.
```

StudentRec																																												
StudentId							StudentName																					DateOfBirth								CourseId					GPA			
1	2	0	5	6	2	1	W	I	L	L	I	A	M			F	I	T	Z	P	A	T	R	I	C	K			1	9	7	5	1	0	2	1	L	M	0	5	1	3	8	5

`StudentRec` has been subdivided into a number of individual data items. Because `StudentRec` is now a group item, it has no `PICTURE` clause. Its size is the sum of the sizes of the elementary items, and its type is alphanumeric.

Defining StudentRec this way presents you with a number of data-manipulation opportunities. You can still manipulate the whole record. For instance, you can flush the entire 44-character area with spaces using a statement like this:

```
MOVE SPACES TO StudentRec
```

Or you can move the entire contents to another data item with a statement such as

```
MOVE StudentRec to StudentRecCopy
```

But now you can manipulate the individual pieces of data with statements such as these:

```
DISPLAY "Student name = " StudentName
MOVE ZEROS TO StudentId
MOVE "LM067" TO CourseId
DISPLAY "Current GPA = " GPA
MOVE 2.55 TO GPA
MOVE 19751022 TO DateOfBirth
```

It is useful to be able to access the individual pieces of data that constitute StudentRec, but the structure is still not quite granular enough. For instance, you can only access the entire student name. It would be nice to be able to manipulate the forename and the surname individually. Similarly, you would like to be able to access the year, month, and day of birth as separate items.

To make these changes, you need to describe StudentName and DateOfBirth as group items. The revised StudentRec description and the effect of this restructuring on the data storage are shown in Example 3-7.

Example 3-7. StudentRec as a Group Data Item

```
WORKING-STORAGE SECTION.
01 StudentRec.
   02 StudentId          PIC 9(7).
   02 StudentName.
      03 Forename        PIC X(9).
      03 Surname         PIC X(12).
   02 DateOfBirth.
      03 YOB             PIC 9(4).
      03 MOB             PIC 99.
      03 DOB            PIC 99.
   02 CourseId          PIC X(5).
   02 GPA               PIC 9V99.
```

StudentRec																																								
StudentId							StudentName												DateOfBirth			CourseId		GPA																
							Forename						Surname						YOB	MOB	DOB																			
1	2	0	5	6	2	1	W	I	l	l	i	a	m	F	i	t	z	p	a	t	r	i	c	k	1	9	7	5	1	0	2	1	L	M	0	5	1	3	8	5

With this new structure, many more data-manipulation opportunities become available. You can still access `StudentRec`, `StudentId`, `StudentName`, `DateOfBirth`, `CourseId`, and `GPA` as before, but now you can also manipulate the data at a more granular level using statements like these:

```
DISPLAY "Student date of birth is " DOB "/" MOB "/" YOY
DISPLAY "Student name = " Surname ", " SPACE Forename
MOVE "Billy" TO Forename
MOVE 22 TO DOB
```

The first statement displays the date of birth on the computer screen:

```
Student date of birth is 21/10/1975
```

The second statement displays the student's name:

```
Student name = Fitzpatrick, William
```

■ **COBOL Detail** When a figurative constant is used with the `DISPLAY` verb, it inserts only one character; it does not matter if `SPACE` or `SPACES` is used, because they are synonyms. If you wanted to insert two spaces in the previous statement, you would have to write the statement as follows:

```
DISPLAY "Student name = " Surname ", " SPACE SPACE Forename
```

Level-Number Relationships Govern Hierarchy

Level numbers express the data hierarchy. A data hierarchy starts with level number 01; the subdivisions then use any number between 02 and 49 to express the hierarchy. The rule to remember is this: a data item with a level number higher than the preceding data item is a subdivision of that data item; a data item with the same level number as the preceding item is at the same level as that item; a data item with a level number lower than the preceding item is at the same level as its first matching preceding level number. For instance, in Example 3-7, `Forename` has a level number higher than `StudentName`, so `Forename` is a subdivision of `StudentName`. `Surname` has the same level number as `Forename`, so it too is a subdivision of `StudentName`.

In a hierarchical data description, what is important is the *relationship* of the level numbers to one another, not the actual level numbers used. For instance, the record descriptions shown in Example 3-8, Example 3-9, and Example 3-10 are equivalent.

Example 3-8 shows my preferred organization and the one used in this book. This organization seems logical and offers benefits of clarity by making the level numbers coincidental with the levels in the structure.

Example 3-8. Preferred Format

```
01 StudentRec.
  02 StudentId      PIC 9(7).
  02 StudentName.
    03 Forename     PIC X(9).
    03 Surname      PIC X(12).
  02 DateOfBirth.
    03 YOY          PIC 9(4).
    03 MOB          PIC 99.
    03 DOB          PIC 99.
```

```

02 CourseId      PIC X(5).
02 GPA           PIC 9V99.

```

Example 3-9 shows that level numbers are used only to show the relationship with the immediately preceding items. For instance, the fact that YOB, MOB, and DOB use level number 14 and Forename and Surname use level 12 is not relevant. What *is* relevant is that the level numbers show that the items are subordinate to their respective preceding items (StudentName in the first case and DateOfBirth in the second).

Example 3-9. Arbitrary Format

```

01 StudentRec.
  07 StudentId      PIC 9(7).
  07 StudentName.
    12 Forename     PIC X(9).
    12 Surname      PIC X(12).
  07 DateOfBirth.
    14 YOB          PIC 9(4).
    14 MOB          PIC 99.
    14 DOB          PIC 99.
  07 CourseId      PIC X(5).
  07 GPA           PIC 9V99.

```

Example 3-10 uses a layout often found in programming shops and COBOL books. This organization lets you create group items by slipping a group item into the description without otherwise disturbing the layout (see the **MOB** and **DOB** data item in Example 3-11). This seems like a good idea, and it is part of the coding standards for some programming shops; but over time, this approach causes the structure's clarity to deteriorate. In my view, if the data hierarchy needs to be reorganized, then it should be reorganized properly, so that future maintenance programmers will have no difficulty in comprehending the structure created.

Example 3-10. Common Format

```

01 StudentRec.
  05 StudentId      PIC 9(7).
  05 StudentName.
    10 Forename     PIC X(9).
    10 Surname      PIC X(12).
  05 DateOfBirth.
    10 YOB          PIC 9(4).
    10 MOB          PIC 99.
    10 DOB          PIC 99.
  05 CourseId      PIC X(5).
  05 GPA           PIC 9V99.

```

Example 3-11. Common Format in Use

```

01 StudentRec.
  05 StudentId      PIC 9(7).
  05 StudentName.
    10 Forename     PIC X(9).
    10 Surname      PIC X(12).
  05 DateOfBirth.
    08 YOB          PIC 9(4).

```

08 MOB and DOB.

```

    10 MOB          PIC 99.
    10 DOB          PIC 99.
05 CourseId       PIC X(5).
05 GPA            PIC 9V99.

```

Summary

This chapter provided an introduction to data in COBOL. It introduced the different types of data used, and it showed how you can create and use variable data in the form of elementary data items. The chapter examined the assignment operation and discussed the data-manipulation opportunities afforded by the hierarchical structure of group item data declarations.

But this is just an introduction to data declaration in COBOL. In the rest of this book, you expand your knowledge of data declaration by exploring such topics as the implicit redefinition of data items in the FILE SECTION, the operation of the REDEFINES clause, the preparation of data for output using edited pictures, the USAGE clause, and the declaration of tabular information.

LANGUAGE KNOWLEDGE EXERCISE

Using a 2B pencil, write your answer to each exercise question in the area provided.

1. Create an elementary data item called `TaxAmount` to hold a value between 0 and 99,999.99.

2. Create an alphanumeric elementary data item called `VideoName` large enough to hold 35 characters. Define `VideoName` so that it is initialized with spaces when the program starts.

3. A data item called `MinimumWage` is defined as `PIC 9V99`. Show what happens to the data after execution of the statement

```
MOVE 123.5 TO MinimumWage
```

MinimumWage

--	--	--

4. A group item called `CustomerRec` is defined

```

01 CustomerRec.
    02 CustId          PIC 9(5)   VALUE ZEROS.
    02 CustName.
        03 Initials   PIC XX     VALUE SPACES.
        03 Surname    PIC X(4)   VALUE SPACES.
    02 Gender          PIC X.     VALUE SPACES.
    02 Payment        PIC 9(5)V99 VALUE ZEROS.

```

- a. A partial diagram representing the CustomerRec is provided. Complete the diagram by showing how the subordinate data items map to the 19 characters of storage reserved for CustomerRec.
- b. In the first row of the diagram, show how each VALUE clause initializes the data items in CustomerRec.
- c. For each statement in the following program, show what happens to the data in CustomerRec. Use a row for each statement.

```

PROCEDURE DIVISION.
10-BEGIN.
MOVE "45145MCRyanF23445.67" TO CustomerRec
MOVE "Male" TO Gender
MOVE "GSPower" TO CustName
MOVE "Fitzroy" TO Surname
MOVE 34 TO Cust-Payment
STOP RUN.
    
```

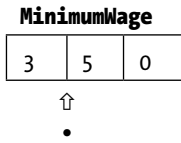
CustomerRec																		
CustId					CustName					Gender					Payment			
					Initials		Surname											

LANGUAGE KNOWLEDGE EXERCISE—ANSWERS

- 1. Create an elementary data item called TaxAmount to hold a value between 0 and 99,999.99.
 01 TaxAmount PIC 9(5)V99.
- 2. Create an alphanumeric elementary data item called VideoName large enough to hold 35 characters. Define VideoName so that it is initialized with spaces when the program starts.
 01 VideoName PIC X(35).

3. A data item called `MinimumWage` is defined as `PIC 9V99`. Show what happens to the data after execution of the statement

```
MOVE 123.5 TO MinimumWage
```



4. A group item called `CustomerRec` is defined as

```
01 CustomerRec.
  02 CustId          PIC 9(5)    VALUE ZEROS.
  02 CustName.
    03 Initials      PIC XX      VALUE SPACES.
    03 Surname       PIC X(4)    VALUE SPACES.
  02 Gender          PIC X.      VALUE SPACES.
  02 Payment        PIC 9(5)V99  VALUE ZEROS.
```

- a. A partial diagram representing the `CustomerRec` is provided. Complete the diagram by showing how the subordinate data items map to the 19 characters of storage reserved for `CustomerRec`.
- b. In the first row of the diagram, show how each `VALUE` clause initializes the data items in `CustomerRec`.
- c. For each statement in the following program, show what happens to the data in `CustomerRec`. Use a row for each statement.

```
PROCEDURE DIVISION.
10-BEGIN.
MOVE "45145MCRyanF23445.67" TO CustomerRec
MOVE "Male" TO Gender
MOVE "GSPower" TO CustName
MOVE "Fitzroy" TO Surname
MOVE 34 TO Cust-Payment
STOP RUN.
```

CustomerRec																			
CustId					CustName						Gender	Payment							
					Initials		Surname												
0	0	0	0	0	*	*	*	*	*	*	*	0	0	0	0	0	0	0	0
4	5	1	4	5	M	C	R	y	a	n	F	2	3	4	4	5	6	7	
4	5	1	4	5	M	C	R	y	a	n	M	2	3	4	4	5	6	7	
4	5	1	4	5	G	S	P	o	w	e	M	2	3	4	4	5	6	7	
4	5	1	4	5	G	S	F	i	t	z	M	2	3	4	4	5	6	7	
4	5	1	4	5	G	S	F	i	t	z	M	0	0	0	3	4	0	0	

CHAPTER 4



Procedure Division Basics

The three preceding chapters covered much of the background material you need before you can write useful programs. Chapter 1 was motivational, Chapter 2 dealt with the structure of COBOL programs, and in Chapter 3 you learned how to define the data storage that dynamic programs require to be useful.

The PROCEDURE DIVISION contains the code used to manipulate data described in the DATA DIVISION. This chapter examines some of the basic PROCEDURE DIVISION commands. You learn how to get data from the user, how to use the COBOL arithmetic verbs to do calculations on the data, and how to display the results on the computer screen.

Input and Output with ACCEPT and DISPLAY

In COBOL, the ACCEPT and DISPLAY verbs are used to read from the keyboard and write to the screen. Input and output using these commands is somewhat primitive. The original purpose of these commands was not to communicate with the end user but for use in a batch-programming environment, to allow interaction with the computer operators. Because computer operators are expert users and the level of their interaction with the program was limited to viewing alerts and action prompts or entering the occasional file name, no great sophistication was required in the ACCEPT and DISPLAY commands.

In recent years, however, many implementers have found a need for more powerful versions of ACCEPT and DISPLAY in order to allow online systems to be created. These implementers have augmented the ACCEPT and DISPLAY syntax to allow such things as cursor positioning, character attribute control, and auto-validation of input. In some cases, they have even implemented a special SCREEN SECTION in the DATA DIVISION.

In a real environment, console-based (as opposed to Windows-based) input and output operations would be handled either by implementer-enhanced versions of ACCEPT and DISPLAY or by calls to forms-management or transaction-processing software such as Terminal Data Management System (TDMS), DECforms, and Customer Information Control System (CICS).

This book considers only the standard ACCEPT and DISPLAY syntax. If the vendor of your version of COBOL offers extended ACCEPT and DISPLAY syntax, you should read the manual to discover how these extensions work.

The DISPLAY Verb

The DISPLAY verb is used to send output to the computer screen or to a peripheral device. A single DISPLAY can be used to display several data items or literals or any combination of these. The concatenation required by some other languages is not required for the DISPLAY verb.

Metalanguage diagrams are used to describe the syntax of COBOL verbs and other elements. The metalanguage for the DISPLAY verb is given in Figure 4-1. In case you have forgotten how to interpret these diagrams, see “Metalanguage Reminder” for a brief refresher on the meaning of the symbols.

DISPLAY OutputItem1 \$#i1 [OutputItem2 \$#i1]...
 [UPONMnemonic-Name][WITH NO ADVANCING]

Figure 4-1. Metalanguage for the *DISPLAY* verb

METALANGUAGE REMINDER

In the COBOL syntax diagrams (the COBOL metalanguage), uppercase words are keywords. If underlined, they are mandatory. In addition

- { } brackets mean one of the options must be selected.
- [] brackets mean the item is optional.
- An ellipsis (...) means the item may be repeated at the programmer's discretion.

The symbols used in the syntax diagram identifiers have the following significance:

- \$ indicates a string (alphanumeric) item.
- # indicates a numeric item.
- i indicates that the item can be a variable identifier.
- l indicates that the item can be a literal.

Notes

As the ellipsis (...) in the metalanguage shows, a single *DISPLAY* can be used to display several data items or literals or any combination of these. The items displayed must be *USAGE DISPLAY* items. *USAGE COMP* or *USAGE INDEX* will not display correctly. *USAGE IS DISPLAY* is the default for COBOL data items; it means the data is held in a displayable format. For efficiency purposes, it is also possible to hold data in a binary format that is not displayable. The *USAGE* clause, which you examine later in the book, is used when you want to hold a data item in one of the more computationally efficient binary formats. For instance:

```
01 SaleValue          PIC 9(5)V99 USAGE IS COMP.
01 TableSubscript    USAGE IS INDEX.
```

The default display device is the computer screen, but you can use other devices for output by specifying a **mnemonic-name** with the *UPON* clause. Mnemonic-names are used to make programs more readable and more maintainable; they are devised by programmers to represent peripheral devices (such as serial ports). A name is connected to an actual device by an entry in the *SPECIAL-NAMES* paragraph of the *CONFIGURATION SECTION* in the *ENVIRONMENT DIVISION*. The actual device to which the mnemonic-name is connected is defined by the language implementer. Consult your COBOL manual to learn what devices your implementer supports.

Ordinarily, after data is displayed on the computer screen, the onscreen cursor moves to the next row. Sometimes, however, you want the cursor to remain on the same row. In these cases, you can use the *WITH NO ADVANCING* clause to ensure that the cursor does not move to the next row.

DISPLAY Examples

This section gives some illustrative DISPLAY examples. The DISPLAY in eg1 sends the data in PrinterSetupCodes to the device represented by the mnemonic-name PrinterPort1. The output from the remaining examples is shown in the *Display Results* diagram. Note that in eg4, the separator spaces inserted between the statement operands have no effect on the output. In a COBOL statement, you can insert separator commas, spaces or semicolons wherever you want to make a statement more readable. Also note that in eg5, the figurative constants SPACE and SPACES are synonyms; they both insert only a single space. Note too that no concatenation operator is required to bind the data items and figurative constants into a single string

```
eg1. DISPLAY PrinterSetupCodes UPON PrinterPort1

eg2. MOVE 3456 TO FinalTotal
     DISPLAY "The final total is " FinalTotal

eg3. DISPLAY "One, " WITH NO ADVANCING
     DISPLAY "two, " WITH NO ADVANCING
     DISPLAY "three."

eg4. DISPLAY 1 ", " 2 ", " 3 "."

eg5. MOVE 10 TO DayOfBirth
     MOVE 12 TO MonthOfBirth
     MOVE 1975 TO YearOfBirth
     DISPLAY "Date of birth is - "
           DayOfBirth SPACES MonthOfBirth SPACE YearOfBirth
```

Display Results

```
The final total is 3456
One, two, three.
1,2,3.
Date of birth is - 10 12 1975
```

The ACCEPT Verb

There are two formats for the ACCEPT verb:

- The first gets data from the keyboard or a peripheral device.
- The second lets you access the system date and time (that is, the date and time held in the computer's internal clock) by using certain system variables.

The metalanguage for the two formats of the ACCEPT are shown in Figure 4-2.

Format 1. ACCEPT ReceivingItem\$#i [FROM Mnemonic - Name]

Format 2. ACCEPT ReceivingItem\$#i FROM {
 DATE [YYYYMMDD]
 DAY [YYYYDDD]
 DAY - OF - WEEK
 TIME

Figure 4-2. Metalinguage for the *ACCEPT* verb

Rules

When you use the first format, *ACCEPT* inserts the data typed on the keyboard into the receiving data item. If the *FROM* option is used, the data inserted into the receiving data item comes from the device indicated by the mnemonic-name. Data is sent to the *ReceivingItem* according to the rules for alphanumeric moves. If the *ReceivingItem* is too small to hold the data, the rightmost characters that do not fit are lost. If the *ReceivingItem* is too large, there is space-filling on the right.

The default input device is the computer keyboard, but you can use other devices by specifying a mnemonic-name with the *FROM* clause. The mnemonic-name is connected to the actual device by an entry in the *SPECIAL -NAMES* paragraph, *CONFIGURATION SECTION*, *ENVIRONMENT DIVISION*.

When you use the second format, *ACCEPT* moves the data from one of the system variables (*DATE*, *DAY*, *DAY-OF-WEEK*, *TIME*) into the receiving data item. Two of the system variables also have optional syntactic elements that allow you to specify that the date be supplied with a four-digit year.

Required Format for System Variables

The declarations and comments that follow show the format required for the data items that *ACCEPT* values from each of the system variables:

```
01 CurrentDate          PIC 9(6).
* Receiving data item for DATE system variable: Format is YYYYMMDD

01 DayOfYear           PIC 9(5).
* Receiving data item for DAY system variable: Format is YYDDD

01 DayOfWeek          PIC 9.
* Receiving item for DAY-OF-WEEK: Format is D (1=Monday)

01 CurrentTime         PIC 9(8).
* Receiving item for TIME: Format is HHMMSSss  s = S/100

01 Y2KDate            PIC 9(8).
* Receiving item for DATE YYYYMMDD system variable: Format is YYYYMMDD

01 Y2KDayOfYear       PIC 9(7).
* Receiving item for DAY YYYYDDD system variable: Format is YYYYDDD
```

Example Program: ACCEPT and DISPLAY

Listing 4-1 gives some examples of how to use the ACCEPT and DISPLAY verbs. The examples use both formats of ACCEPT. The first form of ACCEPT is combined with DISPLAY to prompt for and receive a username. The second form gets data from some of the date and time system variables. Finally, all the gathered information is displayed on the computer screen. The results of running the program are shown in the results diagram.

Listing 4-1. ACCEPT and DISPLAY Examples

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing4-1.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 UserName          PIC X(20).

*> Receiving data item for DATE system variable: Format is YYYYMMDD
01 CurrentDate.
   02 CurrentYear    PIC 99.
   02 CurrentMonth   PIC 99.
   02 CurrentDay     PIC 99.

*> Receiving data item for DAY system variable: Format is YYDDD
01 DayOfYear.
   02 FILLER         PIC 99.
   02 YearDay        PIC 9(3).

*> Receiving item for TIME: Format is HHMMSSss  s = S/100
01 CurrentTime.
   02 CurrentHour    PIC 99.
   02 CurrentMinute  PIC 99.
   02 FILLER         PIC 9(4).

*> Receiving item for DATE YYYYMMDD system variable: Format is YYYYMMDD
01 Y2KDate.
   02 Y2KYear        PIC 9(4).
   02 Y2KMonth       PIC 99.
   02 Y2KDay         PIC 99.

*> Receiving item for DAY YYYYDDD system variable: Format is YYYYDDD
01 Y2KDayOfYear.
   02 Y2KDOY-Year    PIC 9(4).
   02 Y2KDOY-Day     PIC 999.
PROCEDURE DIVISION.
Begin.
   DISPLAY "Please enter your name - " WITH NO ADVANCING
   ACCEPT  UserName
   DISPLAY "*****"
   ACCEPT CurrentDate FROM DATE
   ACCEPT DayOfYear   FROM DAY
   ACCEPT CurrentTime FROM TIME
   ACCEPT Y2KDate     FROM DATE YYYYMMDD
```

```

ACCEPT Y2KDayOfYear FROM DAY YYYYDDD
DISPLAY "Name is " UserName
DISPLAY "Date is " CurrentDay "-" CurrentMonth "-" CurrentYear
DISPLAY "Today is day " YearDay " of the year"
DISPLAY "The time is " CurrentHour ":" CurrentMinute
DISPLAY "Y2KDate is " Y2kDay SPACE Y2KMonth SPACE Y2KYear
DISPLAY "Y2K Day of Year is " Y2KDoy-Day " of " Y2KDOY-Year
STOP RUN.

```

```

Please enter your name - Peter Reid
*****
Name is Peter Reid
Date is 17-08-13
Today is day 229 of the year
The time is 13:24
Y2KDate is 17 08 2013
Y2K Day of Year is 229 of 2013

```

■ **Note** The example programs in this book were compiled by using Micro Focus Visual COBOL and capturing the output results. In most cases, the programs were also compiled and run using the web-based open source COBOL compiler at www.compileonline.com/compile_cobol_online.php. If you want to use this compiler, be aware that interactivity is limited and you must enter keyboard input via the site's STDIN Input box. Some tweaking may be required.

Arithmetic in COBOL

Most procedural programming languages perform computations by assigning the result of an arithmetic expression (or function) to a variable. In COBOL, the COMPUTE verb is used to evaluate arithmetic expressions, but there are also specific commands for adding (ADD), subtracting (SUBTRACT), multiplying (MULTIPLY), and dividing (DIVIDE).

Common Arithmetic Template

With the exception of COMPUTE, DIVIDE with REMAINDER, and some exotic formats of ADD and SUBTRACT, most COBOL arithmetic verbs conform to the template metalanguage shown in Figure 4-3. It is useful to review this metalanguage template because it allows me to discuss the clauses and issues that apply to all the arithmetic verbs.

$$\begin{array}{c}
 \text{VERB Operand1\#il} \left\{ \begin{array}{l} \text{TO} \\ \text{FROM} \\ \text{BY} \\ \text{INTO} \end{array} \right\} \left\{ \begin{array}{l} \{ \text{OperandResult\#i} \text{ [ROUNDED]} \} \dots \\ \text{Operand\#il GIVING } \{ \text{Result\#i} \text{ [ROUNDED]} \} \dots \end{array} \right\} \\
 \left\{ \begin{array}{l} \text{ON SIZE ERROR} \\ \text{[NOT ON SIZE ERROR]} \end{array} \right\} \text{StatementBlock END - VERB}
 \end{array}$$

Figure 4-3. Metalanguage for a common arithmetic template

Arithmetic Template Notes

All the arithmetic verbs move the result of a calculation into a receiving data item according to the rules for a numeric move: that is, with alignment along the assumed decimal point and with zero-filling or truncation as necessary. In all the arithmetic verbs except COMPUTE, the result of the calculation is assigned to the rightmost data item(s).

All arithmetic verbs must use numeric literals or numeric data items (PIC 9) that contain numeric data. There is one exception: data items that *receive* the result of the calculation but are not themselves one of the operands (do not contribute to the result) may be numeric or *edited numeric*.

Where the GIVING phrase is used, the item to the right of the word *giving* receives the result of the calculation but does not contribute to it. Where there is more than one item after the word *giving*, each receives the result of the calculation.

Where the GIVING phrase is not used and there is more than one OperandResult#i, Operand#i is applied to each OperandResult#i in turn, and the result of each calculation is placed in each OperandResult#i.

The maximum size of each operand is 18 digits (31 in ISO 2002 COBOL).

Examples of COBOL Arithmetic Statements

Here are a number of examples, each followed by an explanation of the operation:

ADD Takings TO CashTotal

* Adds the value in Takings to the value in CashTotal and puts the result in CashTotal

ADD Males TO Females GIVING TotalStudents

* Adds the value in Males to the value in Females and overwrites
* the value in TotalStudents with the result.

ADD Sales TO ShopSales, CountySales, CountrySales

* Adds the value of Sales to ShopSales and puts the result in ShopSales.
* Adds the value of Sales to CountySales and puts the result in CountySales
* Adds the value of Sales to CountrySales and puts the result in CountrySales

SUBTRACT Tax FROM GrossPay

* Subtracts the value in Tax from the value in GrossPay and puts the result in GrossPay.

SUBTRACT Tax FROM GrossPay GIVING NetPay

* Subtracts the value in Tax from the value in GrossPay and puts the result in NetPay.

DIVIDE Total BY Members GIVING MemberAverage ROUNDED

* Divides the value in Total by the value in Members and puts
* the rounded result in MemberAverage.

DIVIDE Members INTO Total GIVING MemberAverage

* Divides the value in Members into the value in Total and puts the result in MemberAverage.

MULTIPLY 10 BY Magnitude

* Multiplies 10 by the value in Magnitude and puts the result in Magnitude.

MULTIPLY Members BY Subs GIVING TotalSubs

* Multiplies the value of Members by the value of Subs and puts the result in TotalSubs.

Note that when separating contiguous operands, you may insert commas for clarity. They have no semantic effect, as you will see if you use the following example:

```
DISPLAY "Date of birth = " DayOB, SPACE, MonthOB, SPACE, YearOB
ADD Sales TO ShopSales, CountySales, CountrySales
```

The ROUNDED Phrase

If you use the ROUNDED phrase, then, after decimal point alignment, if the result of the calculation must be truncated on the right side (least significant digits) and the leftmost truncated digit has an absolute value of five or greater, the rightmost digit is increased by one when rounded. That sounds complicated, but it isn't. Let's look at some examples, as shown in Table 4-1.

Table 4-1. ROUNDED Examples. Digits in the Actual Result column that will be truncated are not in bold

Actual Result	Receiving Data Item	Truncated Result	Rounded Result
342.736	PIC 999V99	342.73	342.74
342.734	PIC 999V99	342.73	342.73
342.534	PIC 999	342	343
342.464	PIC 999	342	342
5.958	PIC 9V99	5.95	5.96
12.821565	PIC 99V9(5)	12.82156	12.82157

The ON SIZE ERROR

A size error occurs when the computed result is too large or too small to fit into the receiving field. When the ON SIZE ERROR phrase is used, it is followed by a block of COBOL statements that usually alert you that an error condition has occurred. For instance, in the following example, if FinalResult is too small to hold the result of all these multiplications, the ON SIZE ERROR activates and the alert message is displayed:

```
COMPUTE FinalResult = Num1 * Num2 * Num3 * Num4
  ON SIZE ERROR DISPLAY "Alert: FinalResult too small to hold result"
END-COMPUTE
```

The scope of the statement block is delimited by the appropriate END delimiter (END-ADD, END-SUBTRACT, END-MULTIPLY, END-DIVIDE, END-COMPUTE).

The ON SIZE ERROR acts like a specialized exception handler that comes into play if there is division by zero or if unexpected truncation occurs. When a computation is performed and decimal point alignment has occurred between the calculated result and the receiving data item, the result may be truncated on either the left side or the right. If the most significant digits are truncated, the size error activates. If there is truncation of the least significant digits, size error activation depends on whether the ROUNDED phrase is specified. If it is, then truncation of the least significant digits is ignored because using the ROUNDED phrase indicates that you know there will be truncation and have specified rounding to deal with it. Table 4-2 gives some ON SIZE ERROR examples.

Table 4-2. ON SIZE ERROR Examples. Digits in the Actual Result column that will be truncated are not in bold

Actual Result	Result Data item	Truncated Result	SIZE ERROR?
761.758	999V99	761.75	YES 8 is truncated on the right.
1761.78	999V99	761.78	YES 1 is truncated on the left.
374	999	374	NO
1761	999	761	YES 1 is truncated on the left.
326.475	999V99	326.47	YES 5 is truncated on the right.
326.475	999V99 ROUNDED	326.48	NO 5 is truncated on the right, but rounding is specified.
1326.475	999V99 ROUNDED	326.48	YES 1 is truncated on the left.

Nonconforming Arithmetic Verbs

When the common arithmetic verb template was introduced, I mentioned that there are forms of some verbs that do not conform to the template. This section gives the full metalanguage for COMPUTE, ADD, SUBTRACT, MULTIPLY, and DIVIDE and discusses in more detail the versions of these verbs that do not conform to the template.

The COMPUTE Verb

COMPUTE assigns the result of an arithmetic expression to a data item. The arithmetic expression to the right of the equal sign is evaluated, and the result is assigned to the data item(s) on the left of the equal sign. The arithmetic expression is evaluated according to the normal arithmetic rules. That is, the expression is normally evaluated from left to right, but bracketing and precedence rules (see Table 4-3) can change the order of evaluation.

Table 4-3. Precedence Rules

Precedence	Symbol	Meaning
1	**	Power
2	*	Multiply
	/	Divide
3	+	Add
	-	Subtract

■ **Note** Unlike some other programming languages, COBOL provides the ** expression symbol to represent raising to a power.

COMPUTE is the COBOL verb most similar to assignment in other programming languages. For that reason, you may be tempted to use it for plain assignments of data items to data items. COMPUTE should never be used for that purpose; in COBOL, you have the MOVE verb for that.

The familiarity of COMPUTE may also cause you to use it in preference to the other arithmetic verbs. There is no major objection to doing so, but knowledge of the other arithmetic verbs is required if you will be working with legacy systems.

Figure 4-4 shows the metalanguage for the COMPUTE verb.

```
COMPUTE {Result#i [ ROUNDED ]}... = Arithmetic Expression
      { { ON SIZE ERROR
        { NOT ON SIZE ERROR } StatementBlock END - COMPUTE }
```

Figure 4-4. COMPUTE metalanguage

COMPUTE Examples

Each example in this section is followed by a diagram that shows the value of the data items before and after COMPUTE executes.

Let's start with some literal values:

```
COMPUTE Result = 90 - 7 * 3 + 50 / 2
```

```
01 Result PIC 9(4) VALUE 3333.
```

Before	3333
After	0094

This is equivalent to

```
COMPUTE Result = 90 - (7 * 3) + (50 / 2)
```

```
01 Result PIC 9(4) VALUE 3333.
```

Before	3333
After	0094

Here's another example:

```
COMPUTE Euro ROUNDED = Dollar / ExchangeRate
```

```
01 Euro          PIC 9(5)V99 VALUE 3425.15.
```

```
01 Dollar        PIC 9(5)V99 VALUE 1234.75.
```

```
01 ExchangeRate PIC 9V9(4) VALUE 1.3017.
```

	Euro	Dollar	Exchange Rate
Before	3425.15	1234.75	1.3017
After	0948.57	1234.75	1.3017

The ADD Verb

The ADD verb is used for addition. You might think COMPUTE could be used for that, and of course it can, but sometimes it can be simpler to use ADD. For instance, to increment a counter, you need COMPUTE ItemCount = ItemCount + 1, whereas you could just use ADD 1 TO ItemCount.

The metalanguage for the ADD verb is given in Figure 4-5.

$$\text{ADD Operand\#i1... } \left\{ \begin{array}{l} \text{[TO] \{OperandResult\#i [ROUNDED]\}...} \\ \text{[TO] Operand\#i1 GIVING \{Result\#i [ROUNDED]\}...} \end{array} \right\}$$

[ON SIZE ERROR StatementBlock END - ADD]

Figure 4-5. ADD verb metalanguage

Notes

The ADD verb mostly conforms to the common template, but note the ellipsis after the first operand. This means you could have a statement like

```
ADD Num1, Num2, Num3 TO Num4 GIVING Result.
```

What are the semantics of this version of ADD? The items before TO are all added together, and then the result is applied to the operand or operands after TO.

Note also that in the GIVING version of the ADD verb, the word TO is optional (square brackets). This means you could have a statement like

```
ADD Num1, Num2, Num3 GIVING Result.
```

In this version, all the operands before GIVING are added together, and the result is placed in the Result data item.

ADD Examples

Each example in this section is followed by a figure that shows the value of the data items before and after ADD executes:

```
ADD Cash TO Total.
01 Cash PIC 9(3) VALUE 364.
01 Total PIC 9(4) VALUE 1000.
```

	Cash	Total
Before	364	1000
After	364	1364

```
ADD Cash, 20 TO Total.
01 Cash PIC 9(3) VALUE 364.
01 Total PIC 9(4) VALUE 1000.
```

	Cash	Total
Before	364	1000
After	364	1384

ADD Cash, Checks TO Total.

01 Cash PIC 9(3) VALUE 364.

01 Total PIC 9(4) VALUE 1000.

01 Checks PIC (4) VALUE 1445.

	Cash	Checks	Total
Before	364	1445	1000
After	364	1445	2809

The SUBTRACT Verb

The SUBTRACT verb is a specialized verb used for subtraction. It can be more convenient to use SUBTRACT to decrement a counter rather than COMPUTE. For instance, to decrement a counter you need COMPUTE ItemCount = ItemCount - 1, whereas you could just use SUBTRACT 1 FROM ItemCount.

The metalanguage for the SUBTRACT verb is given in Figure 4-6.

$$\text{SUBTRACT Operand\#i1...}\{\text{FROM}\}\left\{\begin{array}{l} \{\text{OperandResult\#i [ROUNDED]}\}... \\ \{\text{Operand\#il GIVING Result\#i [ROUNDED]}\}... \end{array}\right\}$$

$$[\text{ON SIZE ERROR StatementBlock END-SUBTRACT}]$$

Figure 4-6. Metalanguage for the SUBTRACT verb

Notes

The SUBTRACT verb mostly conforms to the common template, but just as with ADD, there is an ellipsis after the first operand. This means you could have statements like these:

```
SUBTRACT Num1, Num2 FROM Num3 GIVING Result.
```

```
SUBTRACT Num1, Num2 FROM NumResult1, NumResult2.
```

In the first example, all the items before the word FROM are added together, the combined result is subtracted from num3, and the result is placed in the Result data item.

In the second example, all the items before the word FROM are added together. The combined result is subtracted from NumResult1, and the result is placed in NumResult1. The combined result is also subtracted from NumResult2, and the result of that calculation is placed in NumResult2.

SUBTRACT Examples

Here are some examples of SUBTRACT:

SUBTRACT Num1, Num2 FROM Num3 GIVING Result.

```
01 Num1    PIC 9(4) VALUE 364.
01 Num2    PIC 9(4) VALUE 1000.
01 Num3    PIC 9(4) VALUE 5555.
01 Result  PIC 9(4) VALUE 1445.
```

	Num1	Num2	Num3	Result
Before	364	1000	5555	1445
After	364	1000	5555	4191

SUBTRACT Num1, Num2 FROM NumResult1, NumResult2.

```
01 Num1      PIC 9(4) VALUE 364.
01 Num2      PIC 9(4) VALUE 1000.
01 NumResult1 PIC 9(4) VALUE 5555.
01 NumResult2 PIC 9(4) VALUE 1445.
```

	Num1	Num2	NumResult1	NumResult2
Before	364	1000	5555	1445
After	364	1000	4191	0081

SUBTRACT Tax, PRSI, Pension, Levy FROM GrossPay GIVING NetPay.

```
01 GrossPay PIC 9(4)V99 VALUE 6350.75.
01 Tax      PIC 9(4)V99 VALUE 2333.25.
01 PRSI     PIC 9(4)V99 VALUE 1085.45.
01 Pension  PIC 9(4)V99 VALUE 1135.74.
01 Levy     PIC 9(3)V99 VALUE 170.50.
01 NetPay   PIC 9(4)V99 VALUE ZEROS.
```

	GrossPay	Tax	PRSI	Pension	Levy	NetPay
Before	6350.75	2333.25	1085.45	1135.74	170.50	0000.00
After	6350.75	2333.25	1085.45	1135.74	170.50	1625.81

The MULTIPLY Verb

The MULTIPLY verb is one of the arithmetic verbs that fully conforms to the common template given in Figure 4-3. The metalanguage for the MULTIPLY verb is given in Figure 4-7.

$$\text{MULTIPLY Operand\#il } \left\{ \begin{array}{l} \underline{\text{BY}} \\ \underline{\text{INTO}} \end{array} \right\} \left\{ \begin{array}{l} \{ \text{OperandResult\#i } \underline{\text{[ROUNDED]}} \} \dots \\ \{ \text{Operand\#il } \underline{\text{GIVING}} \text{ Result\#i } \underline{\text{[ROUNDED]}} \} \dots \end{array} \right\} \\ \left[\underline{\text{ON SIZE ERROR}} \text{ StatementBlock } \underline{\text{END - MULTIPLY}} \right]$$

Figure 4-7. Metalanguage for the MULTIPLY verb

MULTIPLY Examples

Here are some examples of MULTIPLY:

```

Multiply Fees BY Members GIVING TotalFees
  DISPLAY "Alert: result to large for TotalFees"
01 Fees      PIC 9(3)V99 VALUE 052.24
01 Members   PIC 9(4)   VALUE 1024.
01 TotalFees PIC 9(5)V99 VALUE ZEROS.

```

	Fees	Members	TotalFees
Before	052.24	1024	00000.00
After	052.24	1024	53493.76

The DIVIDE Verb

The DIVIDE verb has two main formats. The metalanguage for the first format is given in Figure 4-8. This format is unremarkable in that it conforms to the common template. The metalanguage for the second format is given in Figure 4-9. This format does *not* conform to the common template, and it provides operations that cannot be done with COMPUTE. The second format of DIVIDE allows you to get the quotient and the remainder in one operation.

$$\text{DIVIDE Operand\#il } \left\{ \begin{array}{l} \underline{\text{BY}} \\ \underline{\text{INTO}} \end{array} \right\} \left\{ \begin{array}{l} \{ \text{OperandResult\#i } \underline{\text{[ROUNDED]}} \} \dots \\ \{ \text{Operand\#il } \underline{\text{GIVING}} \text{ Result\#i } \underline{\text{[ROUNDED]}} \} \dots \end{array} \right\} \\ \left[\underline{\text{ON SIZE ERROR}} \text{ StatementBlock } \underline{\text{END - DIVIDE}} \right]$$

Figure 4-8. Metalanguage for format 1 of the DIVIDE verb

$$\underline{\text{DIVIDE}} \text{ Operand\#il } \left\{ \begin{array}{l} \underline{\text{INTO}} \\ \underline{\text{BY}} \end{array} \right\} \text{Operand\#il } \underline{\text{GIVING}} \{ \text{Quotient\#i } \underline{\text{[ROUNDED]}} \} \underline{\text{REMAINDER}} \text{ Remainder\#i} \\ \left[\left\{ \begin{array}{l} \underline{\text{ON SIZE ERROR}} \\ \underline{\text{NOT ON SIZE ERROR}} \end{array} \right\} \text{StatementBlock } \underline{\text{END - DIVIDE}} \right]$$

Figure 4-9. Metalanguage for format 2 of the DIVIDE verb

DIVIDE Examples

Following are some DIVIDE examples; the third example uses the second format.

In this example, 15 is divided into Amount1, and the result is placed in Amount1; 15 is also divided into Amount2, and result is placed in Amount2. The results calculated are not integer values, so there is truncation of the digits to the left of the decimal point:

```
DIVIDE 15 INTO Amount1, Amount2.
01 Amount1  PIC 9(4) VALUE 2444.
01 Amount2  PIC 9(3) VALUE 354.
```

	Amount1	Amount2
Before	2444	354
After	162	023

In this example, the calculated result is not an integer value, so there is truncation of the digits to the left of the decimal point. But because rounding is requested, the result is rounded to 272 (from 271.7826086956522):

```
DIVIDE Qty By Units GIVING Average ROUNDED.
01 Qty      PIC 9(5) VALUE 31255.
01 Units    PIC 9(3) VALUE 115.
01 Average  PIC 9(4) VALUE ZEROS.
```

	Qty	Units	Average
Before	31255	115	0000
After	31255	115	0272

This example uses the second format of DIVIDE. It shows how you can use DIVIDE to get both the quotient and the remainder in one operation:

```
DIVIDE 215 BY 10 GIVING Quotient REMAINDER Rem.
01 Quotient PIC 999 VALUE ZEROS.
01 Rem      PIC 9  VALUE ZEROS.
```

	Quotient	Rem
Before	000	0
After	021	5

Let's Write a Program

Listing 4-2 presents a very simple program that takes two single-digit numbers from the keyboard, multiplies them together, and then displays the result. This program uses only one of the three classic constructs of structured programming. These constructs are

- Sequence
- Selection
- Iteration

In this program, execution starts in the PROCEDURE DIVISION paragraph CalculateResult and then continues through the program statements one by one, in sequence, until STOP RUN is reached.

Obviously, a program like this has limited usefulness. To make it really useful, you need to be able to selectively execute program statements (selection) and specify that others are to be executed over and over again (iteration). You revisit this program in the next two chapters when you are armed with the necessary selection and iteration constructs.

Listing 4-2. Example Program: ACCEPT, DISPLAY, and MULTIPLY

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing4-2.
AUTHOR. Michael Coughlan.
*> Accepts two numbers from the user, multiplies them together
*> and then displays the result.

DATA DIVISION.
WORKING-STORAGE SECTION.
01 Num1          PIC 9  VALUE 5.
01 Num2          PIC 9  VALUE 4.
01 Result        PIC 99 VALUE ZEROS.

PROCEDURE DIVISION.
CalculateResult.
    DISPLAY "Enter a single digit number - " WITH NO ADVANCING
    ACCEPT Num1
    DISPLAY "Enter a single digit number - " WITH NO ADVANCING
    ACCEPT Num2
    MULTIPLY Num1 BY Num2 GIVING Result
    DISPLAY "Result is = ", Result
    STOP RUN.
```

Summary

In this chapter, you examined the operation of the arithmetic verbs COMPUTE, ADD, SUBTRACT, MULTIPLY, and DIVIDE. The ACCEPT and DISPLAY verbs, which allow you to get input from the keyboard and send output to the screen, were also explored.

The final example program consisted of a sequence of statements that are executed one after another. This kind of program is of limited usefulness. To be truly useful, a program must incorporate iteration and selection. These control structures are explored in the next chapter, along with the jewel in COBOL's crown: condition names.

LANGUAGE KNOWLEDGE EXERCISES

Sharpen up the 2B pencil you used to answer the questions in the last chapter, and fill in the *after* positions for data items that have a *before* entry:

01 Num1 PIC 99.
 01 Num2 PIC 99.
 01 Num3 PIC 99.
 01 Num4 PIC 99.

Statement	Before Values				After Values			
	Num1	Num2	Num3	Num4	Num1	Num2	Num3	Num4
ADD Num1 TO Num2	25	30						
ADD Num1, Num2 TO Num3, Num4	13	04	05	12				
ADD Num1, Num2, Num3 GIVING Num4	04	03	02	01				
SUBTRACT Num1 FROM Num2 GIVING Num3	04	10	55					
SUBTRACT Num1, Num2 FROM Num3	05	10	55					
SUBTRACT Num1, Num2 FROM Num3 GIVING Num4	05	10	55	20				
MULTIPLY Num1 BY Num2	10	05						
MULTIPLY Num1 BY Num2 GIVING Num3	10	05	33					
DIVIDE Num1 INTO Num2	05	64						
DIVIDE Num2 BY Num1 GIVING Num3 REMAINDER Num4	05	64	24	88				
COMPUTE Num1 = 5 + 10 * 30 / 2	25							

LANGUAGE KNOWLEDGE EXERCISES - ANSWERS

Sharpen up the 2B pencil you used to answer the questions in the last chapter, and fill in the *after* positions for data items that have a *before* entry:

01 Num1 PIC 99.
 01 Num2 PIC 99.
 01 Num3 PIC 99.
 01 Num4 PIC 99.

Statement	Before Values				After Values			
	Num1	Num2	Num3	Num4	Num1	Num2	Num3	Num4
ADD Num1 TO Num2	25	30			25	55		
ADD Num1, Num2 TO Num3, Num4	13	04	05	12	13	04	22	29
ADD Num1, Num2, Num3 GIVING Num4	04	03	02	01	04	03	02	09
SUBTRACT Num1 FROM Num2 GIVING Num3	04	10	55		04	10	06	
SUBTRACT Num1, Num2 FROM Num3	05	10	55		05	10	40	
SUBTRACT Num1, Num2 FROM Num3 GIVING Num4	05	10	55	20	05	10	55	40
MULTIPLY Num1 BY Num2	10	05			10	50		
MULTIPLY Num1 BY Num2 GIVING Num3	10	05	33		10	05	50	
DIVIDE Num1 INTO Num2	05	64			05	12		
DIVIDE Num2 BY Num1 GIVING Num3 REMAINDER Num4	05	64	24	88	05	64	12	04
COMPUTE Num1 = 5 + 10 * 30 / 2	25				55			

CHAPTER 5



Control Structures: Selection

The last chapter noted that programs that consist only of a sequence of statements are not very useful. To be useful, a program must use selection constructs to execute some statements rather than others and must use iteration constructs to execute certain statements repeatedly.

In this chapter, you examine the selection constructs available to COBOL. In addition to discussing the IF and EVALUATE statements, this chapter also discusses the condition types recognized by the selection constructs, the creation and use of condition names, the use of the SET verb to manipulate condition names, and the proper naming of condition names.

A number of short example programs are introduced in this chapter. Please keep in mind that these are only used to demonstrate particular language elements. They are not intended as realistic examples.

Selection

In most procedural languages, if and case/switch are the only selection constructs supported. COBOL supports advanced versions of both of these constructs, but it also supports a greater variety of condition types including relation conditions, class conditions, sign conditions, complex conditions, and condition names.

IF Statement

When a program runs, the program statements are executed one after another, in sequence, unless a statement is encountered that alters the order of execution. An IF statement is one of the statement types that can alter the order of execution in a program. It allows you to specify that a block of code is to be executed only if the condition attached to the IF statement is satisfied. The basic metalanguage for the IF statement is given in Figure 5-1.

$$\begin{array}{l} \text{IF Condition THEN } \left\{ \begin{array}{l} \text{StatementBlock} \\ \text{NEXT SENTENCE} \end{array} \right\} \\ \left[\text{ELSE } \left\{ \begin{array}{l} \text{StatementBlock} \\ \text{NEXT SENTENCE} \end{array} \right\} \right] \text{[END - IF]} \end{array}$$

Figure 5-1. Metalanguage for the IF statement/verb

The StatementBlock following the THEN executes, if the condition is true. The StatementBlock following the ELSE (if used) executes, if the condition is false. The StatementBlock(s) can include any valid COBOL statement including further IF constructs. This allows for nested IF statements.

One difference from many other programming languages is that when a condition is evaluated, it evaluates to either true or false. It does not evaluate to 1 or 0.

The explicit scope delimiter END-IF was introduced in ANS 85 COBOL. In the previous versions of COBOL, scope was delimited by means of the period. Although the scope of the IF statement may still be delimited by a period, the END-IF delimiter should always be used because it makes explicit the scope of the IF statement.

There are two problems with using a period as a scope delimiter:

- Periods are hard to see, and this makes it more difficult to understand the code.
- A period delimits all open scopes, and this is a source of many programming errors.

You explore this topic more fully later in the chapter.

Condition Types

The IF statement is not as simple as the metalanguage in Figure 5-1 seems to suggest. The condition that follows the IF is drawn from one of the condition types shown in Table 5-1. If a condition is not a complex condition, then it is regarded as a simple condition. A simple condition may be negated using the NOT keyword. Bracketing a complex condition causes it to be treated as a simple condition.

Table 5-1. *Condition Types*

Condition Type

Relation

Class

Sign

Complex

Condition names

Relation Conditions

Relation conditions are used to test whether a value is less than, equal to, or greater than another value.

These conditions will be familiar to programmers of other languages. The use of words as shown in the relation condition metalanguage in Figure 5-2 may come as bit of a shock, but for most conditions the more familiar symbols (= < > >= <=) may be used. There is one exception to this: unlike in many other languages, in COBOL there is no symbol for NOT. You must use the word NOT if you want to express this condition.

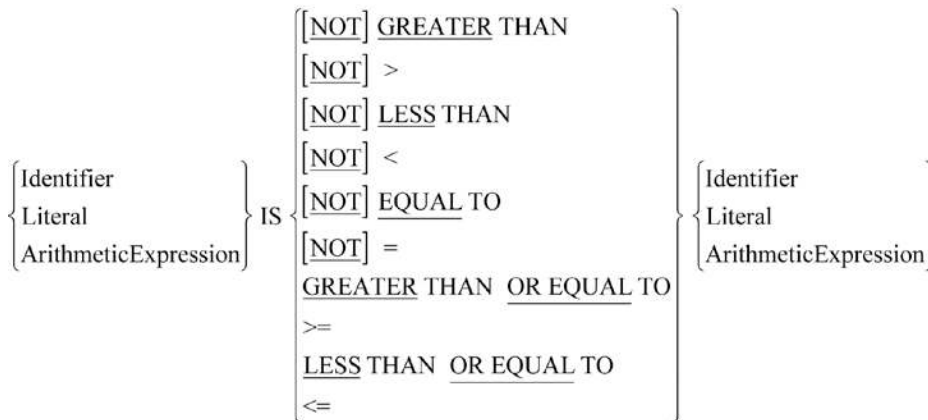


Figure 5-2. Metalanguage for relation conditions

Note that the compared values must be type compatible. For instance, it is not valid to compare a string value to a numeric value. Some examples of relation conditions are shown in Example 5-1. Most of these examples are straight forward, but the final example includes an arithmetic expression. In this case, the arithmetic expression is evaluated and then the result is compared with the value in Num1.

Example 5-1. Some Sample Relation Conditions

```
IF Num1 < 10 THEN
    DISPLAY "Num1 < 10"
END-IF

IF Num1 LESS THAN 10
    DISPLAY "Num1 < 10"
END-IF

IF Num1 GREATER THAN OR EQUAL TO Num2
    MOVE Num1 TO Num2
END-IF

IF Num1 < (Num2 + ( Num3 / 2))
    MOVE ZEROS TO Num1
END-IF
```

Class Conditions

A class condition does not refer to a class in the OO sense. Instead, it refers to the broad category or class (such as numeric, alphabetic, or alphabetic lower or upper) into which a data item may fall (see the metalanguage for class conditions in Figure 5-3). A class condition is used to discover whether the value of data item is a member of one these classes. For instance, a NUMERIC class condition might be used on an alphanumeric (PIC X) or a numeric (PIC 9) data item to see if it contained numeric data. Or an ALPHABETIC-UPPER class condition might be used to discover if a data item contained only capital letters (see Example 5-2).

```

Identifier IS [NOT] {
    NUMERIC
    ALPHABETIC
    ALPHABETIC-LOWER
    ALPHABETIC-UPPER
    UserDefinedClassName
}

```

Figure 5-3. Metalanguage for class conditions

Example 5-2. Class Condition That Checks Whether the StateName Contains All Capitals

```

IF StateName IS ALPHABETIC-UPPER
    DISPLAY "All the letters in StateName are upper case"
END-IF

```

Notes on Class Conditions

The target of a class test must be a data item with an explicit or implicit usage of DISPLAY. In the case of numeric tests, data items with a usage of PACKED-DECIMAL may also be tested.

The numeric test may not be used with data items described as alphabetic (PIC A) or with group items when any of the elementary items specifies a sign. An alphabetic test may not be used with any data items described as numeric (PIC 9).

The UserDefinedClassName is a name that you can assign to a set of characters. You must use the CLASS clause of the SPECIAL-NAMES paragraph, of the CONFIGURATION SECTION, in the ENVIRONMENT DIVISION, to assign a class name to a set of characters. A data item conforms to the UserDefinedClassName if its contents consist entirely of the characters listed in the definition of the UserDefinedClassName (see Listing 5-1 in the next section).

User-Defined Class Names

Whereas ALPHABETIC and NUMERIC are predefined class names that identify a subset of the character set, the UserDefinedClassName in the metalanguage (see Figure 5-3) is a name that you can assign to a defined subset of characters. To define the subset, you must create a CLASS entry in the SPECIAL-NAMES paragraph, of the CONFIGURATION SECTION, in the ENVIRONMENT DIVISION. The CLASS clause assigns a class name to a defined subset of characters. In a class condition, a data item conforms to the UserDefinedClassName if its contents consist entirely of the characters listed in the definition of the UserDefinedClassName.

Listing 5-1 is an example program that shows how to define and use a user-defined class name. In this listing, two class names are defined: HexNumber and RealName. HexNumber is used to test that NumIn contains only hex digits (0-9 and A-F). RealName is used to test that NameIn contains only valid characters. RealName was created because you can't just use the IS ALPHABETIC class condition to test a name—sometimes names, especially Irish names, contain other characters; such as the apostrophe ('). RealName allows you to test that the name entered contains only characters from the set you have defined.

Listing 5-1. User-Defined Class Names Used with a Class Condition

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-1.
AUTHOR. Michael Coughlan.
*> Shows how user defined class names are created and used

ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SPECIAL-NAMES.
    CLASS HexNumber IS "0" THRU "9", "A" THRU "F"
    CLASS RealName IS "A" THRU "Z", "a" THRU "z", "'", SPACE.

DATA DIVISION.
WORKING-STORAGE SECTION.
01 NumIn          PIC X(4).
01 NameIn         PIC X(15).

PROCEDURE DIVISION.
Begin.
    DISPLAY "Enter a Hex number - " WITH NO ADVANCING
    ACCEPT NumIn.
    IF NumIn IS HexNumber THEN
        DISPLAY NumIn " is a Hex number"
    ELSE
        DISPLAY NumIn " is not a Hex number"
    END-IF

    DISPLAY "-----"
    DISPLAY "Enter a name - " WITH NO ADVANCING
    ACCEPT NameIn
    IF NameIn IS ALPHABETIC
        DISPLAY NameIn " is alphabetic"
    ELSE
        DISPLAY NameIn " is not alphabetic"
    END-IF

    IF NameIn IS RealName THEN
        DISPLAY NameIn " is a real name"
    ELSE
        DISPLAY NameIn " is not a real name"
    END-IF
STOP RUN.

```

Listing 5-1 - Run1

```

Enter a Hex number - 12AF
12AF is a Hex number
-----

```

```

Enter a name - Liam O'Riordan
Liam O'Riordan is not alphabetic
Liam O'Riordan is a real name
-----

```

Listing 5-1 - Run2

```

Enter a Hex number - 12DG
12DG is not a Hex number
-----

```

```

Enter a name - Li4m O'Riordan
Li4m O'Riordan is not alphabetic
Li4m O'Riordan is not a real name
-----

```

Listing 5-1 - Run3

```

Enter a Hex number - 0D0A
0D0A is a Hex number
-----

```

```

Enter a name - Michael Power
Michael Power is alphabetic
Michael Power is a real name

```

How the Program Works

The program accepts a hex number from the user, tests that it contains only valid hex digits, and then displays the appropriate message. The program then accepts a name from the user, uses a class condition to test whether the contents are alphabetic, and displays the appropriate message. The program next tests that NameIn contains only the allowed characters and displays the appropriate message. To give you a feel for how the program works, I ran it a number of times and captured the output (see the output attached to Listing 5-1).

Sign Conditions

The sign condition (see the metalanguage in Figure 5-4) is used to discover whether the value of an arithmetic expression is less than, greater than, or equal to zero. Sign conditions are a shorter way of writing certain relation conditions.

$$\text{ArithmeticExpression IS [NOT] } \left\{ \begin{array}{l} \text{POSITIVE} \\ \text{NEGATIVE} \\ \text{ZERO} \end{array} \right\}$$

Figure 5-4. Metalanguage for sign conditions

In Example 5-3, a sign condition is used to discover whether the result of evaluating an arithmetic expression is a negative value. This example also shows the equivalent relation condition.

Example 5-3. Sign Condition Used to Discover Whether a Result Is Negative

```
IF (Num2 * 10 / 50) - 10 IS NEGATIVE
  DISPLAY "Calculation result is negative"
END-IF
```

*> the equivalent Relation Condition is

```
IF (Num2 * 10 / 50) - 10 LESS THAN ZERO
  DISPLAY "Calculation result is negative"
END-IF
```

Complex Conditions

Unlike sign conditions and class conditions, complex conditions (sometimes called compound conditions) should be familiar to programmers of most languages. Even here, however, COBOL has a tweak—in the form of implied subjects—that you may find unusual. The metalanguage for complex conditions is given in Figure 5-5.

$$\text{Condition } \left\{ \left\{ \begin{array}{l} \text{AND} \\ \text{OR} \end{array} \right\} \text{Condition} \right\} \dots$$

Figure 5-5. Metalanguage for complex conditions

Complex conditions are formed by combining two or more simple conditions using the conjunction operator OR or AND. Any condition (simple, complex, condition name) may be negated by preceding it with the word NOT. When NOT is applied to a condition, it toggles the true/false evaluation. For instance, if Num1 < 10 is true then NOT Num1 < 10 is false.

Like other conditions in COBOL, a complex condition evaluates to either true or false. A complex condition is an expression. Like arithmetic expressions, a complex condition is evaluated from left to right unless the order of evaluation is changed by precedence rules or by bracketing.

The precedence rules that apply to complex conditions are given in Table 5-2. To assist your understanding, the equivalent arithmetic precedence rules have been given alongside the condition rules.

Table 5-2. Precedence Rules

Precedence	Condition Value	Arithmetic Equivalent
1	NOT	**
2	AND	* or /
3	OR	+ or -

Example 5-4. Complex Condition to Detect Whether the Cursor Is Onscreen

```
*> A complex condition example that detects if the cursor position located at
*> ScrnRow, ScrnCol is on screen (the text screen is 24 lines by 80 columns)
  IF (ScrnRow > 0 AND ScrnRow < 25) AND (ScrnCol > 0 AND ScrnCol < 81) THEN
    DISPLAY "On Screen"
  END-IF
```

Truth Tables

When a complex condition is being evaluated, it is useful to consider the OR and AND truth tables, shown in Table 5-3.

Table 5-3. OR and AND Truth Tables

OR Truth Table			AND Truth Table		
Condition	Condition	Result	Condition	Condition	Result
T	T	True	T	T	True
T	F	True	T	F	False
F	T	True	F	T	False
F	F	False	F	F	False

The Effect of Bracketing

Bracketing can make the order of evaluation explicit or can change it. Complex conditions are often difficult to understand, so any aid to clarity is welcome. For that reason, when you have to write a complex condition, you should always use bracketing to make explicit what is intended.

Consider the statement

```
IF NOT Num1 < 25 OR Num2 = 80 AND Num3 > 264 THEN
  DISPLAY "Done"
END-IF
```

The rules of precedence govern how this IF statement is evaluated. You can leave it like this and hope that future readers will understand it, or you can assist their understanding by using bracketing to make explicit the order of evaluation already governed by those rules.

To apply bracketing, you note that NOT takes precedence, so you write (NOT Num1 < 25). AND is next according to the precedence rules, so you bracket the ANDED conditions to give (Num2 = 80 AND Num3 > 264). Finally, the OR is evaluated to give the full condition as

```
IF (NOT Num1 < 25) OR (Num2 = 80 AND Num3 > 264) THEN
  DISPLAY "Done"
END-IF
```

Of course, you can use bracketing to change the order of evaluation. For instance, you can change the previous condition to

```
IF NOT (Num1 < 25 OR Num2 = 80) AND Num3 > 264 THEN
  DISPLAY "Done"
END-IF
```

In the original condition, the order of evaluation was NOT . . AND . . OR, but the new bracketing changes that order to OR . . NOT . . AND. This change has a practical effect on the result of the condition.

Suppose all the simple conditions in the original expression are true. The truth table for that expression yields Table 5-4.

Table 5-4. IF Statement Evaluation When All the Simple Conditions Are True

Condition	IF(NOT Num1 < 25)	OR	(Num2 = 80	AND	Num3 > 264)
Expressed as	(NOT T)	OR	(T	AND	T)
Evaluates to	(F)	OR	(T	AND	T)
Evaluates to	(F)	OR		(T)	
Evaluates to		True			

The re-bracketed expression yields Table 5-5.

Table 5-5. The Rebracketed Truth Table

Condition	IF NOT	(Num1 < 25	OR	Num2 = 80)	AND	Num3 > 264
Expressed as	NOT	(T	OR	T)	AND	T
Evaluates to	NOT		(T)		AND	T
Evaluates to		(F)			AND	T
			False			

Implied Subjects

Although COBOL is often verbose, it does occasionally provide constructs that enable quite succinct statements to be written. The *implied subject* is one of those constructs.

When, in a complex condition, a number of comparisons have to be made against a single data item, it can be tedious to have to repeat the data item for each comparison. For instance, the example code fragment you saw earlier could be rewritten using implied subjects as

```
IF (ScrRow > 0 AND < 25) AND (ScrCol > 0 AND < 81) THEN
    DISPLAY "On Screen"
END-IF
```

In this case, the implied subjects are `ScrRow` and `ScrCol`.
Similarly, using `Grade =` as the implied subject, you can rewrite

```
IF Grade = "A" OR Grade = "B" OR Grade = "C" THEN DISPLAY "Passed"
```

as

```
IF Grade = "A" OR "B" OR "C" THEN DISPLAY "Passed"
```

Finally, you can use the implied subject `Num1 >` to rewrite the expression

```
IF Num1 > Num2 AND Num1 > Num3 AND Num1 > Num4 THEN
    DISPLAY "Num1 is the largest"
END-IF
```

as

```
IF Num1 > Num2 AND Num3 AND Num4
    DISPLAY "Num1 is the largest"
END-IF
```

Nested IFs

COBOL allows nested IF statements (see Example 5-5). But be aware that although nested IF statements may be easy to write, they are somewhat difficult to understand when you return to them after an interval of time. Complex, and nested IF, statements are often used as a substitute for clear thinking. When you first attempt to solve a problem, you often don't have a full understanding of it. As a result, your solution may be convoluted and unwieldy. It is often only after you have attempted to solve the problem that you gain sufficient insight to allow you to generate a simpler solution. When you have a better understanding of the problem, you may find that a mere reorganization of your code will greatly reduce both the number and complexity of the IF statements required. Simplicity is difficult to achieve but is a highly desirable objective. It is a principle of good program design that your solution should be only as complex as the problem demands.

Example 5-5. Nested IF..ELSE Statements

```
*> This example uses nested IF statements including IF..THEN..ELSE statements
*> This is quite a straight forward example of nested IFs but nested If & IF.. ELSE statements
*> can get a lot more convoluted and difficult to understand. It is especially difficult if
*> some nested IF statements do not have ELSE branches and others do. It can take some time
*> to untangle which ELSE belongs with which IF
```

```

IF InputVal IS NUMERIC
  MOVE InputVal to Num1
  IF Num1 > 5 AND < 25
    IF Num1 < Num2
      MOVE Num2 TO Num1
    ELSE
      MOVE Num1 TO Num2
  END-IF
  DISPLAY "Num1 & Num2 = " Num1 SPACE Num2
ELSE
  DISPLAY "Num 1 not in range"
END-IF
ELSE
  DISPLAY "Input was not numeric"
END-IF

```

Delimiting Scope: END-IF vs. Period

The scope of an IF statement may be delimited by either an END-IF or a period (full stop). For a variety of reasons, the explicit END-IF delimiter should always be used instead of a period. The period is so problematic that one of the most useful renovations you can perform on legacy COBOL code is to replace the periods with explicit scope delimiters.

There are two main problems with using a period as a scope delimiter. The first is that periods are hard to see, which makes it more difficult to understand the code. The second problem is that a period delimits *all open scopes*. This is a source of many programming errors.

The code fragments in Example 5-6 illustrate the readability problem. Both IF statements are supposed to perform the same task. But the scope of the IF statement on the left is delimited by an END-IF, whereas the statement on the right is delimited by a period.

Example 5-6. Comparing END-IF and Period-Delimited IF Statements

Statement1	Statement1
Statement2	Statement2
IF Num1 > Num2 THEN	IF Num1 > Num2 THEN
Statement3	Statement3
Statement4	Statement4
END-IF	Statement5
Statement5	Statement6.
Statement6.	

Unfortunately, on the right, the programmer has forgotten to follow Statement4 with a delimiting period. This means Statement5 and Statement6 will be included in the scope of the IF. They will be executed only if the condition is true. When periods are used to delimit the scope of an IF statement, this is an easy mistake to make; and, once made, it is difficult to spot. A period is small and unobtrusive compared to an END-IF.

The problem caused by unexpectedly delimiting scope is illustrated by the following code fragment:

```

IF Num1 < 10
  ADD 10 TO Num1
  MULTIPLY Num1 BY 1000 GIVING NUM2
  ON SIZE ERROR DISPLAY "Error: Num2 too small".
  DISPLAY "When is this shown?".

```

In this fragment, it looks as if the DISPLAY on the final line is executed only when Num1 is less than 10. However, a period has been used to delimit the scope of the ON SIZE ERROR (instead of an END-MULTIPLY delimiter), and that period also delimits the scope of the IF (all open scopes). This means the DISPLAY lies outside the scope of the IF and so is always executed.

If you replace the periods with explicit scope delimiters, you can see more clearly what is happening:

```
IF Num1 < 10
  ADD 10 TO Num1
  MULTIPLY Num1 BY 1000 GIVING NUM2
  ON SIZE ERROR DISPLAY "Error: Num2 too small"
END-MULTIPLY
END-IF
DISPLAY "When is this shown?".
```

Even though the indentation used in this version is just as misleading as the period-based version, you are not misled. The explicit scope delimiters used for the IF and the MULTIPLY make the scope of these statements clear.

The use of delimiting periods in the PROCEDURE DIVISION is such a source of programming errors that a minimum period style of programming has been advocated by Howard Tompkins¹ and Robert Baldwin². In the examples in this book, I use a variation of the style suggested by Tompkins. Tompkins was writing before the 1985 standard was produced and so was not able to incorporate END delimiters into his scheme. Nowadays, you can adopt a style that uses only a single period per paragraph. Although Tompkins has persuasive arguments for placing that period alone on the line in column 12, for aesthetic reasons I use it to terminate the last statement in the paragraph. Whether you prefer the Tompkins lonely period style or my variation, I strongly suggest that you adopt the minimum period style. That way you will save yourself a world of hurt.

Condition Names

Wherever a condition tests a variable for equality to a value, a set of values, or a range of values, that condition can be replaced by a kind of abstract condition called a *condition name*. Wherever it is legal to have a condition, it is legal to have a condition name. Just like a condition, a condition name is either true or false.

Condition names allow you to give a meaningful name to a condition while hiding the implementation details of how the condition is detected. For instance,

```
IF CountryCode = 3 OR 7 OR 10 OR 15 THEN
  MOVE 14 TO CurrencyCode
END-IF
```

may be replaced with

```
IF BritishCountry THEN
  SET CurrencyIsPound TO TRUE
END-IF
```

This example illustrates the readability benefits of using condition names. When you encounter code such as

```
IF CountryCode = 3 OR 7 OR 10 OR 15
```

the meaning of what the IF statement is testing is not obvious. You can see that CountryCode is being tested for particular values, but why? What is the significance of the values 3,7,10, and 15? What is the significance of moving 14 to the CurrencyCode? To discover this information, a maintenance programmer has to read external documentation or in-code comments. Now consider the condition name version of the IF statement. It is obvious what you are testing

because the test has been given a meaningful name. Similarly, the action taken when `BritishCountry` is true is also obvious. No documentation and no comments are required.

Ease of maintenance is also improved. If the coding system changed and the countries of the British Isles were now represented by the codes 4, 12, 18, and 25, only the definition of the condition name would have to be changed. In the version that did not use the condition name, you would have to change the code values in all the places in the program where the condition was tested.

Defining Condition Names

Condition names are sometimes called *level 88s* because they are created in the `DATA DIVISION` using the special level number 88. The metalanguage for defining condition names is given in Figure 5-6.

$$88 \text{ ConditionName } \left\{ \begin{array}{l} \text{VALUE} \\ \text{VALUES} \end{array} \right\} \left\{ \begin{array}{l} \text{Literal}\$\# \\ \text{LowValue}\$\# \left\{ \begin{array}{l} \text{THROUGH} \\ \text{THRU} \end{array} \right\} \text{HighValue}\$\# \end{array} \right\} \dots$$

Figure 5-6. Metalanguage for defining condition names

Rules

Condition names are always associated with a particular data item and are defined immediately after the definition of that data item. A condition name may be associated with a group data item and elementary data, or even the element of a table. The condition name is automatically set to true or false the moment the value of its associated data item changes.

When the `VALUE` clause is used with condition names, it does not assign a value. Instead, it identifies the value(s) which, if found in the associated data item, make the condition name true.

When identifying the condition values, a single value, a list of values, a range of values, or any combination of these may be specified. To specify a list of values, the entries are listed after the keyword `VALUE`. The list entries may be separated by commas or spaces but must terminate with a period.

Single Condition Name, Single Value

In Example 5-7, the condition name `CityIsLimerick` has been associated with `CityCode` so that if `CityCode` contains the value 2 (listed in the `CityIsLimerick VALUE` clause), the condition name will be automatically set to true.

Example 5-7. Defining and Using a Condition Name

`DATA DIVISION.`

`WORKING-STORAGE SECTION.`

```
01 CityCode          PIC 9 VALUE ZERO.
   88 CityIsLimerick VALUE 2.
```

`PROCEDURE DIVISION.`

`Begin.`

```
  :   :   :   :   :   :   :
  DISPLAY "Enter a city code (1-6) - " WITH NO ADVANCING
  ACCEPT CityCode
```

```

IF CityIsLimerick
    DISPLAY "Hey, we're home."
END-IF
: : : : : : :

```

In the program fragment, DISPLAY and ACCEPT get a city code from the user. The instant the value in CityCode changes, the CityIsLimerick condition name will be set to true or false, depending on the value in CityCode.

Multiple Condition Names

Several condition names may be associated with a single data item. In Example 5-8, a number of condition names have been associated with CityCode. Each condition name is set to true when CityCode contains the value listed in the condition name VALUE clause. Condition names, like Booleans, can only take the value true or false. If a condition name is not set to true, it is set to false. Table 5-6 shows the Boolean value of each condition name for each value of CityCode.

Example 5-8. Associating Many Condition Names with a Data Item

```

DATA DIVISION.
WORKING-STORAGE SECTION.
01 CityCode PIC 9 VALUE ZERO.
   88 CityIsDublin          VALUE 1.
   88 CityIsLimerick       VALUE 2.
   88 CityIsCork           VALUE 3.
   88 CityIsGalway         VALUE 4.
   88 CityIsSligo          VALUE 5.
   88 CityIsWaterford      VALUE 6.
PROCEDURE DIVISION.
Begin.
: : : : : : :
DISPLAY "Enter a city code (1-6) - " WITH NO ADVANCING
ACCEPT CityCode
IF CityIsLimerick
    DISPLAY "Hey, we're home."
END-IF
IF CityIsDublin
    DISPLAY "Hey, we're in the capital."
END-IF
: : : : : : :

```

Table 5-6. Results for Each Value of CityCode

Data Item / Condition Name	Data Value / Condition Name Result							
CityCode	0	1	2	3	4	5	6	7-9
CityIsDublin	False	TRUE	False	False	False	False	False	False
CityIsLimerick	False	False	TRUE	False	False	False	False	False
CityIsCork	False	False	False	TRUE	False	False	False	False
CityIsGalway	False	False	False	False	TRUE	False	False	False
CityIsSligo	False	False	False	False	False	TRUE	False	False
CityIsWaterford	False	False	False	False	False	False	TRUE	False

Overlapping and Multiple-Value Condition Names

When multiple condition names are associated with a single data item, more than one condition name can be true at the same time. In Listing 5-2, `UniversityCity` is true if `CityCode` contains any value between 1 and 4. These values overlap the values of the first four condition names, so if `UniversityCity` is true, then one of those four must also be true.

Listing 5-2. Multiple Condition Names with Overlapping Values

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-2.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 CityCode PIC 9 VALUE ZERO.
   88 CityIsDublin          VALUE 1.
   88 CityIsLimerick       VALUE 2.
   88 CityIsCork           VALUE 3.
   88 CityIsGalway         VALUE 4.
   88 CityIsSligo          VALUE 5.
   88 CityIsWaterford      VALUE 6.
   88 UniversityCity       VALUE 1 THRU 4.
   88 CityCodeNotValid     VALUE 0, 7, 8, 9.

PROCEDURE DIVISION.
Begin.
  DISPLAY "Enter a city code (1-6) - " WITH NO ADVANCING
  ACCEPT CityCode
  IF CityCodeNotValid
    DISPLAY "Invalid city code entered"
  ELSE
    IF CityIsLimerick
      DISPLAY "Hey, we're home."
    END-IF
    IF CityIsDublin
      DISPLAY "Hey, we're in the capital."
    END-IF
    IF UniversityCity
      DISPLAY "Apply the rent surcharge!"
    END-IF
  END-IF
STOP RUN.
```

Listing 5-2 Run1

```
Enter a city code (1-6) - 8
Invalid city code entered
Listing 5-2 Run1
```

Listing 5-2 Run2

```
Enter a city code (1-6) - 1
Hey, we're in the capital.
Apply the rent surcharge!
```

Listing 5-2 Run3

```
Enter a city code (1-6) - 2
Hey, we're home.
Apply the rent surcharge!
```

The list of values that follows a condition name may be a single value, a number of values, or a range of values, or any mixture of these. When a range is specified, the word `THROUGH` or `THRU` is used to separate the minimum and maximum values in the range. In Listing 5-2, `UniversityCity` is true if `CityCode` contains any value between 1 and 4, whereas `CityCodeNotValid` is true if `CityCode` contains a value of 0 or 7 or 8 or 9. In Listing 5-2 I have chosen to list the individual values for `CityCodeNotValid`, but the value list could have been written as:

```
88 CityCodeNotValid     VALUE 0, 7 THRU 9.
```

Table 5-7 shows the Boolean value of the condition names for each value of `CityCode`.

Table 5-7. Results for Each Value of *CityCode*

Data Item / Condition Name	Data Value / Condition Name Result							
CityCode	0	1	2	3	4	5	6	7 - 9
CityIsDublin	False	TRUE	False	False	False	False	False	False
CityIsLimerick	False	False	TRUE	False	False	False	False	False
CityIsCork	False	False	False	TRUE	False	False	False	False
CityIsGalway	False	False	False	False	TRUE	False	False	False
CityIsSligo	False	False	False	False	False	TRUE	False	False
CityIsWaterford	False	False	False	False	False	False	TRUE	False
UniversityCity	False	TRUE	TRUE	TRUE	TRUE	False	False	False
CityCodeNotValid	TRUE	False	False	False	False	False	False	TRUE

Values Can Be Alphabetic or Numeric

The list of values specified for a condition name can be numeric or alphabetic, as shown in Listing 5-3.

Listing 5-3. Multiple Condition Names with Overlapping Values

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-3.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 InputChar    PIC X.
   88 Vowel     VALUE "A","E","I","O","U".
   88 Consonant VALUE "B" THRU "D", "F","G","H"
                  "J" THRU "N", "P" THRU "T"
                  "V" THRU "Z".
   88 Digit     VALUE "0" THRU "9".
   88 ValidChar VALUE "A" THRU "Z", "0" THRU "9".

PROCEDURE DIVISION.
Begin.
   DISPLAY "Enter a character :- " WITH NO ADVANCING
   ACCEPT InputChar
   IF ValidChar
       DISPLAY "Input OK"
   ELSE
       DISPLAY "Invalid character entered"
   END-IF
   IF Vowel
       DISPLAY "Vowel entered"
   END-IF
   IF Digit
       DISPLAY "Digit entered"
   END-IF
STOP RUN.
```

Listing 5-3 Run1

```
Enter a character :- g
Invalid character entered
```

Listing 5-3 Run2

```
Enter a character :- 5
Input OK
Digit entered
```

Listing 5-3 Run3

```
Enter a character :- E
Input OK
Vowel entered
```

List Values Can Be Whole Words

Although I have used single characters in the examples so far, condition names are not restricted to values with only single characters. Whole words can be used if required, as shown in Listing 5-4.

Listing 5-4. Words as Value Items

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-4.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 MakeOfCar          PIC X(10).
   88 VolksGroup     VALUE "skoda", "seat",
                        "audi", "volkswagen".
   88 GermanMade     VALUE "volkswagen", "audi",
                        "mercedes", "bmw",
                        "porsche".

PROCEDURE DIVISION.
Begin.
  DISPLAY "Enter the make of car - " WITH NO ADVANCING
  ACCEPT MakeOfCar
  IF VolksGroup AND GermanMade
    DISPLAY "Your car is made in Germany by the Volkswagen Group."
  ELSE
    IF VolksGroup
      DISPLAY "Your car is made by the Volkswagen Group."
    END-IF
    IF GermanMade
      DISPLAY "Your car is made in Germany."
    END-IF
  END-IF
STOP RUN.
```

Using Condition Names Correctly

A condition name should express the true condition being tested. It should not express the test that sets the condition name to true. For instance, in Listing 5-2, a value of 1 in the data item CityCode indicates that the city is Dublin, a value of 2 means the city is Limerick, and so on. These condition names allow you to replace conditions such as

```
IF CityCode = 1
```

and

```
IF CityCode = 2
```

with the more meaningful statements

```
IF CityIsDublin
```

and

```
IF CityIsLimerick.
```

```
88
```

Many COBOL beginners would use condition names such as `CityCodeIs1` or `CityCodeIs2` to express these conditions. Those condition names are meaningless because they express the value that makes the condition name true instead of expressing the meaning or significance of `CityCode` containing a particular value. A value of 1 or 2 in `CityCode` is how you detect that the city is Dublin or Limerick. It is not the value of `CityCode` that ultimately interests you; it is the meaning or significance of that value.

Example Program

Listing 5-5 is a small but complete program showing how the `BritishCountry` and `CurrencyIsPound` condition names might be defined and used. There is something unusual about this example, however. What do you imagine happens to the associated data item when the `CurrencyIsPound` condition name is set to true?

Listing 5-5. Detecting `BritishCountry` and Setting and Using `CurrencyIsPound`

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-5.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 CountryCode          PIC 999 VALUE ZEROS.
   88 BritishCountry    VALUES 3, 7, 10, 15.

01 CurrencyCode         PIC 99 VALUE ZEROS.
   88 CurrencyIsPound   VALUE 14.
   88 CurrencyIsEuro    VALUE 03.
   88 CurrencyIsDollar  VALUE 28.

PROCEDURE DIVISION.
Begin.
  DISPLAY "Enter the country code :- " WITH NO ADVANCING
  ACCEPT CountryCode

  IF BritishCountry THEN
    SET CurrencyIsPound TO TRUE
  END-IF
  IF CurrencyIsPound THEN
    DISPLAY "Pound sterling used in this country"
  ELSE
    DISPLAY "Country does not use sterling"
  END-IF
STOP RUN.
```

Listing 5-5 Run1

Enter the country code :- 7
Pound sterling used in this country

Listing 5-5 Run2

Enter the country code :- 5
Country does not use sterling

Setting a Condition Name to True

In Listing 5-5, the SET verb is used to set `CurrencyIsPound` to true. The way condition names normally work is that a value placed into the associated data item automatically sets the condition names that list that value to true. When a condition name is manually set to true using the SET verb, the value listed for that condition name is forced into the associated data item. In Listing 5-5, when the SET verb is used to set `CurrencyIsPound` to true, the value 14 is forced into `CurrencyCode`.

When a condition name that lists more than one value is set to true, the first of the values listed is forced into the associated data item. For instance, if `BritishCountry` were set to true, then the value 3 would be forced into `CountryCode`.

■ **ISO 2002** In standard ANS 85 COBOL, the SET verb cannot be used to set a condition name to false. This can be done in ISO 2002 COBOL, but in that case the level 88 entry must be extended to include the phrase

WHEN SET TO FALSE IS LiteralValue\$#

To set a condition name to true, you use the SET verb. You might think, therefore, that the SET verb is used only for manipulating condition names. But the SET verb is a strange fish. It is used for a variety of unconnected purposes. For instance, it is used to set a condition name to true. It is used to increment or decrement an index item. It is used to assign the value of an index to an ordinary data item and vice versa. It is used to set On or Off the switches associated with mnemonic names. In ISO 2002 COBOL, it is used to manipulate pointer variables (yes, ISO 2002 COBOL has pointers) and object references. It is often the target of implementer extensions.

Because the SET verb has so many different unrelated uses, instead of dealing with it as a single topic I discuss each format as you examine the construct to which it is most closely related.

SET Verb Metalanguage

Figure 5-7 shows the metalanguage for the version of the SET verb that is used to set a condition name to true. When the SET verb is used to set a condition name, the first condition value specified after the VALUE clause in the definition is moved to the associated data item. So setting the condition name to true changes the value of the associated data item. This can lead to some interesting data-manipulation opportunities.

SET ConditionName ... TO TRUE

Figure 5-7. Metalanguage for the SET verb condition name version

In summary, any operation that changes the value of the data item may change the status of the associated condition names, and any operation that changes the status of a condition name will change the value of its associated data item.

SET Verb Examples

In ANS 85 COBOL, you cannot use the SET verb to set a condition name to false. But you can work around this restriction. Consider Example 5-9. This is more a pattern for processing sequential files than real COBOL code, but it serves to illustrate the point.

Example 5-9. Setting the EndOfFile Condition Name

```

01 EndOfFileFlag    PIC 9 VALUE ZERO.
   88 EndOfFile     VALUE 1.
   88 NotEndOfFile  VALUE 0.

   :   :   :   :   :   :   :
   :   :   :   :   :   :   :

READ InFile
  AT END SET EndOfFile TO TRUE
END-READ
PERFORM UNTIL EndOfFile
  Process Record
  READ InFile
    AT END SET EndOfFile TO TRUE
  END-READ
END-PERFORM
Set NotEndOfFile TO TRUE.

```

In this example, the condition name `EndOfFile` has been set up to flag that the end of the file has been reached. You cannot set `EndOfFile` to false, but you can work around this problem by setting another condition name associated with the same data item to true. When `EndOfFile` is set to true, 1 is forced into the data item `EndOfFileFlag`, and this automatically sets `NotEndOfFile` to false. Similarly, when `NotEndOfFile` is set to true, 0 is forced into `EndOfFileFlag`, and this automatically sets `EndOfFile` to false.

Design Pattern: Reading a Sequential File

Because this is your first look at how COBOL processes sequential (as opposed to direct access) files, it might be useful to preview some of the material in Chapter 7 by providing a brief explanation now. The `READ` verb copies a record (a discrete package of data) from the file on backing storage and places it into an area of memory set up to store it. When the `READ` attempts to read a record from the file but discovers that the end of the file has been reached, it activates the `AT END` clause and executes whatever statements follow that clause.

Example 5-9 shows the pattern you generally use to process a stream of items when you can only discover that you have reached the end of the stream by attempting to read the next item. In this pattern, a loop processes the data in the stream. Outside the loop, you have a read to get the first item in the stream or to discover that the stream is empty. Inside the loop, you have statements to process the stream item and get the next item in the stream.

Why do you have this strange arrangement? The chief reason is that this arrangement allows you to place the read at the end of the loop body so that as soon as the end of the file is detected, the loop can be terminated. If you used a structure such as

```

PERFORM UNTIL EndOfFile
  READ InFile
    AT END SET EndOfFile TO TRUE
  END-READ
  Process Record
END-PERFORM

```

then when the end of file was detected, the program would still attempt to process the nonexistent record. Of course, the last valid record would still be in memory, so that last record would be processed twice. Many COBOL beginners make this programming error.

Many beginners attempt to solve this problem by only processing the record if the end of file has not been detected. They use a structure like this:

```
PERFORM UNTIL EndOfFile
  READ InFile
    AT END SET EndOfFile TO TRUE
  END-READ
  IF NOT EndOfFile
    Process Record
  END-IF
END-PERFORM
```

The problem with this arrangement is that the IF statement will be executed for every record in the file. Because COBOL often deals with very large data sets, this could amount to the execution of millions, maybe even hundreds of millions, of unnecessary statements. It is more elegant and more efficient to use what is called the *read-ahead* technique. The read-ahead has a read outside the loop to get the first record and a read inside the loop to get the remaining records. This approach has the added advantage of allowing the empty file condition to be detected before the loop is entered.

Group Item Condition Names

In Example 5-9, stand-alone condition names were used to flag the end-of-file condition. Because the EndOfFile condition name is closely related to the file, it would be better if the declaration of the condition name were kept with the file declaration. The example program in Listing 5-6 shows how that might be done. It also demonstrates how a condition name can be used with a group (as opposed to elementary) data item.

Listing 5-6. Reading a File and Setting the EndOfStudentFile Condition Name

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-6.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
  SELECT StudentFile ASSIGN TO "Listing5-6-TData.Dat"
  ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD StudentFile.
01 StudentDetails.
  88 EndOfStudentFile VALUE HIGH-VALUES.
  02 StudentId      PIC X(8).
  02 StudentName   PIC X(25).
  02 CourseCode    PIC X(5).

PROCEDURE DIVISION.
Begin.
  OPEN INPUT StudentFile
  READ StudentFile
    AT END SET EndOfStudentFile TO TRUE
  END-READ
```

Listing 5-6 Run

Teresa Casey	08712351 LM042
Padraig Quinlan	08712352 LM051
Kevin Tucker	08712353 LM051
Maria Donovan	08712354 LM042
Liam Lorigan	98712355 LM110
Fiachra Luo	98712356 LM051

```

PERFORM UNTIL EndOfStudentFile
  DISPLAY StudentName SPACE StudentId SPACE CourseCode
  READ StudentFile
  AT END SET EndOfStudentFile TO TRUE
END-READ
END-PERFORM
CLOSE StudentFile
STOP RUN.

```

In Listing 5-6, the condition name `EndOfStudentFile` is associated with the group item (which also happens to be a record) `StudentDetails`. When `EndOfStudentFile` is set to true, the entire `StudentDetails` area of storage (38 characters) is flushed with highest possible character value.

This arrangement has two major advantages:

- The `EndOfStudentFile` condition name is kept with its associated file.
- Flushing the record with `HIGH-VALUES` at the end of the file eliminates the need for an explicit condition when doing a key-matching update of a sequential file.

Condition Name Tricks

When you become aware that setting a condition name forces a value into the associated data item, it is tempting to see just how far you can take this idea. Listing 5-7 takes advantage of the way condition names work to automatically move an appropriate error message into a message buffer. The program is just a stub to test this error-messaging idea; it doesn't actually validate the date. Instead, the user manually enters one of the codes that would be returned by the date-validation routine.

Listing 5-7. Using Condition Names to Set Up a Date-Validation Error Message

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-7.
AUTHOR. Michael Coughlan.

```

```

DATA DIVISION.

```

```

WORKING-STORAGE SECTION.

```

```

01 ValidationReturnCode PIC 9.
   88 DateIsOK          VALUE 0.
   88 DateIsInvalid    VALUE 1 THRU 8.
   88 ValidCodeSupplied VALUE 0 THRU 8.

01 DateErrorMessage    PIC X(35) VALUE SPACES.
   88 DateNotNumeric   VALUE "Error - The date must be numeric".
   88 YearIsZero       VALUE "Error - The year cannot be zero".
   88 MonthIsZero      VALUE "Error - The month cannot be zero".
   88 DayIsZero        VALUE "Error - The day cannot be zero".
   88 YearPassed       VALUE "Error - Year has already passed".
   88 MonthTooBig      VALUE "Error - Month is greater than 12".
   88 DayTooBig        VALUE "Error - Day greater than 31".
   88 TooBigForMonth   VALUE "Error - Day too big for this month".

```

PROCEDURE DIVISION.

Begin.

```
PERFORM ValidateDate UNTIL ValidCodeSupplied
```

```
EVALUATE ValidationReturnCode
```

```
WHEN 0 SET DateIsOK TO TRUE
```

```
WHEN 1 SET DateNotNumeric TO TRUE
```

```
WHEN 2 SET YearIsZero TO TRUE
```

```
WHEN 3 SET MonthIsZero TO TRUE
```

```
WHEN 4 SET DayIsZero TO TRUE
```

```
WHEN 5 SET YearPassed TO TRUE
```

```
WHEN 6 SET MonthTooBig TO TRUE
```

```
WHEN 7 SET DayTooBig TO TRUE
```

```
WHEN 8 SET TooBigForMonth TO TRUE
```

```
END-EVALUATE
```

```
IF DateIsInvalid THEN
```

```
    DISPLAY DateErrorMessage
```

```
END-IF
```

```
IF DateIsOK
```

```
    DISPLAY "Date is Ok"
```

```
END-IF
```

```
STOP RUN.
```

ValidateDate.

```
DISPLAY "Enter a validation return code (0-8) " WITH NO ADVANCING
```

```
ACCEPT ValidationReturnCode.
```

Listing 5-7 Run1

Enter a validation return code (0-8) 9

Enter a validation return code (0-8) 0

Date is Ok

Listing 5-7 Run2

Enter a validation return code (0-8) 6

Error - Month is greater than 12

Listing 5-7 Run3

Enter a validation return code (0-8) 8

Error - Day too big for this month

EVALUATE

In Listing 5-7, the EVALUATE verb is used to SET a particular condition name depending on the value in the ValidationReturnCode data item. You probably did not have much difficulty working out what the EVALUATE statement is doing because it has echoes of how the switch/case statement works in other languages. Ruby programmers, with their when-branched case statement, were probably particularly at home. But the resemblance of EVALUATE to the case/switch used in other languages is superficial. EVALUATE is far more powerful than these constructs. Even when restricted to one subject, EVALUATE is more powerful because it is not limited to ordinal types. When used with multiple subjects, EVALUATE is a significantly more powerful construct. One common use for the multiple-subject EVALUATE is the implementation of decision-table logic.

Decision Tables

A *decision table* is a way to model complicated logic in a tabular form. Decision tables are often used by systems analysts to express business rules that would be too complicated and/or too confusing to express in a textual form.

For instance, suppose an amusement park charges different admission fees depending on the age and height of visitors, according to the following rules:

- If the person is younger than 4 years old, admission is free.
- If the person is between 4 and 7, admission is \$10.
- If between 8 and 12, admission is \$15.
- If between 13 and 64, admission is \$25.
- If 65 or older, admission is \$10.
- In addition, in view of the height restrictions on many rides, persons shorter than 48 inches who are between the ages of 8 and 64 receive a discount. Persons between 8 and 12 are charged a \$10 admission fee, whereas those between the ages of 13 and 64 are charged \$18.

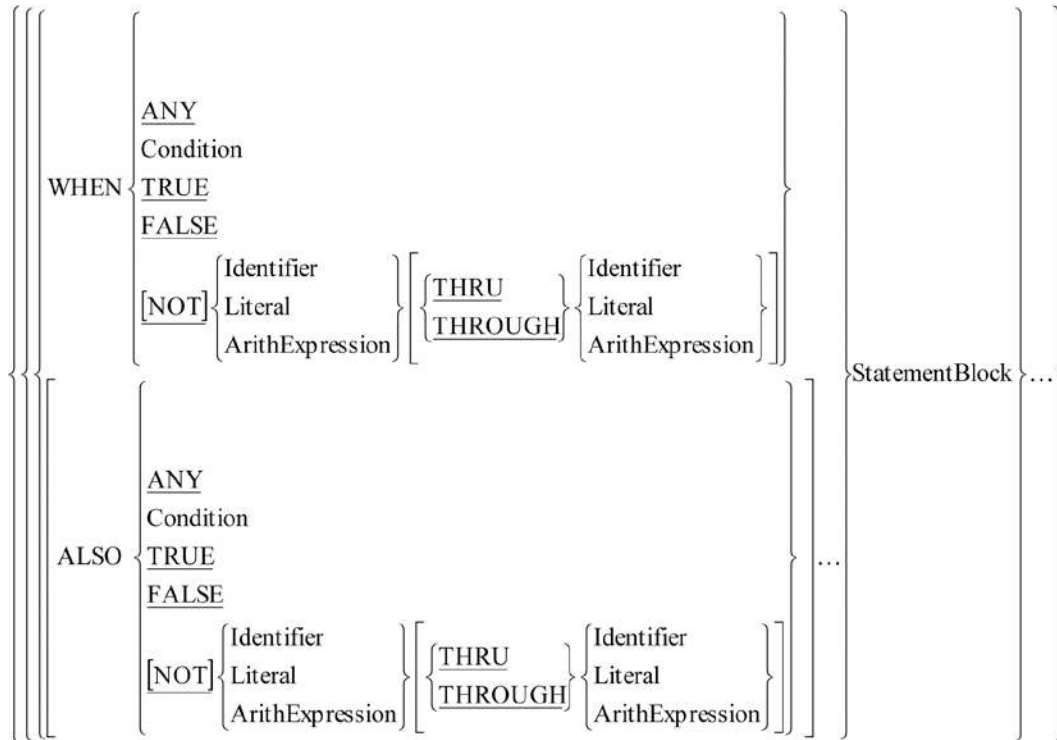
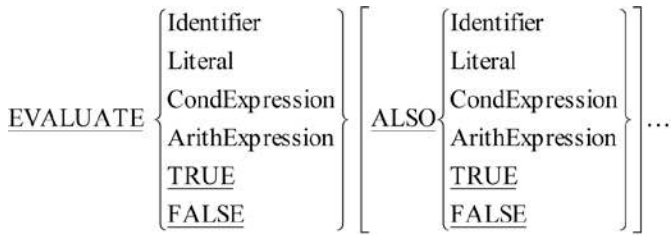
You can represent this textual specification using the decision table in Table 5-8.

Table 5-8. *Amusement Park Decision Table*

Age	Height in inches	Admission
< 4	NA	\$0
4 - 7	NA	\$10
8 - 12	Height \geq 48	\$15
8 - 12	Height < 48	\$10
13 - 64	Height \geq 48 inches	\$25
13 - 64	Height < 48	\$18
\geq 65	NA	\$10

EVALUATE Metalanguage

The EVALUATE metalanguage (see Figure 5-8) looks very complex but is actually fairly easy to understand. It is, though, somewhat difficult to explain in words, so I mainly use examples to explain how it works.



WHEN OTHER StatementBlock]

END - EVALUATE

Figure 5-8. Metalanguage for the EVALUATE verb

Notes

The following are the WHEN branch rules:

- Only one WHEN branch is chosen per execution of EVALUATE.
- The order of the WHEN branches is important because checking of the branches is done from top to bottom.
- If any WHEN branch is chosen, the EVALUATE ends. The break required in other languages to stop execution of the remaining branches is not required in COBOL.
- If none of the WHEN branches can be chosen, the WHEN OTHER branch (if it exists) is executed.
- If none of the WHEN branches can be chosen, and there is no WHEN OTHER phrase, the EVALUATE simply terminates.

The items immediately after the word EVALUATE and before the first WHEN are called *subjects*. The items between the WHEN and its statement block are called *objects*.

The number of subjects must equal the number of objects, and the objects must be compatible with the subjects. For instance, if the subject is a condition, then the object must be either TRUE or FALSE. If the subject is a data item, then the object must be either a literal value or a data item.

Table 5-9 lists the combinations you may have. If there are four subjects, then each WHEN branch must list four objects. If the value of a particular object does not matter, the keyword ANY may be used.

Table 5-9. EVALUATE Subject/Object Combinations

	Subject 1		Subject 2		Subject 3		Subject 4	Action
EVALUATE	Condition	ALSO	True False	ALSO	Identifier	ALSO	Literal	Statement Block
WHEN	True False	ALSO	Condition	ALSO	Literal	ALSO	Identifier	Statement Block
WHEN	ANY	ALSO	ANY	ALSO	Identifier	ALSO	Literal	Statement Block
WHEN	OTHER							Statement Block
END-EVALUATE	Object 1		Object 2		Object 3		Object 4	

EVALUATE Examples

This section looks at three examples of the EVALUATE verb.

Payment Totals Example

Shoppers choose the method of payment as Visa, MasterCard, American Express, Check, or Cash. A program totals the amount paid by each payment method. After a sale, the sale value is added to the appropriate total. Condition names (ByVisa, ByMasterCard, ByAmericanExpress, ByCheck, ByCash) have been set up for each of the payment methods.

You could code this as follows:

```

IF ByVisa ADD SaleValue TO VisaTotal
ELSE
  IF ByMasterCard ADD SaleValue TO MasterCardTotal
  ELSE
    IF ByAmericanExpress ADD SaleValue TO AmericanExpressTotal
    ELSE
      IF ByCheck ADD SaleValue TO CheckTotal
      ELSE
        IF ByCash ADD SaleValue TO CashTotal
        END-IF
      END-IF
    END-IF
  END-IF
END-IF

```

You can replace these nested IF statements with the neater and easier-to-understand EVALUATE statement:

```

EVALUATE TRUE
  WHEN ByVisa          ADD SaleValue TO VisaTotal
  WHEN ByMasterCard    ADD SaleValue TO MasterCardTotal
  WHEN ByAmericanExpress ADD SaleValue TO AmericanExpressTotal
  WHEN ByCheck         ADD SaleValue TO CheckTotal
  WHEN ByCash          ADD SaleValue TO CashTotal
END-EVALUATE

```

In this example, the objects must all be either conditions or condition names, because the subject is TRUE.

Amusement Park Example

EVALUATE can be used to encode a decision table. Listing 5-8 shows how the Amusement Park decision table from Table 5-8 might be encoded.

Listing 5-8. Amusement Park Admission

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-8.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 Age          PIC 99 VALUE ZERO.
   88 Infant    VALUE 0 THRU 3.
   88 YoungChild VALUE 4 THRU 7.
   88 Child     VALUE 8 THRU 12.
   88 Visitor   VALUE 13 THRU 64.
   88 Pensioner VALUE 65 THRU 99.

```

```

01 Height          PIC 999 VALUE ZERO.

01 Admission       PIC $99.99.

PROCEDURE DIVISION.
Begin.
    DISPLAY "Enter age      :- " WITH NO ADVANCING
    ACCEPT Age
    DISPLAY "Enter height :- " WITH NO ADVANCING
    ACCEPT Height

    EVALUATE TRUE      ALSO      TRUE
    WHEN Infant      ALSO      ANY      MOVE 0 TO Admission
    WHEN YoungChild  ALSO      ANY      MOVE 10 TO Admission
    WHEN Child        ALSO      Height >= 48  MOVE 15 TO Admission
    WHEN Child        ALSO      Height < 48  MOVE 10 TO Admission
    WHEN Visitor      ALSO      Height >= 48  MOVE 25 TO Admission
    WHEN Visitor      ALSO      Height < 48  MOVE 18 TO Admission
    WHEN Pensioner   ALSO      ANY      MOVE 10 TO Admission
END-EVALUATE

    DISPLAY "Admission charged is " Admission
STOP RUN.

```

Listing 5-8 Run1

```

Enter age      :- 7
Enter height :- 45
Admission charged is $10.00

```

Listing 5-8 Run2

```

Enter age      :- 9
Enter height :- 52
Admission charged is $15.00

```

Listing 5-8 Run3

```

Enter age      :- 9
Enter height :- 45
Admission charged is $10.00

```

Listing 5-8 Run4

```

Enter age      :- 31
Enter height :- 47

```

Acme Book Club Example

The Acme Book Club is the largest online book club in the world. The book club sells books to both members and non-members all over the world. For each order, Acme applies a percentage discount based on the quantity of books in the current order, the value of books purchased in the last three months (last quarter), and whether the customer is a member of the Book Club.

Acme uses the decision table in Table 5-10 to decide what discount to apply. Listing 5-9 is a small test program that uses EVALUATE to implement the decision table.

Table 5-10. *Acme Book Club Discount Decision Table*

QtyOfBooks	QuarterlyPurchases (QP)	ClubMember	% Discount
1-5	< 500	ANY	0
1-5	< 2000	Y	7
1-5	< 2000	N	5
1-5	>= 2000	Y	10
1-5	>= 2000	N	8
6-20	< 500	Y	3
6-20	< 500	N	2
6-20	< 2000	Y	12
6-20	< 2000	N	10
6-20	>= 2000	Y	25
6-20	>= 2000	N	15
21-99	< 500	Y	5
21-99	< 500	N	3
21-99	< 2000	Y	16
21-99	< 2000	N	15
21-99	>= 2000	Y	30
21-99	>= 2000	N	20

Listing 5-9. *Acme Book Club Example*

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-9.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 Member          PIC X VALUE SPACE.

01 QP              PIC 9(5) VALUE ZEROS.
*> QuarterlyPurchases

01 Qty             PIC 99 VALUE ZEROS.

01 Discount        PIC 99 VALUE ZEROS.

PROCEDURE DIVISION.
Begin.
    DISPLAY "Enter value of QuarterlyPurchases - " WITH NO ADVANCING
    ACCEPT QP
    DISPLAY "Enter qty of books purchased - " WITH NO ADVANCING
    ACCEPT Qty

```

```
DISPLAY "club member enter Y or N - " WITH NO ADVANCING
ACCEPT Member
```

```
EVALUATE Qty      ALSO TRUE      ALSO Member
WHEN 1 THRU 5    ALSO QP < 500  ALSO ANY  MOVE 0  TO Discount
WHEN 1 THRU 5    ALSO QP < 2000 ALSO "Y"  MOVE 7  TO Discount
WHEN 1 THRU 5    ALSO QP < 2000 ALSO "N"  MOVE 5  TO Discount
WHEN 1 THRU 5    ALSO QP >= 2000 ALSO "Y"  MOVE 10 TO Discount
WHEN 1 THRU 5    ALSO QP >= 2000 ALSO "N"  MOVE 8  TO Discount

WHEN 6 THRU 20  ALSO QP < 500  ALSO "Y"  MOVE 3  TO Discount
WHEN 6 THRU 20  ALSO QP < 500  ALSO "N"  MOVE 2  TO Discount
WHEN 6 THRU 20  ALSO QP < 2000 ALSO "Y"  MOVE 12 TO Discount
WHEN 6 THRU 20  ALSO QP < 2000 ALSO "N"  MOVE 10 TO Discount
WHEN 6 THRU 20  ALSO QP >= 2000 ALSO "Y"  MOVE 25 TO Discount
WHEN 6 THRU 20  ALSO QP >= 2000 ALSO "N"  MOVE 15 TO Discount

WHEN 21 THRU 99 ALSO QP < 500  ALSO "Y"  MOVE 5  TO Discount
WHEN 21 THRU 99 ALSO QP < 500  ALSO "N"  MOVE 3  TO Discount
WHEN 21 THRU 99 ALSO QP < 2000 ALSO "Y"  MOVE 16 TO Discount
WHEN 21 THRU 99 ALSO QP < 2000 ALSO "N"  MOVE 15 TO Discount
WHEN 21 THRU 99 ALSO QP >= 2000 ALSO "Y"  MOVE 30 TO Discount
WHEN 21 THRU 99 ALSO QP >= 2000 ALSO "N"  MOVE 20 TO Discount

END-EVALUATE
DISPLAY "Discount = " Discount "%"
STOP RUN.
```

Listing 5-9 Run1

```
Enter value of QuarterlyPurchases - 545
Enter qty of books purchased - 14
club member enter Y or N - Y
Discount = 12%
```

Listing 5-9 Run2

```
Enter value of QuarterlyPurchases - 2534
Enter qty of books purchased - 14
club member enter Y or N - Y
Discount = 25%
```

Listing 5-9 Run3

```
Enter value of QuarterlyPurchases - 2534
Enter qty of books purchased - 23
club member enter Y or N - Y
Discount = 30%
```

Summary

The three classic constructs of structured programming are sequence, selection, and iteration. You have already noted that a COBOL program starts execution with the first statement in the PROCEDURE DIVISION and then continues to execute the statements one after another in sequence until the STOP RUN or the end-of-the-program text is encountered, unless some other statement changes the order of execution. In this chapter, you examined the IF and EVALUATE statements. These statements allow a program to selectively execute program statements. In the next chapter, you discover how iteration, the final classic construct, is implemented in COBOL.

References

1. Tompkins HE. In defense of teaching structured COBOL as computer science (or, notes on being sage struck). ACM SIGPLAN Notices. 1983; 18(4): 86-94.
2. Baldwin RR. A note on H.E. Tompkins's minimum-period COBOL style. ACM SIGPLAN Notices. 1987; 22(5): 27-31. <http://doi.acm.org/10.1145/25267.25273>
doi: [10.1145/25267.25273](https://doi.org/10.1145/25267.25273)

LANGUAGE KNOWLEDGE EXERCISES

Getting out your 2B pencil once more, write answers to the following questions.

- For each of the following condition names, which do you consider to be inappropriately named? Suggest more suitable names for these only.

```
01 Country-Code          PIC XX.
   88 Code-Is-US         VALUE "US".
```

```
01 Operating-System     PIC X(15).
   88 Windows-Or-UNIX   VALUE "WINDOWS".
```

```
01 Room-Type            PIC X(20).
   88 Double-Room       VALUE "DOUBLE".
```

```
88 Single-Room         VALUE "SINGLE".
```

- Write an IF statement that uses the SET verb to manually set the condition name `InvalidCode` to true if `DeptCode` contains anything except 1, 6, or 8.

- Assume the variable `DeptCode` in question 2 is described as

```
01 DeptCode             PIC 9.
```

Write a level 88 condition name called `InvalidCode` that is automatically set to true when the statement `ACCEPT DeptCode` accepts any value other than 1, 6, or 8.

4. In each of the following five groups of skeleton IF statements, state whether the statements in each group have the same effect (in the sense that they evaluate to true or false). Answer yes or no.

Do these statements have the same effect?

Answer

IF Num1 = 1 OR Num1 NOT = 1...

IF NOT (Num1 = 1 AND Num1 = 2) ...

IF TransCode IS NOT = 3 OR Total NOT > 2550 ...

IF NOT (TransCode IS = 3 OR Total > 2550) ...

IF Num1 = 31 OR Num2 = 12 AND Num3 = 23 OR Num4 = 6 ...

IF (Num1 = 31 OR (Num2 = 12 AND Num3 = 23)) OR Num4 = 6 ...

IF Num1 = 15 OR Num1 = 12 OR Num1 = 7 AND City = "Cork" ...

IF (Num1 = 15 OR Num1 = 12 OR Num1 = 7) AND City = "Cork" ...

IF (Num1 = 1 OR Num1 = 2) AND (Num2 = 6 OR Num2 = 8) ...

IF Num1 = 1 OR Num1 = 2 AND Num2 = 6 OR Num2 = 8 ...

5. Write an EVALUATE statement to implement the decision part of a game of rock, paper, scissors. Most of the program has been written for you. Just complete the EVALUATE. ADD a WHEN OTHER branch to the EVALUATE to detect when a player enters a code other than 1, 2, or 3.

IDENTIFICATION DIVISION.

PROGRAM-ID. Listing5-10.

AUTHOR. Michael Coughlan.

DATA DIVISION.

WORKING-STORAGE SECTION.

01 PlayerGuess-A PIC 9 VALUE 1.

88 Rock-A VALUE 1.

88 Paper-A VALUE 2.

88 Scissors-A VALUE 3.

01 PlayerGuess-B PIC 9 VALUE 2.

88 Rock-B VALUE 1.

88 Paper-B VALUE 2.

88 Scissors-B VALUE 3.

PROCEDURE DIVISION.

BEGIN.

DISPLAY "Guess for player A (1=rock, 2=scissors, 3=paper) : "
WITH NO ADVANCING

ACCEPT PlayerGuess-A

DISPLAY "Guess for player B (1=rock, 2=scissors, 3=paper) : "
WITH NO ADVANCING

ACCEPT PlayerGuess-B

EVALUATE

PROGRAMMING EXERCISE

Listing 4-2 is a program that accepts two numbers from the user, multiplies them together, and then displays the result. Modify the program so that

- It also accepts an operator symbol (+ - / *).
- It uses EVALUATE to discover which operator has been entered and to apply that operator to the two numbers entered.
- It uses the condition name `ValidOperator` to identify the valid operators and only displays the result if the operator entered is valid.
- The `Result` data item is changed to accommodate the possibility that subtraction may result in a negative value.
- The `Result` data item is changed to accommodate the decimal fractions that may result from division. The result data item should be able to accept values with up to two decimal places (for example, 00.43 or 00.74).

LANGUAGE KNOWLEDGE EXERCISES—ANSWERS

1. For each of the following condition names, which do you consider to be inappropriately named? Suggest more suitable names for these only.

```
01 Country-Code      PIC XX.
   88 UnitedStates   VALUE "US".
```

* Change

* Example of use - IF UnitedStates DISPLAY "We are in America" END-IF

```
01 Operating-System  PIC X(15).
   88 Windows        VALUE " WINDOWS".
```

* Change

* Example of use - IF Windows DISPLAY "Windows is best" END-IF

```
01 Room-Type         PIC X(20).
   88 Double-Room    VALUE "DOUBLE".
   88 Single-Room    VALUE "SINGLE".
```

* No change.

* Example of use -IF Double-Room ADD DoubleRoomSurcharge TO RoomRent END-IF

2. Write an IF statement that uses the SET verb to manually set the condition name InvalidCode to true if DeptCode contains anything except 1, 6, or 8.

```
IF NOT (DeptCode = 1 OR DeptCode = 6 OR DeptCode = 8) THEN
    SET InvalidCode TO TRUE
END-IF.
```

Or, using implied subjects:

```
IF NOT (DeptCode = 1 OR 6 OR 8) THEN
    SET InvalidCode TO TRUE
END-IF.
```

3. Assume the variable DeptCode in question 2 is described as

```
01 DeptCode          PIC 9.
   88 InvalidCode    VALUE 0, 2 THRU 5,7,9.
```

Write a level 88 condition name called InvalidCode that is automatically set to true when the statement ACCEPT DeptCode accepts any value other than 1, 6, or 8.

4. In each of the following five groups of skeleton IF statements, state whether the statements in each group have the same effect (in the sense that they evaluate to true or false). Answer yes or no.

Do these statements have the same effect?

```
IF Num1 = 1 OR Num1 NOT = 1...
IF NOT (Num1 = 1 AND Num1 = 2)...
```

```
IF TransCode IS NOT = 3 OR Total NOT > 2550 ...
IF NOT (TransCode IS = 3 OR Total > 2550)...
```

```
IF Num1 = 31 OR Num2 = 12 AND Num3 = 23 OR Num4 = 6...
IF (Num1 = 31 OR (Num2 = 12 AND Num3 = 23)) OR Num4 = 6...
```

```
IF Num1 = 15 OR Num1 = 12 OR Num1 = 7 AND City = "Cork"...
IF (Num1 = 15 OR Num1 = 12 OR Num1 = 7) AND City =
"Cork"...
```

```
IF (Num1 = 1 OR Num1 = 2) AND (Num2 = 6 OR Num2 = 8) ...
IF Num1 = 1 OR Num1 = 2 AND Num2 = 6 OR Num2 = 8 ...
```

Answer

YES

In the sense that they are both always true.

NO

YES

The brackets only make explicit what is ordained by the precedence rules.

NO

In the first Num1=7 AND City=SPACES are ANDed together but in the second City="Cork" is ANDed with the result of the expression in the parentheses

NO

5. Write an EVALUATE statement to implement the decision part of a game of rock, paper, scissors. Most of the program has been written for you. Just complete the EVALUATE. ADD a WHEN OTHER branch to the EVALUATE to detect when a player enters a code other than 1, 2, or 3.

Listing 5-10. Rock, Paper, Scissors Game

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-10.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
    01 PlayerGuess-A    PIC 9   VALUE 1.
    88 Rock-A          VALUE 1.
    88 Paper-A         VALUE 2.
    88 Scissors-A      VALUE 3.

    01 PlayerGuess-B    PIC 9   VALUE 2.
    88 Rock-B          VALUE 1.
    88 Paper-B         VALUE 2.
    88 Scissors-B      VALUE 3.
```

Listing 5-10 Run1

```
Guess for player A (1=rock, 2=scissors, 3=paper): 1
Guess for player B (1=rock, 2=scissors, 3=paper): 3
Player A wins
```

Listing 5-10 Run2

```
Guess for player A (1=rock, 2=scissors, 3=paper): 1
Guess for player B (1=rock, 2=scissors, 3=paper): 2
Player B wins
```

Listing 5-10 Run3

```
Guess for player A (1=rock, 2=scissors, 3=paper): 1
Guess for player B (1=rock, 2=scissors, 3=paper): 1
Draw
```

```

PROCEDURE DIVISION.
BEGIN.
    DISPLAY "Guess for player A (1=rock, 2=scissors, 3=paper) : "
        WITH NO ADVANCING
    ACCEPT PlayerGuess-A
    DISPLAY "Guess for player B (1=rock, 2=scissors, 3=paper) : "
        WITH NO ADVANCING
    ACCEPT PlayerGuess-B
    EVALUATE TRUE    ALSO    TRUE
        WHEN Rock-A    ALSO    Rock-B    DISPLAY "Draw"
        WHEN Rock-A    ALSO    Paper-B   DISPLAY "Player B wins"
        WHEN Rock-A    ALSO    Scissors-B DISPLAY "Player A wins"
        WHEN Paper-A   ALSO    Rock-B    DISPLAY "Player A wins"
        WHEN Paper-A   ALSO    Paper-B   DISPLAY "Draw"
        WHEN Paper-A   ALSO    Scissors-B DISPLAY "Player B wins"
        WHEN Scissors-A ALSO    Rock-B    DISPLAY "Player B wins"
        WHEN Scissors-A ALSO    Paper-B   DISPLAY "Player A wins"
        WHEN Scissors-A ALSO    Scissors-B DISPLAY "Draw"
        WHEN OTHER    DISPLAY "Evaluate problem"
    END-EVALUATE
STOP RUN.

```

PROGRAMMING EXERCISE ANSWER

Listing 5-11. Simple Calculator

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing5-11.
AUTHOR. Michael Coughlan.
*> Accepts two numbers and an operator from the user.
*> Applies the appropriate operation to the two numbers.

```

```

DATA DIVISION.
WORKING-STORAGE SECTION.
01 Num1          PIC 9 VALUE 7.
01 Num2          PIC 9 VALUE 3.
01 Result        PIC --9.99 VALUE ZEROS.
01 Operator      PIC X VALUE "-".
    88 ValidOperator VALUES "*", "+", "-", "/".

```

```

PROCEDURE DIVISION.
CalculateResult.
    DISPLAY "Enter a single digit number : " WITH NO ADVANCING
    ACCEPT Num1
    DISPLAY "Enter a single digit number : " WITH NO ADVANCING

```

```
ACCEPT Num2
DISPLAY "Enter the operator to be applied : " WITH NO ADVANCING
ACCEPT Operator   EVALUATE Operator
  WHEN "+"   ADD Num2 TO Num1 GIVING Result
  WHEN "-"   SUBTRACT Num2 FROM Num1 GIVING Result
  WHEN "*"   MULTIPLY Num2 BY Num1 GIVING Result
  WHEN "/"   DIVIDE Num1 BY Num2 GIVING Result ROUNDED
  WHEN OTHER DISPLAY "Invalid operator entered"
END-EVALUATE
IF ValidOperator
  DISPLAY "Result is = ", Result
END-IF
STOP RUN.
```

Listing 5-11 Run1

```
Enter a single digit number : 5
Enter a single digit number : 3
Enter the operator to be applied : /
Result is = 1.67
```

Listing 5-11 Run2

```
Enter a single digit number : 5
Enter a single digit number : 3
Enter the operator to be applied : -
Result is = 2.00
```

Listing 5-11 Run3

```
Enter a single digit number : 3
Enter a single digit number : 5
Enter the operator to be applied : -
Result is = -2.00
```

CHAPTER 6



Control Structures: Iteration

The previous chapter dealt with COBOL's selection constructs: IF and EVALUATE. In this chapter, you examine the last of the classic structured programming constructs: iteration.

In almost every programming job, there is some task that needs to be done over and over again. The job of processing a file of records is an iteration of this task: get and process record. The job of getting the sum of a stream of numbers is an iteration of this task: get and add number. The job of searching through an array for a particular value is an iteration of this task: get next element and check element value. These jobs are accomplished using iteration constructs.

Other languages support a variety of iteration constructs, each designed to achieve different things. In Modula-2 and Pascal, `while`, `do` and `Repeat`..`Until` implement pre-test and post-test iteration. The `for` loop is used for counting iteration. The many C-language derivatives use `while` and `do`..`while` for pre-test and post-test iteration, and again the `for` loop is used for counting iteration.

COBOL supports all these different kinds of iteration, but it has only one iteration construct: the `PERFORM` verb (see Table 6-1). Pre-test and post-test iteration are supported by `PERFORM WITH TEST BEFORE` and `PERFORM WITH TEST AFTER`. Counting iteration is supported by `PERFORM`..`VARYING`. COBOL even has variations that are not found in other languages. `PERFORM`..`VARYING`, for instance, can take more than one counter, and it has both pre-test and post-test variations. Whereas in most languages the loop target is an inline block of code, in COBOL it can be either an inline block or a named out-of-line block of code.

Table 6-1. Iteration Constructs and Their COBOL Equivalents

	C, C++, Java	Modula-2, Pascal	COBOL
Pre-test	<code>while {}</code>	<code>While..DO</code>	<code>PERFORM WITH TEST BEFORE UNTIL</code>
Post-test	<code>do {}</code> <code>while</code>	<code>Repeat..Until</code>	<code>PERFORM WITH TEST AFTER UNTIL</code>
Counting	<code>for</code>	<code>For..DO</code>	<code>PERFORM..VARYING..UNTIL</code>

Paragraphs Revisited

In the `PROCEDURE DIVISION`, a paragraph is a block of code to which you have given a name. A paragraph begins with the paragraph name (see Example 6-1) and ends when the next paragraph or section name is encountered or when the end of the program text is reached. The paragraph name must *always* be terminated with a period (full stop).

There may be any number of statements and sentences in a paragraph; but there must be at least one sentence, and the last statement in the paragraph must be terminated with a period. In fact, as I mentioned in the previous chapter, there is a style of COBOL programming called the *minimum-period* style¹⁻², which you should adopt. This style suggests that there should be only one period in the paragraph. It is particularly important to adhere to this style when coding inline loops, because a period has the effect of delimiting the scope of an inline `PERFORM`.

Example 6-1. Two Paragraphs: ProcessRecord Ends Where ProcessOutput Begins

```

ProcessRecord.
    DISPLAY StudentRecord
    READ StudentFile
    AT END MOVE HIGH-VALUES TO StudentRecord
    END-READ.

ProduceOutput.
    DISPLAY "Here is a message".

```

The PERFORM Verb

Unless it is instructed otherwise, a computer running a COBOL program processes the statements in sequence, starting at the first statement of the PROCEDURE DIVISION and working its way down through the program until the STOP RUN, or the end of the program text, is reached. The PERFORM verb is one way of altering the sequential flow of control in a COBOL program. The PERFORM verb can be used for two major purposes;

- To transfer control to a designated block of code
- To execute a block of code iteratively

Whereas the other formats of the PERFORM verb implement iteration of one sort or another, this first format is used to transfer control to an out-of-line block of code—that is, to execute an open subroutine. You have probably have come across the idea of a subroutine before. A *subroutine* is a block of code that is executed when invoked by name. Methods, procedures, and functions are subroutines. You may not have realized that there are two types of subroutine:

- Open subroutines
- Closed subroutines

If you have learned BASIC, you may be familiar with open subroutines. If you learned C, Modula-2, or Java, you are probably familiar with closed subroutines.

Open Subroutines

An *open* subroutine is a named block of code that control (by which I mean program statement execution) can fall into, or through. An open subroutine has access to all the data items declared in the main program, and it cannot declare any local data items.

Although an open subroutine is normally executed by invoking it by name, it is also possible, unless you are careful, to fall into it from the main program. In BASIC, the GOSUB and RETURN commands allow you to implement open subroutines. Example 6-2 is a short BASIC program that illustrates the fall-through problem. Two outputs are provided: one where the EXIT statement prevents fall-through and the other where control falls through into OpenSub because the EXIT statement has been removed.

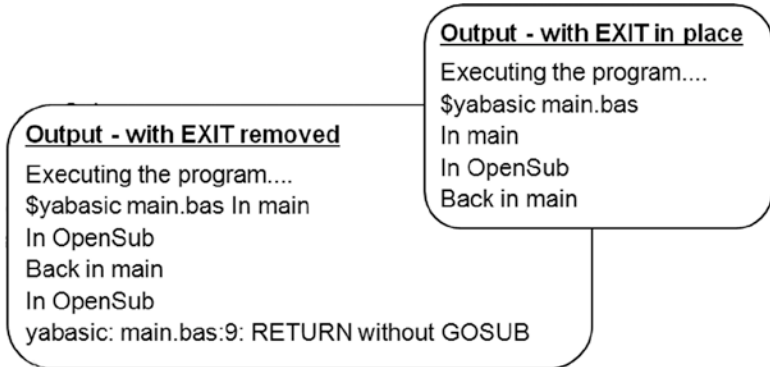
Example 6-2. Open Subroutine in Yabasic³ Showing Output With and Without the EXIT Statement

```

REM Demonstrates Open subroutines in Yabasic
REM When the EXIT is removed, control falls
REM through into OpenSub
REM Author. Michael Coughlan
PRINT "In main"
GOSUB OpenSub
PRINT "Back in main"
EXIT

LABEL OpenSub
  PRINT "In OpenSub"
  RETURN

```



In some legacy COBOL programs, falling through the program from paragraph to paragraph is a deliberate strategy. In this scheme, which has been called *gravity-driven programming*, control falls through the program until it encounters an IF and GO TO combination that drives it to a paragraph in the code above it; after that, control starts to fall through the program again. Example 6-3 provides an outline of how such a program works (P1, P2, P3, and P4 are paragraph names).

Example 6-3. Model for a Gravity-Driven COBOL Program

```

P1.
  statement
  statement
  statement

P2.
  statement
  statement

P3.
  statement
  IF cond GO TO P2
  statement
  statement
  IF cond GO TO P3

P4.
  statement
  IF cond GO TO P2
  statement
  statement
  STOP RUN

```

Closed Subroutines

A *closed* subroutine is a named block of code that can *only* be executed by invoking it by name. Control cannot “fall into” a closed subroutine. A closed subroutine can usually declare its own local data, and that data cannot be accessed outside the subroutine. Data in the main program can be passed to the subroutine by means of parameters specified when the subroutine is invoked. In C and Modula-2, procedures and functions implement closed subroutines. In Java, methods are used.

COBOL Subroutines

COBOL supports both open and closed subroutines. Open subroutines are implemented using the first format of the PERFORM verb. Closed subroutines are implemented using the CALL verb and contained or external subprograms. You learn about contained and external subprograms later in the book.

■ **ISO 2002** ISO 2002 COBOL provides additional support for closed subroutines in the form of methods. Methods in COBOL bear a very strong syntactic resemblance to contained subprograms.

Why Use Open Subroutines?

The open subroutines represented by paragraphs (and sections) are used to make programs more readable and maintainable. Although PERFORMed paragraphs are not as robust as the user-defined procedures or functions found in other languages, they are still useful. They allow you to partition code into a hierarchy of named tasks and subtasks without the formality or overhead involved in coding a procedure or function. COBOL programmers who require the protection of that kind of formal partitioning can use contained or external subprograms.

Partitioning a task into subtasks makes each subtask more manageable; and using meaningful names for the subtasks effectively allows you to document in code what the program is doing. For instance, a block of code that prints report headings can be removed to a paragraph called `PrintReportHeadings`. The details of *how* the task is being accomplished can be replaced with a name that indicates *what* is being done.

Consider the partitioning and documentation benefits provided by the program skeleton in Example 6-4. The skeleton contains no real code (only PERFORMs and paragraph names), but the hierarchy of named tasks and subtasks allows you to understand that the program reads through a file containing sales records for various shops and for each shop prints a line on the report that summarizes the sales for that shop.

Example 6-4. Program Skeleton

```
PrintSummarySalesReport.
    PERFORM PrintReportHeadings
    PERFORM PrintSummaryBody UNTIL EndOfFile
    PERFORM PrintFinalTotals
    STOP RUN.

PrintSummaryBody.
    PERFORM SummarizeShopSales
        UNTIL ShopId <> PreviousShopId
        OR EndOfFile
    PERFORM PrintShopSummary

SummarizeShopSales.
    Statements
```

PrintReportHeadings.
Statements

PrintShopSummary.
Statements

PrintFinalTotals.
Statements

Obviously, it is possible to take partitioning to an extreme. You should try to achieve a balance between making the program too fragmented and too monolithic. As a rule of thumb, there should be a good reason for creating a paragraph that contains five statements or fewer.

PERFORM NamedBlock

This first format of the PERFORM (see Figure 6-1) is not an iteration construct. It simply instructs the computer to transfer control to an out-of-line block of code (that is, an open subroutine). The block of code may be a paragraph or a section. When the end of the block is reached, control reverts to the statement (not the sentence) immediately following the PERFORM.

$$\underline{\text{PERFORM}} \left[\text{StartblockName} \left\{ \begin{array}{l} \text{THRU} \\ \text{THROUGH} \end{array} \right\} \text{EndblockName} \right]$$

Figure 6-1. Metalanguage for PERFORM format 1

In Figure 6-1, StartblockName and EndblockName are the names of paragraphs or sections. PERFORM..THRU instructs the computer to treat the paragraphs or sections from StartblockName TO EndblockName as a single block of code.

PERFORM s can be nested. A PERFORM may execute a paragraph that contains another PERFORM, but neither direct nor indirect recursion is allowed. Unfortunately, this restriction is not enforced by the compiler, so a syntax error does not result; but your program will not work correctly if you use recursive PERFORMs.

The order of execution of the paragraphs is independent of their physical placement. It does not matter where you put the paragraphs—the PERFORM will find and execute them.

How PERFORM Works

Listing 6-1 shows a short COBOL program that demonstrates how PERFORM works. The program executes as follows:

1. Control starts in paragraph LevelOne, and the message “Starting to run program” is displayed.
2. When PERFORM LevelTwo is executed, control is passed to LevelTwo and the statements in that paragraph start to execute.
3. When PERFORM LevelThree is executed, control passes to LevelThree. When PERFORM LevelFour is executed, the message “Now in LevelFour” is displayed.
4. When the end of LevelFour is reached, *control returns to the statement following the PERFORM that invoked it*, and the message “Back in LevelThree” is displayed.

5. When LevelThree ends, control returns to the statement following the PERFORM, and the message “Back in LevelTwo” is displayed. Finally, when LevelTwo ends, control returns to paragraph LevelOne, and the “Back in LevelOne” message is displayed.
6. When STOP RUN is reached, the program stops.

Notice that the order of paragraph execution is independent of physical placement. For instance, although the paragraph LevelTwo comes after LevelThree and LevelFour in the program text, it is executed before them.

As I mentioned earlier, although PERFORMs can be nested, neither direct nor indirect recursion is allowed. So it would not be valid for paragraph LevelThree to contain the statement PERFORM LevelThree. This would be direct recursion. Neither would it be valid for LevelTwo to contain the statement PERFORM LevelOne. This would be indirect recursion because LevelOne contains the instruction PERFORM LevelTwo.

A frequent mistake made by beginning COBOL programmers is to forget to include STOP RUN at the end of the first paragraph. Example 6-5 shows the output that would be produced by Listing 6-1 if you forgot to include STOP RUN. From the output produced, try to follow the order of execution of the paragraphs.

Example 6-5. Output when STOP RUN is missing

```
> Starting to run program
> > Now in LevelTwo
> > > Now in LevelThree
> > > > Now in LevelFour
> > > Back in LevelThree
> > Back in LevelTwo
> Back in LevelOne
> > > > Now in LevelFour
> > > Now in LevelThree
> > > > Now in LevelFour
> > > Back in LevelThree
> > Now in LevelTwo
> > > Now in LevelThree
> > > > Now in LevelFour
> > > Back in LevelThree
> > Back in LevelTwo
```

Listing 6-1. Demonstrates How PERFORM Works

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing6-1.
AUTHOR. Michael Coughlan.
PROCEDURE DIVISION.
LevelOne.
    DISPLAY "> Starting to run program"
    PERFORM LevelTwo
    DISPLAY "> Back in LevelOne"
    STOP RUN.

LevelFour.
    DISPLAY "> > > > Now in LevelFour".

LevelThree.
```

Program Output

```
> Starting to run program
> > Now in LevelTwo
> > > Now in LevelThree
> > > > Now in LevelFour
> > > Back in LevelThree
> > Back in LevelTwo
> Back in LevelOne
```

```

DISPLAY "> > > Now in LevelThree"
PERFORM LevelFour
DISPLAY "> > > Back in LevelThree".

```

LevelTwo.

```

DISPLAY "> > Now in LevelTwo"
PERFORM LevelThree
DISPLAY "> > Back in LevelTwo".

```

PERFORM..THRU Dangers

One variation that exists in all the PERFORM formats is PERFORM. . THRU. When you use PERFORM. . THRU, all the code from StartblockName to EndblockName is treated as a single block of code. Because PERFORM. . THRU is generally regarded as a dangerous construct, it should only be used to PERFORM a paragraph and its immediately succeeding paragraph exit.

The problem with using PERFORM. . THRU to execute a number of paragraphs as one unit is that, in the maintenance phase of the program's life, another programmer may need to create a new paragraph and may physically place it in the middle of the PERFORM. . THRU block. Suddenly the program stops working correctly. Why? Because now PERFORM. . THRU is executing an additional, unintentional, paragraph.

Using PERFORM..THRU Correctly

The warning against using PERFORM. . THRU is not absolute, because when used correctly, PERFORM. . THRU can be very useful. In COBOL there is no way to break out a paragraph that is the target of a PERFORM. All the statements have to be executed until the end of the paragraph is reached. But sometimes, such as when you encounter an error condition, you do not want to execute the remaining statements in the paragraph. This is a circumstance when PERFORM. . THRU can be handy.

Consider the program outline in Example 6-6. In this example, control will not return to Begin until SumEarnings has ended, but you do not want to execute the remaining statements if an error is detected. The solution adopted is to hide the remaining statements behind an IF NoErrorFound statement. This might be an adequate solution if there were only one type of error; but if there is more than one type, then nested IF statements must be used. This quickly becomes unsightly and cumbersome.

Example 6-6. Using IFs to Skip Statements When an Error Is Detected

```

PROCEDURE DIVISION.
Begin.
    PERFORM SumEarnings
    STOP RUN.

SumEarnings.
    Statements
    Statements
    IF NoErrorFound
        Statements
        Statements
        IF NoErrorFound
            Statements
            Statements
            Statements
        END-IF
    END-IF.

```

In Example 6-7, `PERFORM..THRU` is used to deal with the problem in a more elegant manner. The dangers of `PERFORM..THRU` are ameliorated by having only two paragraphs in the target block and by using a name for the second paragraph that clearly indicates that it is bound to the first.

Example 6-7. Using `PERFORM..THRU` and `GO TO` to Skip Statements

PROCEDURE DIVISION

Begin.

```
PERFORM SumEarnings THRU SumEarningsExit
STOP RUN.
```

SumEarnings.

Statements

Statements

IF ErrorFound

```
GO TO SumEarningsExit
```

END-IF

Statements

Statements

IF ErrorFound

```
GO TO SumEarningsExit
```

END-IF

Statements

Statements

Statements

SumEarningsExit.

EXIT.

When the statement `PERFORM SumEarnings THRU SumEarningsExit` is executed, both paragraphs are performed as if they are one paragraph. The `GO TO` jumps to the exit paragraph, which, because the paragraphs are treated as one, is the end of the block of code. This technique allows you to skip over the code that should not be executed when an error is detected.

The `EXIT` statement in `SumEarningsExit` is a dummy statement. It has absolutely no effect on the flow of control. It is in the paragraph merely to conform to the rule that every paragraph must have one sentence. It has the status of a comment.

The `PERFORM..THRU` and `GO TO` constructs used in this example are dangerous. `GO TO` in particular is responsible for the “spaghetti code” that plagues many COBOL legacy systems. For this reason, you should use `PERFORM..THRU` and `GO TO` only as demonstrated in Example 6-7.

PERFORM..TIMES

`PERFORM..TIMES` (see Figure 6-2) is the second format of the `PERFORM` verb.

$$\text{PERFORM} \left[\text{StartblockName} \left\{ \begin{array}{l} \text{THRU} \\ \text{THROUGH} \end{array} \right\} \text{EndblockName} \right]$$

RepeatCount#il TIMES

[InlineBlock END - PERFORM]

Figure 6-2. Metalanguage for `PERFORM` format 2

This format has no real equivalent in most programming languages, perhaps because of its limited usefulness. It simply allows a block of code to be executed RepeatCount#i1 times before returning control to the statement following PERFORM.

Like the other formats of PERFORM, this format allows two types of execution:

- Out-of-line execution of a block of code
- Inline execution of a block of code

Example 6-8 gives some example PERFORM. .TIMES statements. These examples specify the RepeatCount using both literals and identifiers and show the inline and out-of-line variants of PERFORM.

Example 6-8. Using PERFORM. .TIMES

```
PERFORM PrintBlankLine 10 Times

MOVE 10 TO RepetitionCount
PERFORM DisplayName RepetitionCount TIMES

PERFORM 15 TIMES
  DISPLAY "Am I repeating myself?"
END-PERFORM
```

Inline Execution

Inline execution will be familiar to programmers who have used the iteration constructs (while, do/repeat, for) of most other programming languages. An inline PERFORM iteratively executes a block of code contained within the same paragraph as the PERFORM. That is, the loop body is inline with the rest of the paragraph code. The block of code to be executed starts at the keyword PERFORM and ends at the keyword END-PERFORM (see Listing 6-2).

Listing 6-2. Demonstrates PERFORM. .TIMES and Inline vs. Out-of-Line Execution

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing6-2.
AUTHOR. Michael Coughlan.
*> in-line and out-of-line PERFORM..TIMES

DATA DIVISION.
WORKING-STORAGE SECTION.
01 NumOfTimes PIC 9 VALUE 5.

PROCEDURE DIVISION.
Begin.
  DISPLAY "About to start in-line Perform"
  PERFORM 4 TIMES
  DISPLAY "> > > In-line Perform"
  END-PERFORM
  DISPLAY "End of in-line Perform"

  DISPLAY "About to start out-of-line Perform"
  PERFORM OutOfLineCode NumOfTimes TIMES
  DISPLAY "End of out-of-line Perform"
  STOP RUN.

OutOfLineCode.
  DISPLAY "> > > > Out-of-line Perform".
```

Listing 6-2 Output

```
About to start in-line Perform
>>>> In-line Perform
>>>> In-line Perform
>>>> In-line Perform
>>>> In-line Perform
End of in-line Perform
About to start out-of-line Perform
>>>>> Out-of-line Perform
>>>>> Out-of-line Perform
>>>>> Out-of-line Perform
>>>>> Out-of-line Perform
>>>>> Out-of-line Perform
End of out-of-line Perform
```

■ **ANS 85** In-line PERFORMS were only introduced as part of the ANS 85 COBOL specification. In older legacy systems, the loop body is always out of line.

Out-of-Line Execution

In an out-of-line PERFORM, the loop body is a separate paragraph or section. This is the equivalent, in other languages, of having a procedure, function, or method invocation inside the loop body of a `while` or `for` construct.

When a loop is required, but only a few statements are involved, you should use an inline PERFORM. When a loop is required, and the loop body executes some specific task or function, out-of-line code should be used. The paragraph name chosen for the out-of-line code should identify the task or function of the code.

PERFORM..UNTIL

PERFORM..UNTIL (see Figure 6-3) is the third format of the PERFORM verb. This format implements both pre-test and post-test iteration in COBOL. It is the equivalent of Java's `while` and `do..while` or Pascal's `While` and `Repeat..Until` looping constructs.

$$\text{PERFORM} \left[\text{StartBlockName} \left\{ \begin{array}{l} \text{THRU} \\ \text{THROUGH} \end{array} \right\} \text{EndBlockName} \right] \left[\text{WITH TEST} \left\{ \begin{array}{l} \text{BEFORE} \\ \text{AFTER} \end{array} \right\} \right] \\ \text{UNTIL Condition} \\ \left[\text{InlineBlock END - PERFORM} \right]$$

Figure 6-3. Metalinguage for PERFORM format 3

Pre-test and post-test iteration structures seem to be strangely implemented in many languages. Some languages confuse *when* the test is done with *how* the terminating condition is tested (Pascal's `While` and `Repeat` structures, for example). In many languages, the test for how the loop terminates emphasizes what makes the loop keep going, rather than what makes it stop. Although this may make formal reasoning about the loop easier, it does not come across as an entirely natural way of framing the question. In your day-to-day life, you do not say, "Heat the water while the water is not boiled" or "Pour water into the cup while the cup is not full."

Pre-test and post-test looping constructs are one area where COBOL seems to have things right. Whether the loop is pre-test or post-test, it is separated from *how* the terminating condition is tested; and the test for termination emphasizes what makes the loop stop, rather than what makes it keep going. In COBOL you might write


```
PERFORM ProcessSalesFile WITH TEST BEFORE
    UNTIL EndOfSalesFile
```

or

```
PERFORM GetNextCharacter WITH TEST AFTER
    UNTIL Letter = "s"
```

Notes on PERFORM..UNTIL

If you use the `WITH TEST BEFORE` phrase, `PERFORM` behaves like a `while` loop and the condition is tested before the loop body is entered. If you use the `WITH TEST AFTER` phrase, `PERFORM` behaves like a `do..while` loop and the condition is tested after the loop body is entered. The `WITH TEST BEFORE` phrase is the default and so is rarely explicitly stated.

How PERFORM..UNTIL Works

Although flowcharts are generally derided as a program-design tool, they are very useful for showing flow of control. The flowcharts in Figure 6-4 and Figure 6-5 show how the `WITH TEST BEFORE` and `WITH TEST AFTER` variations of `PERFORM..UNTIL` work.

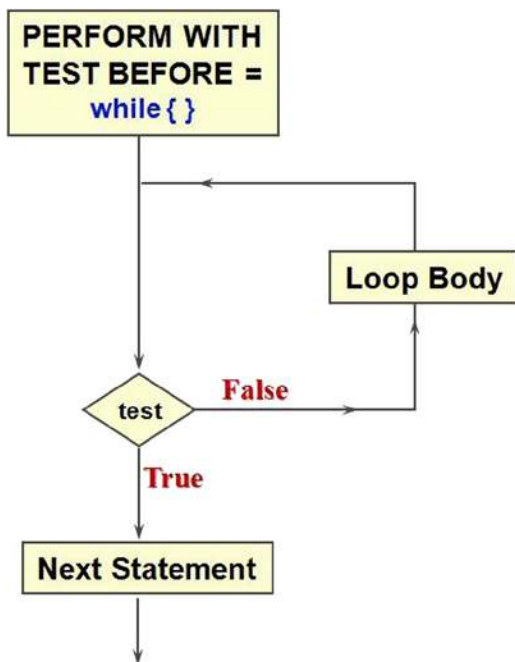


Figure 6-4. Pre-test loop

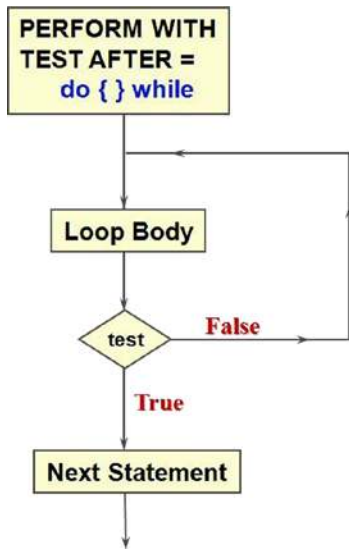


Figure 6-5. Post-test loop

Note that the terminating condition is checked only at the beginning of each iteration (PERFORM WITH TEST BEFORE) or at the end of each iteration (PERFORM WITH TEST AFTER). If the terminating condition is reached in the middle of the iteration, the rest of the loop body is still executed. The terminating condition cannot be checked until all the statements in the loop body have been executed. COBOL has no equivalent of the break command that allows control to break out of a loop without satisfying the terminating condition.

PERFORM..VARYING

PERFORM..VARYING (see Figure 6-6) is the final format of the PERFORM verb.

```

PERFORM [ StartBlockName [ { THRU } EndblockName ] ] [ WITH TEST { BEFORE } ]
        VARYING { Counter1#i } FROM { StartValue#il }
        BY Step Value#il UNTIL Condition1
        [ AFTER { Counter2#i } FROM { StartValue2#il } ] ...
        [ InLineBlock END - PERFORM ]
  
```

Figure 6-6. Metalanguage for PERFORM format 4

PERFORM. .VARYING is used to implement counting iteration. It is similar to the for construct in languages like Pascal, C, and Java. However, there are some differences:

- Most languages permit only one counting variable per loop instruction. COBOL allows up to three. Why only three? Before ANS 85 COBOL, tables were allowed only a maximum of three dimensions, and PERFORM. .VARYING was used to process them.
- Both pre-test and post-test variations of counting iteration are supported.
- The terminating condition does not have to involve the counting variable. For instance:

```
PERFORM CountRecordsInFile
      VARYING RecordCount FROM 1 BY 1 UNTIL EndOfFile
```

Notes on PERFORM..VARYING

The inline version of PERFORM. .VARYING cannot take the AFTER phrase. This means only one counter may be used with an inline PERFORM.

When you use more than one counter, the counter after the VARYING phrase is the most significant, that after the first AFTER phrase is the next most significant, and the last counter is the least significant. Just like the values in an odometer, the least-significant counter must go through all its values and reach its terminating condition before the next-most-significant counter can be incremented.

The item after the word FROM is the starting value of the counter (initialization). An index item is a special data item. Index items are examined when tables are discussed.

The item after the word BY is the step value of the counter (increment). It can be negative or positive. If you use a negative step value, the counter should be signed (PIC S99, for instance). When the iteration ends, the counters retain their terminating values.

The WITH TEST BEFORE phrase is the default and so is rarely specified.

How PERFORM..VARYING Works

Figure 6-7 shows the flowchart for PERFORM. .VARYING. .AFTER. Because there is no WITH TEST phrase, WITH TEST BEFORE is assumed. The table shows the number of times the loop body is processed and the value of each counter as displayed in the loop body. The terminating values of the counters are also given.

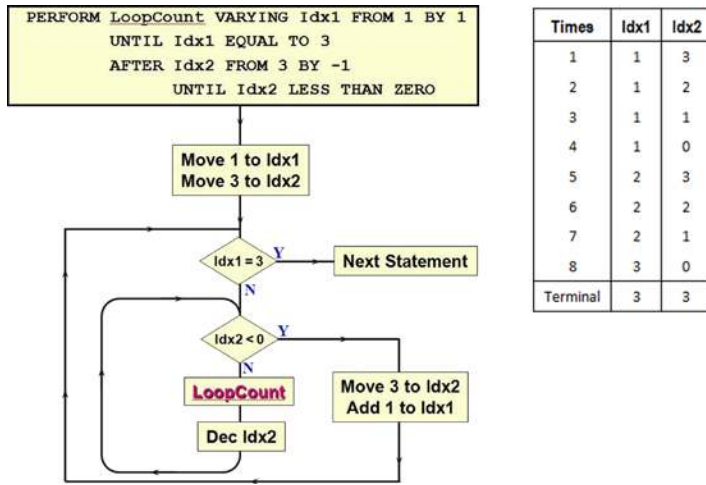


Figure 6-7. PERFORM..VARYING..AFTER

Note how the counter Idx2 must go through all its values and reach its terminating value before the Idx1 counter is incremented. An easy way to understand this is to think of it as an odometer. In an odometer, the units counter must go through all its values 0–9 before the tens counter is incremented.

Many of the example programs in this book provide a gentle preview of language elements to come. Listing 6-3 previews edited pictures. Examine the description of PrnRepCount provided by its picture, and review the output produced. Can you figure out how the edited picture works? Why do you think it was necessary to move RepCount to PrnRepCount? Why not just use the edited picture with RepCount?

Listing 6-3. Using PERFORM..VARYING for Counting

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing6-3.
AUTHOR. Michael Coughlan.

DATA DIVISION.
WORKING-STORAGE SECTION.
01 RepCount          PIC 9(4).
01 PrnRepCount      PIC Z,ZZ9.
01 NumberOfTimes    PIC 9(4) VALUE 1000.

PROCEDURE DIVISION.
Begin.
    PERFORM VARYING RepCount FROM 0 BY 50
        UNTIL RepCount = NumberOfTimes
        MOVE RepCount TO PrnRepCount
        DISPLAY "counting " PrnRepCount
    END-PERFORM
    MOVE RepCount TO PrnRepCount
    DISPLAY "If I have told you once, "
    DISPLAY "I've told you " PrnRepCount " times."

STOP RUN.
```

```
Output from Listing 6-3
counting 0
counting 50
counting 100
counting 150
counting 200
counting 250
counting 300
counting 350
counting 400
counting 450
counting 500
counting 550
counting 600
counting 650
counting 700
counting 750
counting 800
counting 850
counting 900
counting 950
If I have told you once,
I have told you 1,000 times.
```

■ **Answer** RepCount can't be an edited picture because an edited picture contains non-numeric characters (spaces, in this case), and you can't do computations with non-numeric characters. You have to do the computations with the numeric RepCount and then move it to the edited field PrnRepCount when you want it printed.

The explanation of the operation of `PERFORM. .VARYING. .AFTER` compares the construct to an odometer. The program in Listing 6-4 reinforces this idea by using `PERFORM. .VARYING` to emulate an odometer. The program uses both out-of-line and inline versions of `PERFORM. .VARYING`. Notice that when the inline variation is used, you cannot have an `AFTER` phrase but must instead use nested `PERFORM`s just as in Java or Pascal. Because the output is voluminous, only the final part is shown here.

Listing 6-4. Odometer Simulation

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing6-4.
AUTHOR. Michael Coughlan.
```

```
DATA DIVISION.
WORKING-STORAGE SECTION.
```

```
01 Counters.
    02 HundredsCount    PIC 99 VALUE ZEROS.
    02 TensCount        PIC 99 VALUE ZEROS.
    02 UnitsCount      PIC 99 VALUE ZEROS.
```

```
01 Odometer.
    02 PrnHundreds     PIC 9.
    02 FILLER          PIC X VALUE "-".
    02 PrnTens         PIC 9.
    02 FILLER          PIC X VALUE "-".
    02 PrnUnits        PIC 9.
```

```
PROCEDURE DIVISION.
```

```
Begin.
    DISPLAY "Using an out-of-line Perform".
    PERFORM CountMileage
        VARYING HundredsCount FROM 0 BY 1 UNTIL HundredsCount > 9
        AFTER TensCount FROM 0 BY 1 UNTIL TensCount > 9
        AFTER UnitsCount FROM 0 BY 1 UNTIL UnitsCount > 9

    DISPLAY "Now using in-line Perform"
    PERFORM VARYING HundredsCount FROM 0 BY 1 UNTIL HundredsCount > 9
        PERFORM VARYING TensCount FROM 0 BY 1 UNTIL TensCount > 9
            PERFORM VARYING UnitsCount FROM 0 BY 1 UNTIL UnitsCount > 9
                MOVE HundredsCount TO PrnHundreds
                MOVE TensCount TO PrnTens
                MOVE UnitsCount TO PrnUnits
                DISPLAY "In - " Odometer
            END-PERFORM
        END-PERFORM
    END-PERFORM
```

Listing 6-4 Partial Output

```
In - 9-8-0
In - 9-8-1
In - 9-8-2
In - 9-8-3
In - 9-8-4
In - 9-8-5
In - 9-8-6
In - 9-8-7
In - 9-8-8
In - 9-8-9
In - 9-9-0
In - 9-9-1
In - 9-9-2
In - 9-9-3
In - 9-9-4
In - 9-9-5
In - 9-9-6
In - 9-9-7
In - 9-9-8
In - 9-9-9
End of odometer simulation.
```

```

DISPLAY "End of odometer simulation."
STOP RUN.

```

```
CountMileage.
```

```

MOVE HundredsCount TO PrnHundreds
MOVE TensCount     TO PrnTens
MOVE UnitsCount    TO PrnUnits
DISPLAY "Out - " Odometer.

```

You might be wondering why the word FILLER is used in the description of Odometer. In COBOL, instead of having to make up dummy names, you can use FILLER when you need to reserve an area of storage but are never going to refer to it by name. For instance, in the data item Odometer, you want to separate the digits with hyphens, so you declare a character of storage for each hyphen and assign it the value -. But you will never refer to this part of Odometer by name. The hyphens only have significance as part of the group item.

Summary

This chapter examined the iteration constructs supported by COBOL. You learned the differences between COBOL's version of pre-test and post-test iteration and those of other languages. I contrasted counting iteration in its PERFORM. .VARYING. .AFTER implementation, which has both pre-test and post-test variations, with the offerings of other languages. You also explored the ability to create open subroutines in COBOL, and I provided a rationale for using them.

LANGUAGE KNOWLEDGE EXERCISE

Unleash your 2B pencil. It is exercise time again.

In the columns provided, write out what you would expect to be displayed on the computer screen if you ran the program shown in Listing 6-5. Use the Continue Run column to show what happens after the statement DISPLAY "STOP RUN should be here". has been executed.

Listing 6-5. Program to Test Your Knowledge of the PERFORM Verb

	Start Run	Continue Run
DATA DIVISION.		
IDENTIFICATION DIVISION.		
PROGRAM-ID. Listing6-5.		
AUTHOR. Michael Coughlan.		
DATA DIVISION.		
WORKING-STORAGE SECTION.		
01 LoopCount PIC 9 VALUE 1.		
01 LoopCount2 PIC 9 VALUE 1.		

PROCEDURE DIVISION.	Start Run	Continue Run
P1.		
DISPLAY "S-P1"		
PERFORM P2		
PERFORM P3		
MOVE 7 TO LoopCount		
PERFORM VARYING LoopCount		
FROM 1 BY 1 UNTIL LoopCount = 2		
DISPLAY "InLine - " LoopCount		
END-PERFORM		
DISPLAY "E-P1".		
DISPLAY "STOP RUN should be here".		
P2.		
DISPLAY "S-P2"		
PERFORM P5 WITH TEST BEFORE VARYING LoopCount		
FROM 1 BY 1 UNTIL LoopCount > 2		
DISPLAY "E-P2".		
P3.		
DISPLAY "S-P3"		
PERFORM P5		
PERFORM P6 3 TIMES		
DISPLAY "E-P3".		
P4.		
DISPLAY "P4-" LoopCount2		
ADD 1 TO LoopCount2.		
P5.		
DISPLAY "S-P5"		
DISPLAY LoopCount "-P5-" LoopCount2		
PERFORM P4 WITH TEST AFTER UNTIL LoopCount2 > 2		
DISPLAY "E-P5".		
P6.		
DISPLAY "P6".		

PROGRAMMING EXERCISE 1

In this programming exercise, you amend the program you wrote for the programming exercise in Chapter 5 (or amend the answer provided in Listing 5-11). That programming exercise required you to create a calculator program, but the program halted after only one calculation.

Amend the program so it runs until the user enters the letter *s* instead of an operator (+ - / *). The result of running the program is shown in the sample output in Example 6-9.

Example 6-9. Sample Run (User Input Shown in Bold)

```

Enter an arithmetic operator (+ - * /) (s to end) : *
Enter a single digit number - 4
Enter a single digit number - 5
Result is = 20.00
Enter an arithmetic operator (+ - * /) (s to end) : +
Enter a single digit number - 3
Enter a single digit number - 3
Result is = 06.00
Enter an arithmetic operator (+ - * /) (s to end) : -
Enter a single digit number - 5
Enter a single digit number - 3
Result is = -02.00
Enter an arithmetic operator (+ - * /) (s to end) : /
Enter a single digit number - 5
Enter a single digit number - 3
Result is = 00.60
Enter an arithmetic operator (+ - * /) (s to end) : s
End of calculations

```

PROGRAMMING EXERCISE 2

Write a program that gets the user's name and a countdown value from the keyboard and then displays a countdown before displaying the name that was entered. Use `PERFORM. .VARYING` to create the countdown.

The program should produce results similar to those shown in Example 6-10. For purposes of illustration, user input is in bold.

Example 6-10. Sample Run

```

Enter your name :- Mike Ryan
Enter the count-down start value :- 05
Getting ready to display your name.
05
04
03
02
01
Your name is Mike Ryan

```

LANGUAGE KNOWLEDGE EXERCISE—ANSWER

	Start Run	Continue Run
DATA DIVISION.		
IDENTIFICATION DIVISION.		
PROGRAM-ID. Listing6-5.		
AUTHOR. Michael Coughlan.		
DATA DIVISION.		
WORKING-STORAGE SECTION.		
01 LoopCount PIC 9 VALUE 1.	S-P1	S-P2
01 LoopCount2 PIC 9 VALUE 1.	S-P2	S-P5
	S-P5	1-P5-5
	1-P5-1	P4-5
	P4-1	E-P5
	P4-2	S-P5
	E-P5	2-P5-6
	S-P5	P4-6
	2-P5-3	E-P5
PROCEDURE DIVISION.		
P1.	P4-3	E-P2
DISPLAY "S-P1"	E-P5	S-P3
PERFORM P2	E-P2	S-P5
PERFORM P3	S-P3	3-P5-7
MOVE 7 TO LoopCount	S-P5	P4-7
PERFORM VARYING LoopCount	3-P5-4	E-P5
FROM 1 BY 1 UNTIL LoopCount = 2	P4-4	P6
DISPLAY "InLine - " LoopCount	E-P5	P6
END-PERFORM	P6	P6
DISPLAY "E-P1".	P6	E-P3
DISPLAY "STOP RUN should be here".	P6	P4-8
	E-P3	S-P5
P2.	InLine - 1	3-P5-9
DISPLAY "S-P2"	E-P1	P4-9
PERFORM P5 WITH TEST BEFORE VARYING LoopCount	STOP RUN should be here	E-P5
FROM 1 BY 1 UNTIL LoopCount > 2		P6
DISPLAY "E-P2".		
P3.		
DISPLAY "S-P3"		
PERFORM P5		
PERFORM P6 3 TIMES		
DISPLAY "E-P3".		
P4.		
DISPLAY "P4-" LoopCount2		
ADD 1 TO LoopCount2.		
P5.		
DISPLAY "S-P5"		
DISPLAY LoopCount "-P5-" LoopCount2		
PERFORM P4 WITH TEST AFTER UNTIL LoopCount2 > 2		
DISPLAY "E-P5".		
P6.		
DISPLAY "P6".		

PROGRAMMING EXERCISE 1—ANSWER

Listing 6-6. The Full Calculator Program

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing6-6.
AUTHOR. Michael Coughlan.
*> Continually calculates using two numbers and an operator
*> Ends when "s" is entered instead of an operator.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 Num1      PIC 9      VALUE ZERO.
01 Num2      PIC 9      VALUE ZERO.
01 Result    PIC --9.99 VALUE ZEROS.
01 Operator  PIC X      VALUE SPACE.
      88 ValidOperator    VALUES "*", "+", "-", "/", "s".
      88 EndOfCalculations VALUE "s".

PROCEDURE DIVISION.
Begin.
  PERFORM GetValidOperator UNTIL ValidOperator
  PERFORM UNTIL EndOfCalculations OR NOT ValidOperator
    PERFORM GetTwoNumbers
    EVALUATE Operator
      WHEN "+" ADD      Num2 TO  Num1 GIVING Result
      WHEN "-" SUBTRACT Num2 FROM Num1 GIVING Result
      WHEN "*" MULTIPLY Num1 BY  Num2 GIVING Result
      WHEN "/" DIVIDE   Num1 BY  Num2 GIVING Result ROUNDED
    END-EVALUATE
    DISPLAY "Result is = ", Result
    MOVE SPACE TO Operator
    PERFORM GetValidOperator UNTIL ValidOperator
  END-PERFORM
  DISPLAY "End of calculations"
  STOP RUN.

GetValidOperator.
  DISPLAY "Enter an arithmetic operator (+ - * /) (s to end) : "
    WITH NO ADVANCING
  ACCEPT Operator.

GetTwoNumbers.
  DISPLAY "Enter a single digit number - " WITH NO ADVANCING
  ACCEPT Num1

  DISPLAY "Enter a single digit number - " WITH NO ADVANCING
  ACCEPT Num2.

```

PROGRAMMING EXERCISE 2—ANSWER

Listing 6-7. Uses PERFORM. . VARYING to Display a Countdown from XX to 01

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing6-7.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 UserName      PIC X(20).
01 StartValue    PIC 99 VALUE ZEROS.
01 Countdown     PIC 99 VALUE ZEROS.

PROCEDURE DIVISION.
DisplayCountdown.
    DISPLAY "Enter your name :- " WITH NO ADVANCING
    ACCEPT UserName

    DISPLAY "Enter the count-down start value :- " WITH NO ADVANCING
    ACCEPT StartValue

    PERFORM VARYING Countdown FROM StartValue BY -1 UNTIL Countdown = ZERO
        DISPLAY Countdown
    END-PERFORM

    DISPLAY "Your name is " UserName
STOP RUN.
```

References

1. Tompkins HE. In defense of teaching structured COBOL as computer science (or, notes on being sage struck). ACM SIGPLAN Notices. 1983; 18(4): 86-94.
2. Baldwin, RR. A note on H.E. Tompkins's minimum-period COBOL style. ACM SIGPLAN Notices. 1987; 22(5): 27-31. <http://doi.acm.org/10.1145/25267.25273>
doi: 10.1145/25267.25273
3. Compiled and run at compileonline.com—Execute BASIC Program Online (Yabasic 2.9.15). www.compileonline.com/execute_basic_online.php



Introduction to Sequential Files

An important characteristic of a programming language designed for enterprise or business computing is that it should have an external, rather than an internal focus. It should concentrate on processing data held externally in files and databases rather than on manipulating data in memory through linked lists, trees, stacks, and other sophisticated data structures. Whereas in most programming languages the focus is internal, in COBOL it is external. A glance at the table of contents of any programming book on Java, C, Pascal, or Ruby emphasizes the point. In most cases, only one chapter, if that, is devoted to files. In this book, over a quarter of the book deals with files: it covers such topics as sequential files, relative files, indexed files, the SORT, the MERGE, the Report Writer, control breaks, and the file-update problem.

COBOL supports three file organizations: sequential files, relative files, and indexed files. Relative and indexed are direct-access file organizations that are discussed later in the book. They may be compared to a music CD on which you select the track you desire. Sequential files are like a music cassette: to listen to a particular song, you must go through all the preceding songs.

This chapter provides a gentle introduction to sequential files. I introduce some of the terminology used when referring to files and explain how sequential files are organized and processed. Every COBOL file organization requires entries in the INPUT-OUTPUT SECTION of the ENVIRONMENT DIVISION and the FILE SECTION of the DATA DIVISION, and these declarations are specified and explained. Because files require more sophisticated data definition than the elementary data items introduced in Chapter 3, this chapter also introduces hierarchically structured data definitions.

What Is a File?

A *file* is a repository for data that resides on backing storage (hard disk, magnetic tape, or CD-ROM). Nowadays, files are used to store a variety of different types of information such as programs, documents, spreadsheets, videos, sounds, pictures, and record-based data. In a record-based file, the data is organized into discrete packages of information. For instance, a customer record holds information about a customer such as their identifying number, name, address, date of birth, and gender. A customer file may contain thousands or even millions of instances of the customer record. In a picture file or music file, by way of contrast, the information is essentially an undifferentiated stream of bytes.

COBOL is often used in systems where the volume of data to be processed is large—not because the data is inherently voluminous, as it is in video or sound files, but because the same items of information have been recorded about a great many instances of the same object. Although COBOL can be used to process other kinds of data files, it is generally used only to process record-based files.

There are essentially two types of record-based file organization—serial files (COBOL calls these sequential files) and direct-access files:

- In a serial file, the records are organized and accessed serially (one after another).
- In a direct-access file, the records are organized in a manner that allows direct access to a particular record based on a key value. Unlike serial files, a record in a direct-access file can be accessed without having to read any of the preceding records.

Terminology

Before I discuss sequential files, I need to introduce some terminology:

- *Field*: An item of information that you are recording about an object (StockNumber, SupplierCode, DateOfBirth, ValueOfSale)
- *Record*: The collection of fields that record information about an object (for example, a CustomerRecord is a collection of fields recording information about a customer)
- *File*: A collection of one or more occurrences (instances) of a record template (structure)

Files, Records, and Fields

It is important to distinguish between the record *occurrence* (the instance or values of a record) and the record *template* (the structure of the record). Every record in a file has a different value but the same structure. For instance, the record template illustrated in Figure 7-1 describes the structure of each record occurrence (instance).

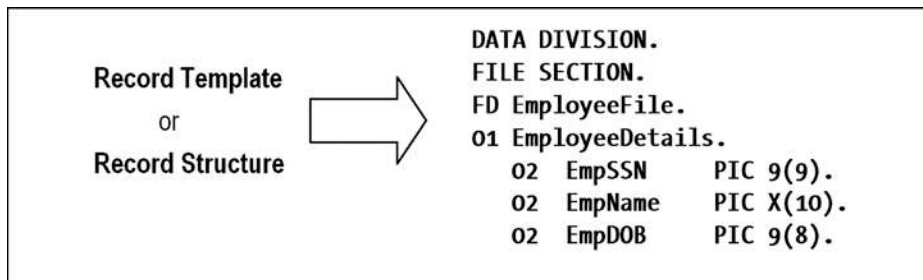


Figure 7-1. Record template/structure

The occurrences of the employee records (Figure 7-2) are the actual values in the file. There is only one record template, but there are many record instances.

Employee.DAT		
EmpSSN	EmpName	EmpDOB
097234562	COUGHLAN	10091961
109724567	RYAN	31121976
329534118	COFFEY	23061964
4794234580	' BRIEN	03111979
587312876	SMITH	12121976

Occurrences
(instances)

Arrows from the label "Occurrences (instances)" point to the EmpDOB column of each row in the table.

Figure 7-2. Record occurrences/instances

How Files Are Processed

Before a computer can process a piece of data, the data must be loaded into the computer's main memory (RAM). For instance, if you want to manipulate a picture in Photoshop or edit a file in Word, you have to load the data file into main memory (RAM), make the changes you want, and then save the file on to backing storage (disk).

Programmers in other languages, who may not be used to processing record-based data, often seek to load the entire file into memory as if it were an undifferentiated stream of bytes. For record-based data, this is inefficient and consumes unnecessary computing resources.

A record-based file may consist of millions, tens of millions, or even hundreds of millions of records and may require gigabytes of storage. For instance, suppose you want to keep some basic census information about all the people in the United States. Suppose that each record is about 1,000 characters/bytes (1KB) in size. If you estimate the population of the United States at 314 million, this gives you a size for the file of $1,000 \times 314,000,000 = 314,000,000,000$ bytes = 314GB. Most computers do not have 314GB of RAM available, and those that do are unlikely to be stand-alone machines running only your program. The likelihood is that your program is only one of many running on the machine at the same time. If your program is found to be using a substantial proportion of the available RAM, your manager is going to be less than grunted.

■ **Note** I once asked an M.Sc. student who was a proficient C++ programmer to write the C++ equivalent of a COBOL file processing program I had written. His first action was to load the entire file into memory. Doing this used an inordinate amount of memory and offered no benefit. He still had to read the file from disk, and the file size so overwhelmed the available RAM that the virtual memory manager had to keep paging to disk.

The data in a record-based file consists of discrete packages of information (records). The correct way to process such a file is to load a record into RAM, process it, and then load the next record. To store the record in memory and allow access to its individual fields, you must declare the record structure (Figure 7-1) in your program. The computer uses your description of the record (the record template) to set aside sufficient memory to store one instance of the record.

The memory allocated for storing a record is usually called a *record buffer*. To process a file, a program reads the records, one at a time, into the record buffer, as shown in Figure 7-3. The record buffer is the only connection between the program and the records in the file.

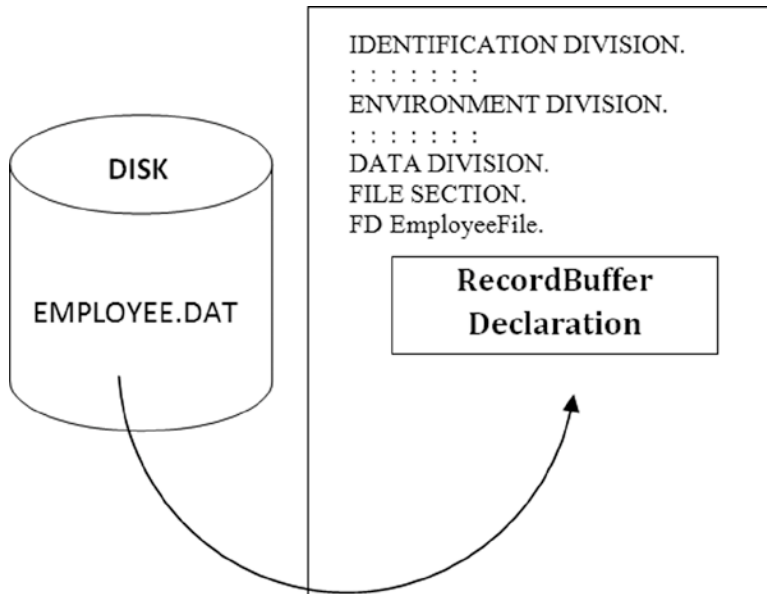


Figure 7-3. Reading records into the record buffer

Implications of Buffers

If your program processes more than one file, you have to describe a record buffer for each file. To process all the records in an *input* file, each record instance must be copied (read) from the file into the record buffer when required. To create an *output* file, each record must be placed in the record buffer and then transferred (written) to the file. To transfer a record from an input file to an output file, your program will have to do the following:

- Read the record into the input record buffer.
- Transfer it to the output record buffer.
- Write the data to the output file from the output record buffer.

This type of data transfer between buffers is common in COBOL programs.

File and Record Declarations

Suppose you want to create a file to hold information about your employees. What kind of information do you need to store about each employee?

One thing you need to store is the employee's Name. Each employee is also assigned a unique Social Security Number (SSN), so you need to store that as well. You also need to store the employee's date of birth and gender.

These fields are summarized here:

- Employee SSN
- Employee Name
- Employee DOB
- Employee Gender

■ **Note** This is for demonstration only. In reality, you would need to include far more items than these.

Creating a Record

To create a record buffer large enough to store one instance of the employee record you must decide on the type and size of each of the fields:

- Employee SSN is nine digits in size, so the data item to hold it is declared as PIC 9(9).
- To store Employee Name, you can assume that you require only 25 characters. So the data item can be declared as PIC X(25).
- Employee Date of Birth requires eight digits, so you can declare it as PIC 9(8).
- Employee Gender is represented by a one-letter character, where *m* is male and *f* is female, so it can be declared as PIC X.

These fields are individual data items, but they are collected together into a record structure as shown in Example 7-1.

Example 7-1. The EmployeeDetails Record Description/Template

```
01 EmployeeDetails.
02 EmpSSN          PIC 9(9).
02 EmpName        PIC X(25).
02 EmpDateOfBirth PIC 9(8).
02 EmpGender      PIC X.
```

This record description reserves the correct amount of storage for the record buffer, but it does not allow access to all the individual parts of the record that might be of interest.

For instance, the name is actually made up of the employee's surname and forename. And the date consists of four digits for the year, two digits for the month, and two digits for the day. To be able to access these fields individually, you need to declare the record as shown in Example 7-2.

Example 7-2. A More Granular Version of the EmployeeDetails Record

```
01 EmployeeDetails.
02 EmpSSN          PIC 9(9).
02 EmpName.
03 EmpSurname     PIC X(15).
03 EmpForename    PIC X(10).
02 EmpDateOfBirth.
03 EmpYOB        PIC 9(4).
03 EmpMOB        PIC 99.
03 EmpDOB        PIC 99.
02 EmpGender      PIC X.
```

Declaring the Record Buffer in Your Program

The record description in Example 7-2 sets aside sufficient storage to store one instance of the employee record. This area of storage is the record buffer; it's the only connection between the program and the records in the file. To process the file, you must read the records from the file, one at a time, into the record buffer. The record buffer

is connected to the file that resides on backing storage by declarations made in the FILE SECTION of the DATA DIVISION and the SELECT and ASSIGN clause of the ENVIRONMENT DIVISION.

A record template (description/buffer) for every file used in a program must be described in the FILE SECTION by means of an FD (file description) entry. The FD entry consists of the letters FD and an internal name that you assign to the file. The full file description for the employee file might be as shown in Example 7-3.

Example 7-3. The DATA DIVISION Declarations for the Employee File.

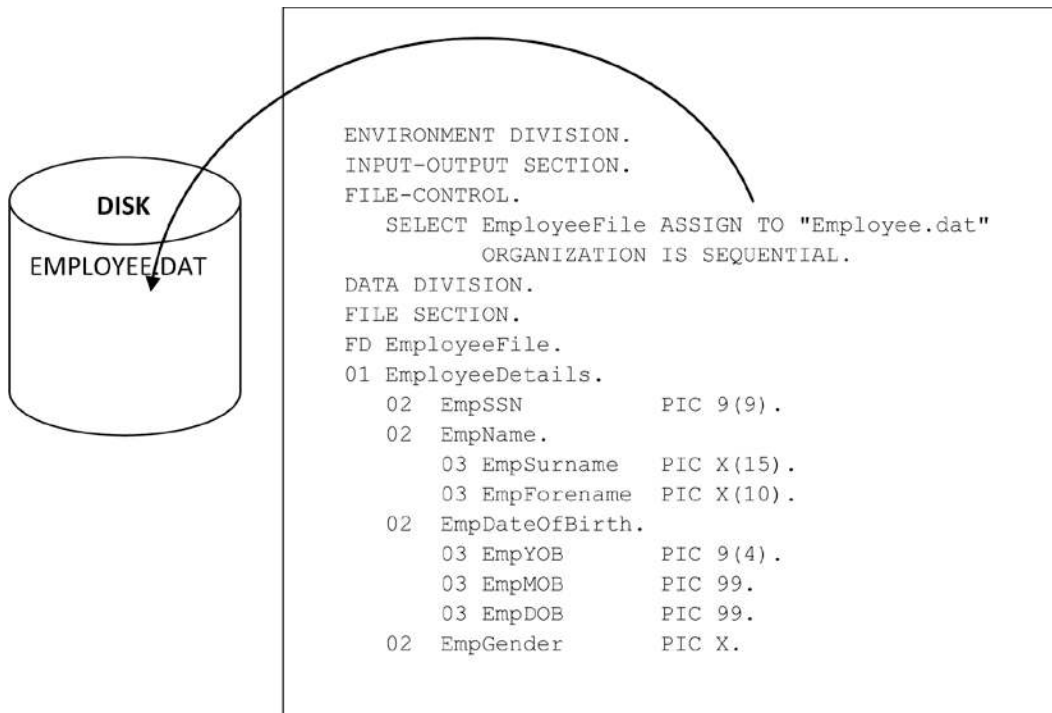
```
DATA DIVISION.
FILE SECTION.
FD EmployeeFile.
01 EmployeeDetails.
    02 EmpSSN          PIC 9(9).
    02 EmpName.
        03 EmpSurname PIC X(15).
        03 EmpForename PIC X(10).
    02 EmpDateOfBirth.
        03 EmpYOB      PIC 9(4).
        03 EmpMOB      PIC 99.
        03 EmpDOB      PIC 99.
    02 EmpGender       PIC X.
```

In this example, the name `EmployeeFile` has been assigned as the internal name for the file. This name is then used in the program for file operations such as these:

```
OPEN INPUT EmployeeFile
READ EmployeeFile
CLOSE EmployeeFile
```

The SELECT and ASSIGN Clause

Although you are going to refer to the employee file as `EmployeeFile` in the program, the actual name of the file on disk is `Employee.dat`. To connect the name used in the program to the file's actual name on backing storage, you require entries in the SELECT and ASSIGN clause of the FILE-CONTROL paragraph, in the INPUT-OUTPUT SECTION of the ENVIRONMENT DIVISION. As shown in Example 7-4, the SELECT and ASSIGN clause allows you to specify that an internal file name is to be connected to an external data resource. It also lets you specify how the file is organized. In the case of a sequential file, you specify that the file organization is sequential. Sequential files are ordinary text files such as you might create with a text editor.

Example 7-4. Using SELECT and ASSIGN

SELECT and ASSIGN Syntax

Here is the SELECT and ASSIGN syntax:

```

SELECT InternalFileName
    ASSIGN TO ExternalFileSpecification
    [ [ORGANIZATION IS ] SEQUENTIAL ]

```

■ **Note** The SELECT and ASSIGN clause has far more entries (even for sequential files) than those shown here. I deal with these entries in this book as you require them.

As illustrated by the examples in Example 7-5, ExternalFileSpecification can be either an identifier or a literal. The identifier or literal can consist of a simple file name or a full or partial file specification. If you use a simple file name, the drive and directory where the program is running are assumed.

When you use a literal, the file specification is hard-coded into the program; but if you want to specify the name of a file when you run the program, you can use an identifier. If an identifier is used, you must move the actual file specification into the identifier before the file is opened.

Example 7-5. Some Example SELECT and ASSIGN Declarations

```

SELECT EmployeeFile
    ASSIGN TO "D:\Cobol\ExampleProgs\Employee.Dat"
    ORGANIZATION IS SEQUENTIAL.

SELECT EmployeeFile
    ASSIGN TO "Employee.Dat"
    ORGANIZATION IS SEQUENTIAL.

SELECT EmployeeFile
    ASSIGN TO EmployeeFileName
    ORGANIZATION IS SEQUENTIAL.
: : : : : : : : : : :
MOVE "C:\datafiles\Employee.dat" TO EmployeeFileName
OPEN INPUT EmployeeFile

```

EXTENDED SELECT AND ASSIGN

I mentioned that sequential files are ordinary text files such as might be created with a text editor. This is not entirely true. A text editor appends the Carriage Return (CR) and Line Feed (LF) characters to each line of text. If you specify `ORGANIZATION IS SEQUENTIAL` and create your test data as lines of text in an ordinary text editor, these extra characters will be counted, and this will throw your records off by two characters each time you read a new record. For this reason, some vendors have extended `SELECT` and `ASSIGN` to allow these line-terminating characters to be either ignored or included. For instance, in Micro Focus COBOL, the metalanguage for the `SELECT` and `ASSIGN` is

```

SELECT InternalFileName
    ASSIGN TO ExternalFileSpecification
    [ ORGANIZATION IS ] [ LINE SEQUENTIAL
                        | RECORD SEQUENTIAL ] ]

```

Here `LINE SEQUENTIAL` means the CR and LF characters are not considered part of the record, and `RECORD SEQUENTIAL` means they are (same as the standard `SEQUENTIAL`).

Because it is very convenient to be able to use an ordinary text editor to create test data files, I use the Micro Focus `LINE SEQUENTIAL` extension in the example programs.

Processing Sequential Files

Unlike direct-access files, sequential files are uncomplicated both in organization and in processing. To write programs that process sequential files, you only need to know four new verbs: `OPEN`, `CLOSE`, `READ`, and `WRITE`.

The OPEN Statement

Before your program can access the data in an input file or place data in an output file, you must make the file available to the program by OPENing it. When you open a file, you have to indicate how you intend to use it (INPUT, OUTPUT, EXTEND) so the system can manage the file correctly:

$$\text{OPEN } \left. \begin{array}{l} \boxed{\text{INPUT}} \\ \boxed{\text{OUTPUT}} \\ \boxed{\text{EXTEND}} \end{array} \right\} \text{InternalFileName ...}$$

Opening a file *does not* transfer any data to the record buffer; it simply provides access.

Notes on the OPEN Statement

When a file is opened for INPUT or EXTEND, the file must exist or the OPEN will fail.

When a file is opened for INPUT, the Next Record Pointer is positioned at the beginning of the file. The Next Record Pointer is conceptual; it points to the position in the file where the file system will get or put the next record.

When the file is opened for EXTEND, the Next Record Pointer is positioned after the last record in the file. This allows records to be appended to the file.

When a file is opened for OUTPUT, it is created if it does not exist, and it is overwritten if it already exists.

■ **Bug Alert** Although the ellipses after `InternalFileName` in the metalanguage indicate that it is possible to open a number of files with one OPEN statement, it is not advisable to do so. If an error is detected on opening a file and only one OPEN statement has been used to open all the files, the system will not be able to indicate which particular file is causing the problem. If all the files are opened separately, it will.

The CLOSE Statement

The metalanguage for the CLOSE statement is fairly simple:

`CLOSE` InternalFilename ...

Notes

Before the program terminates, you must make sure the program closes all the open files. Failure to do so may result in some data not being written to the file or users being prevented from accessing the file.

Hard disk access is about a million times slower than RAM access (hard disk access times are measured in milliseconds, whereas RAM access is measured in nanoseconds: 1 millisecond = 1,000 microseconds = 1,000,000 nanoseconds), so data is often cached in memory until a sufficient quantity of records have been accumulated to make the write to disk worthwhile. If the file is not closed, it is possible that these cached records will never be sent to the file.

■ **Bug Alert** The ellipses in the CLOSE metalanguage indicate that you may specify more than one file name. I advised against this for the OPEN statement; but because very few errors affect the CLOSE statement, the same advice does not hold. For convenience, you can often choose to close multiple files in one CLOSE statement.

The READ Statement

Once the system has opened a file and made it available to the program, it is your responsibility to process it correctly. To process all the records in the file, the program has to transfer them, one record at a time, from the file to the file's record buffer. The READ is provided for this purpose:

```
READ InternalFilename [NEXT] RECORD
    [INTO Identifier]
    [AT END StatementBlock1]
    [NOT AT END StatementBlock2]
[END-READ]
```

The READ statement copies a record occurrence (instance) from the file on backing storage and places it in the record buffer defined for it.

Notes

When the READ attempts to read a record from the file and encounters the end of file marker, the AT END is triggered and StatementBlock1 is executed. If the NOT AT END clause is specified then StatementBlock2 is executed.

When the INTO clause is used, the data is read into the record buffer and then copied from there, to the Identifier, in one operation. This option creates two copies of the data: one in the record buffer and one in the Identifier. Using the INTO clause is equivalent to reading a record and then moving the contents of the record buffer to the Identifier.

■ **COBOL Detail** Because AT END is an optional element, you might have wondered how the end-of-file condition can be detected in its absence. COBOL has a special kind of exception handler for files called *declaratives*. When declaratives are specified for a file, any file error—including the end-of-file condition, causes the code in the declaratives to execute. Declaratives are an advanced topic that I address later in the book.

How READ Works

Listing 7-1 is a small program that simply reads the records in the employee file: `employee.dat`. The test data for the program is given in Figure 7-4. The effect on the data storage of running the program with this data is shown in Figure 7-5.

Listing 7-1. Reading the Employee File

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing7-1.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT EmployeeFile ASSIGN TO "Employee.dat"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD EmployeeFile.
01 EmployeeDetails.
```

```

88 EndOfEmployeeFile  VALUE HIGH-VALUES.
02 EmpSSN             PIC 9(9).
02 EmpName.
   03 EmpSurname      PIC X(15).
   03 EmpForename     PIC X(10).
02 EmpDateOfBirth.
   03 EmpYOB         PIC 9(4).
   03 EmpMOB         PIC 99.
   03 EmpDOB         PIC 99.
02 EmpGender         PIC X.

```

PROCEDURE DIVISION.

Begin.

```

OPEN INPUT EmployeeFile
READ EmployeeFile
  AT END SET EndOfEmployeeFile TO TRUE
END-READ
PERFORM UNTIL EndOfEmployeeFile
  READ EmployeeFile
  AT END SET EndOfEmployeeFile TO TRUE
  END-READ
END-PERFORM
CLOSE EmployeeFile
STOP RUN.

```

Employee.dat

097234562	COUGHLAN	MIKE	19610910m
109724567	RYAN	MARY	19761231f
329534118	COFFEY	MARTIN	19640623m

Figure 7-4. *Employee.dat* test data file

EmployeeDetails							
EmpSSN	EmpName		EmpDateOfBirth			EmpGender	
	EmpSurname	EmpForename	EmpYOB	EmpMOB	EmpDOB		
Read1	097234562	COUGHLAN	MIKE	1961	09	10	m
Read2	109724567	RYAN	MARY	1976	12	31	f
Read3	329534118	COFFEY	MARTIN	1964	06	23	m
Read4	*****	*****	*****	****	**	**	*

Figure 7-5. *Effect on data storage of reading each record in the file*

The effect on the data storage each time the READ is executed is shown in Figure 7-5:

- Read1 shows the effect of reading the first record. When the record is read from `Employee.dat`, it is copied into the `EmployeeDetails` area of storage as shown.
- Read2 and Read3 show the results of reading the second and third records.
- Read4 shows what happens when an attempt to read a fourth record is made. Because there is no fourth record, the `AT END` activates and the condition name `EndOfEmployeeFile` is set to `TRUE`. This condition name is defined on the whole record, and as a result the whole record is filled with `HIGH-VALUES` (represented here as the `◆` symbol).

■ **Note** Because of space constraints in this book, the various pieces of test data given obviously are not comprehensive enough to test any of the programs adequately. The test data is provided for the purposes of illustration only. You should create your own, more comprehensive test data if you want to test the programs.

Of course, this program does not do anything practical. It reads the file but doesn't do anything with the records it reads. Listing 7-2 tweaks the program a little so that it displays the name and date of birth of each employee in the file. Notice that I have chosen not to display the data items in the same order they are in in the record. The employee name is displayed in forename-surname order, and the date of birth is displayed in the standard U.S. order (month, day, year).

Listing 7-2. Reading the Employee File and Displaying the Records

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing7-2.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT EmployeeFile ASSIGN TO "Employee.dat"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD EmployeeFile.
01 EmployeeDetails.
    88 EndOfEmployeeFile VALUE HIGH-VALUES.
    02 EmpSSN PIC 9(9).
    02 EmpName.
        03 EmpSurname PIC X(15).
        03 EmpForename PIC X(10).
    02 EmpDateOfBirth.
        03 EmpYOB PIC 9(4).
        03 EmpMOB PIC 99.
        03 EmpDOB PIC 99.
    02 EmpGender PIC X.
```

Listing 7-2 Output

MIKE	COUGHLAN	- 09/10/1961
MARY	RYAN	- 12/31/1976
MARTIN	COFFEY	- 06/23/1964

PROCEDURE DIVISION.

Begin.

```

OPEN INPUT EmployeeFile
READ EmployeeFile
  AT END SET EndOfEmployeeFile TO TRUE
END-READ
PERFORM UNTIL EndOfEmployeeFile
  DISPLAY EmpForename SPACE EmpSurname " - "
    EmpMOB "/" EmpDOB "/" EmpYOB
  READ EmployeeFile
  AT END SET EndOfEmployeeFile TO TRUE
END-READ
END-PERFORM
CLOSE EmployeeFile
STOP RUN.
```

The WRITE Statement

The WRITE statement is used to copy data from the record buffer (RAM) to the file on backing storage (tape, disk, or CD-ROM). To write data to a file, the data must be moved to the record buffer (declared in the file's FD entry), and then the WRITE statement is used to send the contents of the record buffer to the file:

WRITE RecordName [FROM Identifier]

$$\left[\left. \left. \left. \left. \begin{array}{l} \text{BEFORE} \\ \text{AFTER} \end{array} \right\} \text{ADVANCING} \left. \left. \left. \begin{array}{l} \text{AdvanceNum} \left[\begin{array}{l} \text{LINE} \\ \text{LINES} \end{array} \right] \\ \text{MnemonicName} \\ \text{PAGE} \end{array} \right\} \right\} \right\} \right]$$

When WRITE .. FROM is used, the data contained in the Identifier is copied into the record buffer and is then written to the file. WRITE .. FROM is the equivalent of a MOVE Identifier TO RecordName statement followed by a WRITE RecordName statement.

■ **Note** The full metalanguage for the sequential-file version of WRITE statement is given here, but I postpone discussion of the ADVANCING clause until later in the book. This clause is used when writing print files and is a bit more complicated than it appears on the surface. It is best discussed when considering files with multiple record types.

Write a Record, Read a File

You probably noticed that the metalanguage for the READ and WRITE statements indicates that while you read a file, you write a record. You may have wondered why there is this difference.

So far, you have only seen files that contain one type of record. In the employee file, for example, there is only one type of employee record. But a file may contain a number of different types of record. For instance, if you wanted to update the employee file, you might have a file of transaction records containing both Employee Insertion records and Employee Deletion records. Although an Insertion record would have to contain all the fields in the employee record, a Deletion record would only need the Employee SSN.

The reason you *read a file*, not a record, is that until the record is in the buffer you cannot tell what type of record it is. You have to read the file and then look at the data in the buffer to see what type of record has been supplied. It is your responsibility to discover what type of record has been read into the buffer and then to take the appropriate actions.

The reason you *write a record* instead of a file is that when the output file will contain multiple types of record, you have to specify which record type you want to write to the file.

How WRITE works

Suppose you want to add some records to the end of the employee file. To do so, you use this statement:

```
OPEN EXTEND EmployeeFile
```

This tells the system that you are going to add records to the end of the file. If you opened the file for OUTPUT, then `Employee.dat` would be replaced (overwritten) with a new version of the employee file.

To write a record to the file, you place the data in the `EmployeeDetails` record buffer and then use the following statement:

```
WRITE EmployeeDetails
```

The example program fragment in Example 7-6 writes two records to the end of the employee file. Figure 7-6 shows the interaction between the data in memory and the file on backing storage. The first MOVE statement places the record data in the record buffer, and the WRITE statement (`Write1`) copies it to the file. The second MOVE places the second record in the record buffer, and the WRITE (`Write2`) copies it to the file.

Example 7-6. Writing Records to the End of a Sequential File

```
PROCEDURE DIVISION.
```

```
Begin.
```

```
OPEN EXTEND EmployeeFile
```

```
MOVE "456867564NEWGIRL      MARTHA    19820712f"
    TO EmployeeDetails
```

```
WRITE EmployeeDetails
```

```
MOVE "622842649NEWBOY      MALCOLM  19810925m"
    TO EmployeeDetails
```

```
WRITE EmployeeDetails
```

```
CLOSE EmployeeFile
```

```
STOP RUN.
```



```
02  EmpDateOfBirth.  
    03  EmpYOB          PIC 9(4).  
    03  EmpMOB          PIC 99.  
    03  EmpDOB          PIC 99.  
02  EmpGender          PIC X.
```

PROCEDURE DIVISION.

Begin.

```
OPEN EXTEND EmployeeFile  
PERFORM GetEmployeeData  
PERFORM UNTIL EmployeeDetails = SPACES  
    WRITE EmployeeDetails  
    PERFORM GetEmployeeData  
END-PERFORM  
CLOSE EmployeeFile  
DISPLAY "***** End of Input *****"
```

```
OPEN INPUT EmployeeFile  
READ EmployeeFile  
    AT END SET EndOfEmployeeFile TO TRUE  
END-READ  
PERFORM UNTIL EndOfEmployeeFile  
    DISPLAY EmployeeDetails  
    READ EmployeeFile  
    AT END SET EndOfEmployeeFile TO TRUE  
END-READ  
END-PERFORM  
CLOSE EmployeeFile  
STOP RUN.
```

GetEmployeeData.

```
DISPLAY "nnnnnnnnSSSSSSSSSSSSFFFFFFFFFyyyMMddG"  
ACCEPT EmployeeDetails.
```

Summary

This chapter provided a gentle introduction to sequential files. You learned how to declare the record buffer for a file. You learned how to connect the file's internal file name with its name and location on the backing storage device. You saw how to READ records from a file and how to WRITE them to a file.

Although this chapter is a good start, there is still much more to discover about sequential files. Although I touched on the idea of files that contain multiple record types, I did not explore the full ramifications of this concept; nor did I discuss the true magic of the FILE SECTION. I mentioned print files, but I did not explore the relevant options in the metalanguage; nor did I discuss how to create a print file. I also have not mentioned or discussed the idea of variable-length records. I discussed some of the mechanics of using sequential files in this chapter, but I did not discuss sequential-file processing issues. The chapters that follow explore some of those issues by examining the control-break and file-update problems.

LANGUAGE KNOWLEDGE EXERCISE

Unsheathe your 2B pencil. It is exercise time again.

1. Locate errors in these FILE SECTION entries.

(a)

```
FD SalesFile.
01 SalesRecord          PIC X(13).
02 SalesmanNumber      PIC 9(7).
02 SaleValue           PIC 9(5)V99.
```

(b)

```
FD TemperatureFile.
01 DayRecord.
05 MonthNumber         PIC 99
05 MaxTemp             PIC 999
05 MinTemp             PIC 999
06 AverageTemp        PIC 999
```

(c)

```
FD StudentFile
01 StudentRecord.
02 StudentName.        PIC X(20).
05 StudentInitials    PIC XX.
05 StudentSurname     PIC X(18).
02 StudentAddress     PIC X(65).
03 AddressLine1.     PIC X(10).
03 AddressLine2      PIC X(10).
03 AddressLine3      PIC X(10).
02 StudentGPA.
05 Year1GPA
10 Sem1GPA            PIC 9V99.
10 Sem2GPA            PIC 9V99.
05 Year2GPA.
10 Sem1GPA            PIC 9V99.
10 Sem2GPA            PIC 9V99.
05 Year3GPA
10 Sem1GPA            PIC 9V99.
10 Sem2GPA            PIC 9V99.
```

2. Complete the SELECT and ASSIGN clause for a sequential file called `Stock.dat` in the directory `C:\COBOL-Data\`. The record buffer for the file has this description:

```
FD StockFile.  
01 StockRec.  
   02 StockNumber      PIC 9(5)  
   02 ManfNumber       PIC 9(4)  
   02 QtyInStock       PIC 9(6)  
   02 ReorderLevel     PIC 9(6)  
   02 ReorderQty       PIC 9(6).
```

Write your answer here:

```
IDENTIFICATION DIVISION.  
PROGRAM-ID. Exercise7-2.  
ENVIRONMENT DIVISION.
```

PROGRAMMING EXERCISE 1

A StockFile holds details of gadgets sold by the Gadget Shop (GadgetShop.Com). The StockFile is a sequential file sorted in ascending GadgetId order. It is named GadgetStock.dat. Each record has the following description:

Field	Type	Length	Value
GadgetID	N	6	000001-999999
GadgetName	X	30	-
QtyInStock	N	4	0000-9999
Price	N	6	0000.00-9999.99

Write a program to process the data in the StockFile and, for each record, display the item's GadgetName and the total value of the quantity in stock ($\text{QtyInStock} * \text{Price}$). When the StockFile has ended, display the total value of all the stock.

Example Test Data

```
123456SoundDisk MP3 Player 4GB      0650003095
234567BioLite Camp Stove           0057029550
345678Collapsible Kettle - Green   0155002590
456789Digital Measuring Jug        0325000895
567890MicroLite LED Torch          0512000745
678901Pocket Sized Fishing Rod     0055001799
```

Note: Place the test data in the data file as one long string.

Example Run

```
SoundDisk MP3 Player 4GB      $20,117.50
BioLite Camp Stove           $16,843.50
Collapsible Kettle - Green   $4,014.50
Digital Measuring Jug        $2,908.75
MicroLite LED Torch          $3,814.40
Pocket Sized Fishing Rod     $989.45
      Stock Total:          $48,688.10
```

PROGRAMMING EXERCISE 2

Amend the program you wrote for exercise 1 so that it adds the following two records to the end of the file. Then display the stock report as before:

```
313245Spy Pen - HD Video Camera      0125003099
593486Scout Cash Capsule - Red       1234000745
```

The records in the `StockFile` are held in ascending `GadgetID` order. When you add these two records to the file, the records will be out of order. Without sorting the `StockFile` after the update, how could you update the file so that the ordering of the records was maintained?

Example Run

SoundDisk MP3 Player 4GB	\$20,117.50
BioLite Camp Stove	\$16,843.50
Collapsible Kettle - Green	\$4,014.50
Digital Measuring Jug	\$2,908.75
MicroLite LED Torch	\$3,814.40
Pocket Sized Fishing Rod	\$989.45
Spy Pen - HD Video Camera	\$3,873.75
Scout Cash Capsule - Red	\$9,193.30
Stock Total:	\$61,755.15

LANGUAGE KNOWLEDGE EXERCISES: ANSWERS

Unsheath your 2B pencil. It is exercise time again.

1. Locate errors in these `FILE SECTION` entries.

1. Locate errors in these FILE SECTION entries.

(a)

```

FD SalesFile.
01 SalesRecord
02 SalesmanNumber
02 SaleValue

```

PIC X(13).
PIC 9(7).
PIC 9(5)V99.

A group item should not have a picture clause.

(b)

```

FD TemperatureFile.
01 DayRecord.
05 MonthNumber PIC 99
05 MaxTemp PIC 999
05 MinTemp PIC 999
06 AverageTemp PIC 999

```

These data items should have periods (full stops).

This level number indicates that AverageTemp is subordinate to MinTemp but it is at the same level. Should be 05.

(c)

```

FD StudentFile
01 StudentRecord.
02 StudentName.
03 StudentInitials PIC XX.
03 StudentSurname PIC X(19).
02 StudentAddress.
03 AddressLine1 PIC X(10).
03 AddressLine2 PIC X(10).
03 AddressLine3 PIC X(10).
02 StudentGPA.
03 Year1GPA.
04 Sem1GPA PIC 9V99.
04 Sem2GPA PIC 9V99.
03 Year2GPA.
04 Sem1GPA PIC 9V99.
04 Sem2GPA PIC 9V99.
03 Year3GPA.
04 Sem1GPA PIC 9V99.
04 Sem2GPA PIC 9V99.

```

For (c), I have corrected the problems with StudentRecords instead of just pointing them out. StudentName is a group item. It should not have had a picture clause.

StudentAddress should not have a picture clause. It is a group item.

AddressLine1 should not have been followed by a period.

AddressLine2 should have been followed by a period.

The 05 level number was not an error but 03 makes more sense.

Year1GPA should have a period.

Note how much easier it is to understand the record structure when proper indentation and numbering is used.

Data items *can* have the same name as long as they can be qualified to make them unique. For instance
 DISPLAY Sem1GPA OF Year1GPA
 DISPLAY Sem1GPA OF Year2GPA
 DISPLAY Sem1GPA OF Year2GPA
 The clumsiness of the COBOL qualification method is what makes us try to choose unique names.

2. Complete the SELECT and ASSIGN clause for a sequential file called `Stock.dat` in the directory `C:\COBOL-Data\`. The record buffer for the file has this description:

```
FD StockFile.
01 StockRec.
   02 StockNumber      PIC 9(5)
   02 ManfNumber       PIC 9(4)
   02 QtyInStock       PIC 9(6)
   02 ReorderLevel    PIC 9(6)
   02 ReorderQty      PIC 9(6).
```

Write your answer here:

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Exercise7-2.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT StockFile ASSIGN TO "C:\COBOL-Data\Stock.dat"
    ORGANIZATION IS SEQUENTIAL.
```

PROGRAMMING EXERCISE 1: ANSWER

A `StockFile` holds details of gadgets sold by the Gadget Shop (GadgetShop.Com). The `StockFile` is a sequential file sorted in ascending `GadgetId` order. It is named `GadgetStock.dat`. Each record has the following description.

Field	Type	Length	Value
GadgetID	N	6	000001-999999
GadgetName	X	30	-
QtyInStock	N	4	0000-9999
Price	N	6	0000.00-9999.99

Write a program to process the data in the `StockFile` and, for each record, display the item's `GadgetName` and the total value of the quantity in stock (`QtyInStock * Price`). When the `StockFile` has ended, display the total value of all the stock.

Example Test Data

```
123456SoundDisk MP3 Player 4GB      0650003095
234567BioLite Camp Stove           0057029550
345678Collapsible Kettle - Green   0155002590
456789Digital Measuring Jug        0325000895
567890MicroLite LED Torch          0512000745
678901Pocket Sized Fishing Rod     0055001799
```

Note: Place the test data in the data file as one long string.

Example Run

SoundDisk MP3 Player 4GB	\$20,117.50
Biolite Camp Stove	\$16,843.50
Collapsible Kettle - Green	\$4,014.50
Digital Measuring Jug	\$2,908.75
MicroLite LED Torch	\$3,814.40
Pocket Sized Fishing Rod	\$989.45
Stock Total:	\$48,688.10

Listing 7-4. Displays the Value of the Gadgets in Stock

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing7-4.
AUTHOR. Michael Coughlan

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT GadgetStockFile ASSIGN TO "input.txt"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD GadgetStockFile.
01 StockRec.
    88 EndOfStockFile      VALUE HIGH-VALUES.
    02 GadgetID            PIC 9(6).
    02 GadgetName         PIC X(30).
    02 QtyInStock         PIC 9(4).
    02 Price              PIC 9(4)V99.

WORKING-STORAGE SECTION.
01 PrnStockValue.
    02 PrnGadgetName     PIC X(30).
    02 FILLER            PIC XX VALUE SPACES.
    02 PrnValue          PIC $$$,$$9.99.

01 PrnFinalStockTotal.
    02 FILLER            PIC X(16) VALUE SPACES.
    02 FILLER            PIC X(16) VALUE "Stock Total:".
    02 PrnFinalTotal     PIC $$$,$$9.99.

01 FinalStockTotal     PIC 9(6)V99.
01 StockValue         PIC 9(6)V99.
```

PROCEDURE DIVISION.

Begin.

```

OPEN INPUT GadgetStockFile
READ GadgetStockFile
  AT END SET EndOfStockFile TO TRUE
END-READ
PERFORM DisplayGadgetValues UNTIL EndOfStockFile
MOVE FinalStockTotal TO PrnFinalTotal
DISPLAY PrnFinalStockTotal
CLOSE GadgetStockFile
STOP RUN.

```

DisplayGadgetValues.

```

COMPUTE StockValue = Price * QtyInStock
ADD StockValue TO FinalStockTotal
MOVE GadgetName TO PrnGadgetName
MOVE StockValue TO PrnValue
DISPLAY PrnStockValue
READ GadgetStockFile
  AT END SET EndOfStockFile TO TRUE
END-READ.

```

PROGRAMMING EXERCISE 2: ANSWER

Amend the program you wrote for exercise 1 so that it adds the following two records to the end of the file. Then display the stock report as before:

```

313245Spy Pen - HD Video Camera      0125003099
593486Scout Cash Capsule - Red       1234000745

```

The records in the StockFile are held in ascending GadgetID order. When you add these two records to the file, the records will be out of order. Without sorting the StockFile after the update, how could you update the file so that the ordering of the records was maintained?

Example Run

SoundDisk MP3 Player 4GB	\$20,117.50
Biolite Camp Stove	\$16,843.50
Collapsible Kettle - Green	\$4,014.50
Digital Measuring Jug	\$2,908.75
MicroLite LED Torch	\$3,814.40
Pocket Sized Fishing Rod	\$989.45
Spy Pen - HD Video Camera	\$3,873.75
Scout Cash Capsule - Red	\$9,193.30
Stock Total:	\$61,755.15

Listing 7-5. Adds Two Records and Then Displays Stock Values Again

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing7-5.
AUTHOR. Michael Coughlan

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT GadgetStockFile ASSIGN TO "input.txt"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD GadgetStockFile.
01 StockRec.
    88 EndOfStockFile      VALUE HIGH-VALUES.
    02 GadgetID            PIC 9(6).
    02 GadgetName          PIC X(30).
    02 QtyInStock          PIC 9(4).
    02 Price                PIC 9(4)V99.

WORKING-STORAGE SECTION.
01 PrnStockValue.
    02 PrnGadgetName       PIC X(30).
    02 FILLER                PIC XX VALUE SPACES.
    02 PrnValue            PIC $$$,$$9.99.

01 PrnFinalStockTotal.
    02 FILLER                PIC X(16) VALUE SPACES.
    02 FILLER                PIC X(16) VALUE "Stock Total:".
    02 PrnFinalTotal        PIC $$$,$$9.99.

01 FinalStockTotal        PIC 9(6)V99.
01 StockValue              PIC 9(6)V99.

PROCEDURE DIVISION.
Begin.
    OPEN EXTEND GadgetStockFile
    MOVE "313245Spy Pen - HD Video Camera      0125003099"
        TO StockRec
    WRITE StockRec
    MOVE "593486Scout Cash Capsule - Red      1234000745"
        TO StockRec
    WRITE StockRec
    CLOSE GadgetStockFile

    OPEN INPUT GadgetStockFile
    READ GadgetStockFile
    AT END SET EndOfStockFile TO TRUE
END-READ

```

```
PERFORM DisplayGadgetValues UNTIL EndOfStockFile
MOVE FinalStockTotal TO PrnFinalTotal
DISPLAY PrnFinalStockTotal
CLOSE GadgetStockFile
STOP RUN.
```

DisplayGadgetValues.

```
COMPUTE StockValue = Price * QtyInStock
ADD StockValue TO FinalStockTotal
MOVE GadgetName TO PrnGadgetName
MOVE StockValue TO PrnValue
DISPLAY PrnStockValue
READ GadgetStockFile
    AT END SET EndOfStockFile TO TRUE
END-READ.
```

CHAPTER 8



Advanced Sequential Files

In the previous chapter, you saw how sequential files are declared, written, and read. In this chapter, you continue your exploration of sequential files by examining advanced issues such as multiple-record-type files, print files, and variable-length records.

The previous chapter dealt with sequential files that contained only fixed-length records of a single record type. This chapter shows how a file may have records of different lengths either because the file contains a number of different types of fixed-length records or because it contains variable-length records. The discussion of files that contain multiple record types also considers the implications of these multiple record types for the record buffer.

When the `WRITE` verb was introduced in the previous chapter, I ignored some of the metalanguage because it dealt with print files. This chapter addresses the issue of print files and shows how they are declared and used. I also discuss the problem caused by the different types of print lines that must be sent to a print file.

Files with Multiple Record Types

Quite often, complex data sets cannot store all their data in just one record type. In such cases, a single file contains more than one type of record. For instance, consider the following problem specification.

Problem Specification

A company has shops all over Ireland. Every night, a sequential file of cash register receipts is sent from each branch to the head office. These files are merged into a single, large, sequential file called the `ShopReceiptsFile`.

In the `ShopReceiptsFile`, there are two types of records:

- A `ShopDetails` record, used to record the `ShopId` and `ShopLocation`
- A `SaleReceipt` record, used to record the `ItemId`, `QtySold`, and `ItemCost` for each item sold

In the file, a single shop record precedes all the `SaleReceipt` records for a particular shop.

Write a program to process the `ShopReceiptsFile` and, for each shop in the file, produce a summary line that shows the `ShopId` of the shop and the total value of sales for that shop.

Implications of Files with Multiple Record Types

As you can see from the previous specification, the `ShopReceiptsFile` contains two different types of records. When a file contains different record types, the records will have different structures and, possibly, different lengths. In a specification, the different record types are usually represented as shown in Figure 8-1 and Figure 8-2. The `ShopDetails` record is 35 characters in size, but the `SaleReceipt` record is only 16 characters. For each shop in the file, there is one `ShopDetails` record but many `SaleReceipt` records.

ShopDetails

FieldName	Type	Size	Value
ShopId	X	5	-
ShopLocation	X	30	-

*Figure 8-1. ShopDetails description***SaleReceipt**

FieldName	Type	Size	Value
ItemId	X	8	-
QtySold	9	3	1–999
ItemCost	9	5	0.00–999.99

Figure 8-2. SaleReceipt description

The different types of records in the ShopReceiptsFile means you need more than one record description in the file's file description (FD) entry. Because record descriptions always begin with level 01, you must provide a 01-level description for each type of record in the file.

Example 8-1 shows the file description for the ShopReceiptsFile. What is not obvious from this description is that even though there are two record descriptions, only one area of memory is reserved for the record buffer, and it is only able to store a single record at a time. Because only one area of memory is reserved, both record descriptions map on to the same record buffer. The size of that record buffer is the size of the largest record.

Example 8-1. File Description for the ShopReceiptsFile

```
FILE SECTION.
FD ShopReceiptsFile.
01 ShopDetails.
   02 ShopId          PIC X(5).
   02 ShopLocation    PIC X(30).

01 SaleReceipt.
   02 ItemId          PIC X(8).
   02 QtySold         PIC 9(3).
   02 ItemCost        PIC 999V99.
```

This is the magic of the FILE SECTION. When, in the FILE SECTION, multiple records are defined in a file's FD entry, all the record descriptions share (map on to) the same area of memory, and all the record descriptions are current (live) at the same time.

Multiple Record Descriptions, One Record Buffer

When multiple records are described for the same FD entry, only a single area of storage (record buffer) is created (the size of the largest record). All the record descriptions map on to this single area of storage, and all the descriptions are current no matter which record is actually in the buffer. Obviously, though, even though both record descriptions are available, only one makes sense for the values in the buffer. For instance, Figure 8-3 is a graphical representation of the shared buffer for the `ShopReceiptsFile`, and the record currently in the buffer is a `SaleReceipt` record. If you execute the statement `DISPLAY ItemId`, the value `ABC12345` is displayed. If you execute `DISPLAY QtySold`, you get the value `003`. But because both record descriptions are current at the same time, you can also execute `DISPLAY ShopLocation`, which displays the nonsensical value `34500300399`. It is up to the programmer to know what type of record is in the buffer and to use only the record description that makes sense for those values. The question is, how can you know what type of record has been read into the buffer?

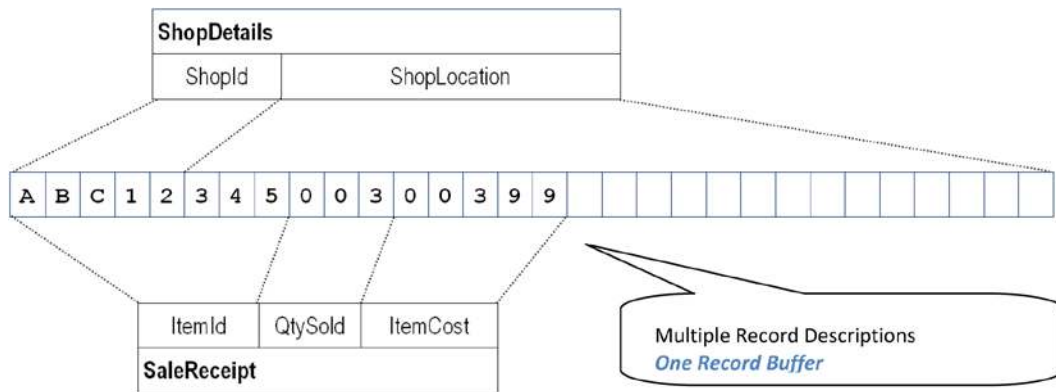


Figure 8-3. A graphical representation of the shared record buffer

The Type Code

When a record is read into a shared record buffer, it is your responsibility to discover what type of record has been read in and to refer only to the fields that make sense for that type of record. Looking at the record in Figure 8-3, you might wonder how you can discover what type of record had been read into the buffer. Sometimes you can determine the record type by looking for identifying characteristics that are unique to that type of record, such as a particular value or data type. However, generally it is not possible to establish reliably what type of record is in the buffer simply by examining the buffer values.

A special identifying data item called the *type code* is usually inserted into each record to allow you to distinguish between record types. The type code is usually one character in size and is the first field in each record, but its size and placement are merely conventions. The type code can be placed anywhere in the record and be of any size and any type.

The `ShopReceiptsFile` uses the character `H` to indicate the `ShopDetails` record (the header record) and `S` to indicate the `SaleReceipt` record (the sales record). To detect the type of record read into the buffer, you could use statements such as `IF TypeCode = "H"` or `IF TypeCode = "S"`. But this is COBOL. It offers a better way. You can define condition names to monitor the type code so that if it contains `H` the condition name `ShopHeader` is set to true, and if it contains `S` the condition name `ShopSale` is set to true. The record descriptions required to accommodate these changes for the `ShopReceiptsFile` are shown in Example 8-2.

Example 8-2. ShopReceiptsFile Record Descriptions with Type Code

```

FILE SECTION.
FD ShopReceiptsFile.
01 ShopDetails.
   02 TypeCode          PIC X.
   88 ShopHeader       VALUE "H".
   88 ShopSale         VALUE "S".
   02 ShopId           PIC X(5).
   02 ShopLocation     PIC X(30).

01 SaleReceipt.
   02 TypeCode          PIC X.
   02 ItemId           PIC X(8).
   02 QtySold          PIC 9(3).
   02 ItemCost         PIC 999V99.

```

A graphical representation of the new record descriptions is shown in Figure 8-4. In this case, there is a ShopDetails record in the buffer. Again, both record descriptions are current (live), but only the ShopDetails record description makes sense for the values in the buffer.

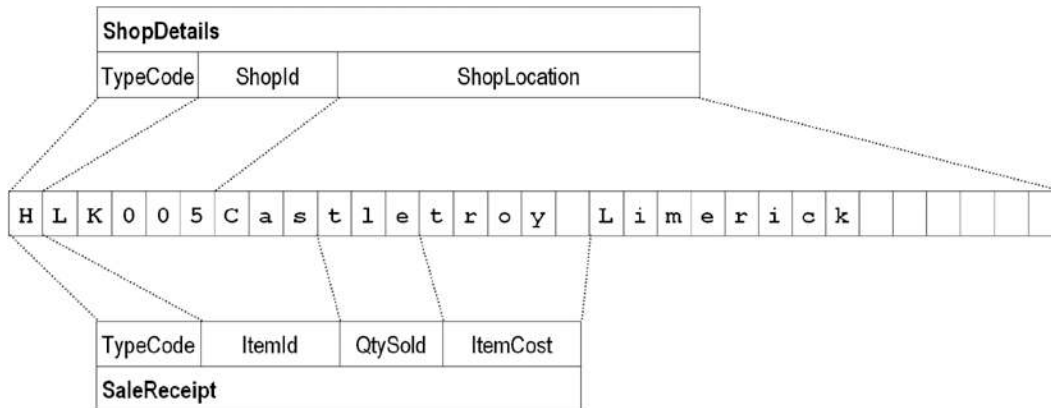


Figure 8-4. Representation of a record buffer that includes the TypeCode

When you examined the file description given in Example 8-2, perhaps it occurred to you to ask, why have condition names been defined only for the ShopDetails record and not for the SaleReceipt record? The answer is that TypeCode in both records maps on to the same area of storage; and that because both record descriptions, including the condition names, are current, it does not matter which record is read into the buffer—the condition names can detect it.

Example Program

The program specification given at the beginning of the chapter required you to write a program to process the ShopReceiptsFile. For each shop in the file, you were asked to produce a summary line that shows the ShopId and the total value of sales for that shop. The program to implement the specification is given in Listing 8-1.

Listing 8-1. Summarizes the Header and Sale records of the ShopReceiptsFile

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing8-1.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    Select ShopReceiptsFile ASSIGN TO "Listing8-1-ShopSales.Dat"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD ShopReceiptsFile.
01 ShopDetails.
    88 EndOfShopReceiptsFile VALUE HIGH-VALUES.
    02 RecTypeCode PIC X.
        88 ShopHeader VALUE "H".
        88 ShopSale VALUE "S".
    02 ShopId PIC X(5).
    02 ShopLocation PIC X(30).

01 SaleReceipt.
    02 RecTypeCode PIC X.
    02 ItemId PIC X(8).
    02 QtySold PIC 9(3).
    02 ItemCost PIC 999V99.

WORKING-STORAGE SECTION.
01 PrnShopSalesTotal.
    02 FILLER PIC X(21) VALUE "Total sales for shop ".
    02 PrnShopId PIC X(5).
    02 PrnShopTotal PIC $$$,$$9.99.

01 ShopTotal PIC 9(5)V99.

PROCEDURE DIVISION.
ShopSalesSummary.
    OPEN INPUT ShopReceiptsFile
    READ ShopReceiptsFile
        AT END SET EndOfShopReceiptsFile TO TRUE
    END-READ
    PERFORM SummarizeCountrySales
        UNTIL EndOfShopReceiptsFile
    CLOSE ShopReceiptsFile
    STOP RUN.

SummarizeCountrySales.
    MOVE ShopId TO PrnShopId
    MOVE ZEROS TO ShopTotal
    READ ShopReceiptsFile
        AT END SET EndOfShopReceiptsFile TO TRUE
    END-READ

```

```

PERFORM SummarizeShopSales
        UNTIL ShopHeader OR EndOfShopReceiptsFile
MOVE ShopTotal TO PrnShopTotal
DISPLAY PrnShopSalesTotal.

```

```
SummarizeShopSales.
```

```

COMPUTE ShopTotal = ShopTotal + (QtySold * ItemCost)
READ ShopReceiptsFile
        AT END SET EndOfShopReceiptsFile TO TRUE
END-READ.

```

Some basic test data and the results produced by running the program against this test data are shown in Figure 8-5.

```

HID006This is location of shop ID006
SItemid2500500595
SItemid2201500395
SItemid1000100195
SItemid0300100350
SItemid2500100195
SItemid2100100350
HID001This is location of shop ID001
SItemid0500500595
SItemid0201500395
SItemid1000100195
SItemid0300100350
HID002This is location of shop ID002
SItemid1500500595
SItemid0100100350
HID003This is location of shop ID003
SItemid0500500595
SItemid0201500395
SItemid1211501395
SItemid0500100195
SItemid1500100195
SItemid2100100350
SItemid0500100195

```

Run of Listing 8-1	
Total sales for shop ID006	\$99.90
Total sales for shop ID001	\$94.45
Total sales for shop ID002	\$33.25
Total sales for shop ID003	\$1,702.60

Figure 8-5. Basic test data for Listing 8-1

When you consider the solution produced in Listing 8-1, you may be a little puzzled. Where is the IF statement that checks whether the record is a ShopHeader or a ShopSale record? The answer to this question lies in the approach to the problem solution. Many programmers would solve the problem by having a loop to read the records in the file and an IF statement to check what kind of record has been read. If a ShopSale record was read, then the required computations would be done; and if a ShopDetails record was read, the summary line would be produced and displayed. This is not a terrible solution for a problem of this size; but when you get to control breaks—a type of problem of which this is a near relation—this type of solution quickly becomes complicated.

The solution adopted in Listing 8-1 involves examining the structure of the records in the ShopReceiptsFile and producing a solution that reflects that structure. What do I mean by the *structure* of the file? The records in the file are not thrown randomly into the file: they are grouped by shop, and each grouping starts with a ShopDetails header record followed by many SaleReceipt records. The solution in Listing 8-1 reflects the structure of the file. It has a loop

to process the SaleReceipt records and an outer loop to process the whole file. You know you have come to the end of the sales records for a particular shop when you encounter the ShopDetails record for the next shop. At that point, you display the summary information you have accumulated for the previous shop. A graphical representation of this solution as applied to the test data is given in Figure 8-6.

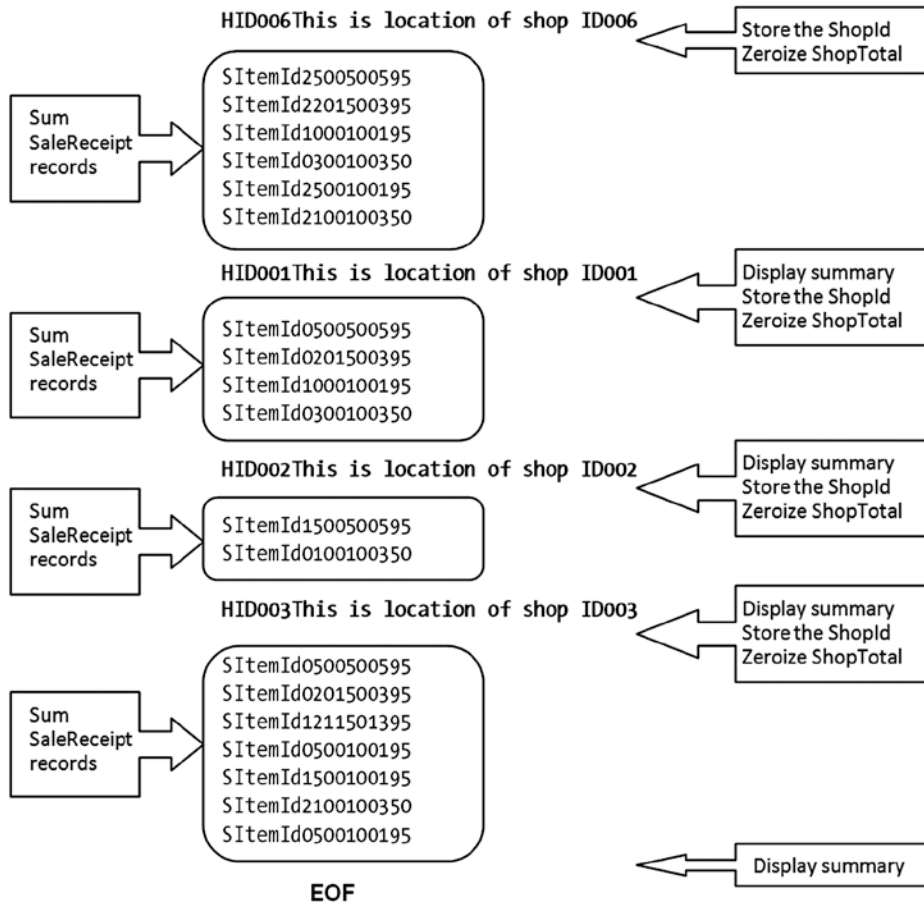


Figure 8-6. Representation of the solution as applied to the test data

■ **Note** This solution uses the Micro Focus `LINE SEQUENTIAL` extension. The reason is that when a file contains records of different lengths, the system has to use a record terminator to detect when one record ends and the next begins. The record terminator is specified by the language implementer. Where the terminator is not a fixed implementer default, it can be specified by using the `RECORD DELIMITER IS` clause in the file's `SELECT` and `ASSIGN` clause.

Because there is no generic, standard way of specifying the terminator, I chose to use the Micro Focus `LINE SEQUENTIAL` extension. When `LINE SEQUENTIAL` is used, each record is terminated by the carriage return and line feed ASCII characters. Adopting this extension has the added benefit that the test data can be written using a standard text editor such as Microsoft Notepad.

Specification Amendment

In a file such as `ShopReceiptsFile`, which consists of groups that contain a header record followed by many body records, there is often a third type of record. A footer record is frequently used to ensure that the group is complete and that none of the records in the group body has been lost. The footer record might simply contain a count of the records in the group body, or it might do some calculations to produce a checksum.

Let's amend the `ShopReceiptsFile` to include the footer record; and let's amend the specification to say that if the record count in the footer record is not the same as the actual record count, then an error message should be displayed instead of the sales total. The footer record is indicated by the *F* character.

A program to implement the specification is given in Listing 8-2.

Listing 8-2. Summarizes the Header, Sale, and Footer records of the `ShopReceiptsFile`

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing8-2.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    Select ShopReceiptsFile ASSIGN TO "Listing8-2-ShopSales.dat"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD ShopReceiptsFile.
01 ShopDetails.
    88 EndOfShopReceiptsFile VALUE HIGH-VALUES.
    02 TypeCode PIC X.
        88 ShopHeader VALUE "H".
        88 ShopSale VALUE "S".
        88 ShopFooter VALUE "F".
    02 ShopId PIC X(5).
    02 ShopLocation PIC X(30).

01 SaleReceipt.
    02 TypeCode PIC X.
    02 ItemId PIC X(8).
    02 QtySold PIC 9(3).
    02 ItemCost PIC 999V99.

01 ShopSalesCount.
    02 TypeCode PIC X.
    02 RecCount PIC 9(5).

WORKING-STORAGE SECTION.
01 PrnShopSalesTotal.
    02 FILLER PIC X(21) VALUE "Total sales for shop ".
    02 PrnShopId PIC X(5).
    02 PrnShopTotal PIC $$$,$$9.99.
```

```

01 PrnErrorMessage.
  02 FILLER          PIC X(15) VALUE "Error on Shop: ".
  02 PrnErrorShopId PIC X(5).
  02 FILLER          PIC X(10) VALUE " RCount = ".
  02 PrnRecCount    PIC 9(5).
  02 FILLER          PIC X(10) VALUE " ACount = ".
  02 PrnActualCount PIC 9(5).

```

```

01 ShopTotal      PIC 9(5)V99.
01 ActualCount    PIC 9(5).

```

PROCEDURE DIVISION.

ShopSalesSummary.

```

  OPEN INPUT ShopReceiptsFile
  PERFORM GetHeaderRec
  PERFORM SummarizeCountrySales
    UNTIL EndOfShopReceiptsFile
  CLOSE ShopReceiptsFile
  STOP RUN.

```

SummarizeCountrySales.

```

  MOVE ShopId TO PrnShopId, PrnErrorShopId
  MOVE ZEROS TO ShopTotal

```

```

  READ ShopReceiptsFile
    AT END SET EndOfShopReceiptsFile TO TRUE
  END-READ
  PERFORM SummarizeShopSales
    VARYING ActualCount FROM 0 BY 1 UNTIL ShopFooter
  IF RecCount = ActualCount
    MOVE ShopTotal TO PrnShopTotal
    DISPLAY PrnShopSalesTotal
  ELSE
    MOVE RecCount TO PrnRecCount
    MOVE ActualCount TO PrnActualCount
    DISPLAY PrnErrorMessage
  END-IF
  PERFORM GetHeaderRec.

```

SummarizeShopSales.

```

  COMPUTE ShopTotal = ShopTotal + (QtySold * ItemCost)
  READ ShopReceiptsFile
    AT END SET EndOfShopReceiptsFile TO TRUE
  END-READ.

```

GetHeaderRec.

```

  READ ShopReceiptsFile
    AT END SET EndOfShopReceiptsFile TO TRUE
  END-READ.

```

The new test data and the result of running the program against that test data are shown in Figure 8-7.

```
HID006This is location of shop ID006
SItemId2500500595
SItemId2201500395
SItemId1000100195
SItemId0300100350
SItemId2500100195
SItemId2100100350
F00006
HID001This is location of shop ID001
SItemId0500500595
SItemId0201500395
SItemId1000100195
SItemId0300100350
F00006
HID002This is location of shop ID002
SItemId1500500595
SItemId0100100350
F00002
HID003This is location of shop ID003
SItemId0500500595
SItemId0201500395
SItemId1211501395
SItemId0500100195
SItemId1500100195
SItemId2100100350
SItemId0500100195
F00007
```

Run of Listing 8-2	
Total sales for shop ID006	\$99.90
Error on Shop: ID001 RCount = 00006 ACount = 00004	
Total sales for shop ID002	\$33.25
Total sales for shop ID003	\$1,702.60

Figure 8-7. Test data and results for Listing 8-2

Some Comments about the Program

The `GetHeaderRec` paragraph has only one statement. Ordinarily this would be bad practice, but in this instance, I wanted to use the paragraph name to indicate the purpose of this particular `READ` statement. In a real program, the `PERFORM GetHeaderRec` statements would be replaced with the `READ` in the `GetHeaderRec` paragraph.

The logic of the program has been changed, because now the end of the shop group is indicated by the presence of a footer record. The sale records for each shop group are counted by means of the `PERFORM. . VARYING`. For a variety of reasons, including book space constraints, the only error the program checks for is missing sale receipt records. It is assumed that in all other respects, the file is correct.

Printer Sequential Files

In a business or enterprise environment, the ability to print reports is an important property for a programming language. COBOL allows programmers to write to the printer, either directly or through an intermediate print file. COBOL treats the printer as a serial file but uses a special variant of the `WRITE` verb to control the placement of lines on the page. Printing is regarded as so important that not only does COBOL have the printer sequential files discussed in this section, but it also supports a special set of declarations and verbs that together constitute the COBOL Report Writer. The Report Writer introduces elements of declarative programming to COBOL. It is discussed in detail in a later chapter.

SELECT and ASSIGN

As with ordinary sequential files, the internal name used for the print file is associated with an external device, which could be an actual printer or a print file. A *print file* is a file that contains embedded printer control codes such as form feed. Generally, you write to a print file; but in a COBOL programming shop, your program may well have direct control of the printer. The metalanguage for print files is given in Figure 8-8. Since ORGANIZATION IS SEQUENTIAL is the default it may be omitted.

```
SELECT InternalFileName
      ASSIGN TO { Implementer Name
                { ExternalFileSpecification }
                [[ORGANIZATION IS] SEQUENTIAL]
```

Figure 8-8. Print file SELECT and ASSIGN metalanguage

Notes

Where direct control of the printer is assumed, the internal print name is assigned to an `ImplementerName`, which depends on the vendor. For instance, in HP COBOL (really VAX COBOL), the `ImplementerName` is `LINE-PRINTER` (see Example 8-3) and the name is attached to an actual printer by a `LINE-PRINTER IS DeviceName` entry in the `SPECIAL-NAMES` paragraph (`CONFIGURATION SECTION, ENVIRONMENT DIVISION`).

Example 8-3. SELECT and ASSIGN clauses for a Print File and a Print Device

```
SELECT MembershipReport ASSIGN TO "MembershipRpt.rpt".
SELECT MembershipReport ASSIGN TO LINE-PRINTER.
```

What Is in a Report

Even when the Report Writer is not directly used, a report created with a printer sequential file consists of groups of printed lines of different types. For instance, suppose you want to print a report that lists the membership of your local golf club. This report might consist of the following types of print lines:

- **Page Heading**
Rolling Greens Golf Club - Membership Report
- **Page Footing**
Page: *PageNum*
- **Column Headings**
MemberID Member Name Type Gender
- **Membership detail line**
MemberID MemberName MembershipType Gender
- **Report Footing**
**** End of Membership Report ****

To set up the printer sequential file, you must create an FD for the file and a print record for each type of print line that will appear on the report. For instance, for the golf club membership report, you have to have the records shown in Example 8-4.

Example 8-4. Print Lines Required for the Golf Club Membership Report

```

01 PageHeading.
   02 FILLER          PIC X(44)
      VALUE "Rolling Greens Golf Club - Membership Report".

01 PageFooting.
   02 FILLER          PIC X(15) VALUE SPACES.
   02 FILLER          PIC X(7)  VALUE "Page : ".
   02 PrnPageNum     PIC Z9.

01 ColumnHeadings   PIC X(41)
   VALUE "MemberID  Member Name          Type Gender".

01 MemberDetailLine.
   02 FILLER          PIC X  VALUE SPACES.
   02 PrnMemberId    PIC 9(5).
   02 FILLER          PIC X(4) VALUE SPACES.
   02 PrnMemberName  PIC X(20).
   02 FILLER          PIC XX VALUE SPACES.
   02 PrnMemberType  PIC X.
   02 FILLER          PIC X(4) VALUE SPACES.
   02 PrnGender      PIC X.

01 ReportFooting    PIC X(38)
   VALUE "**** End of Membership Report ****".

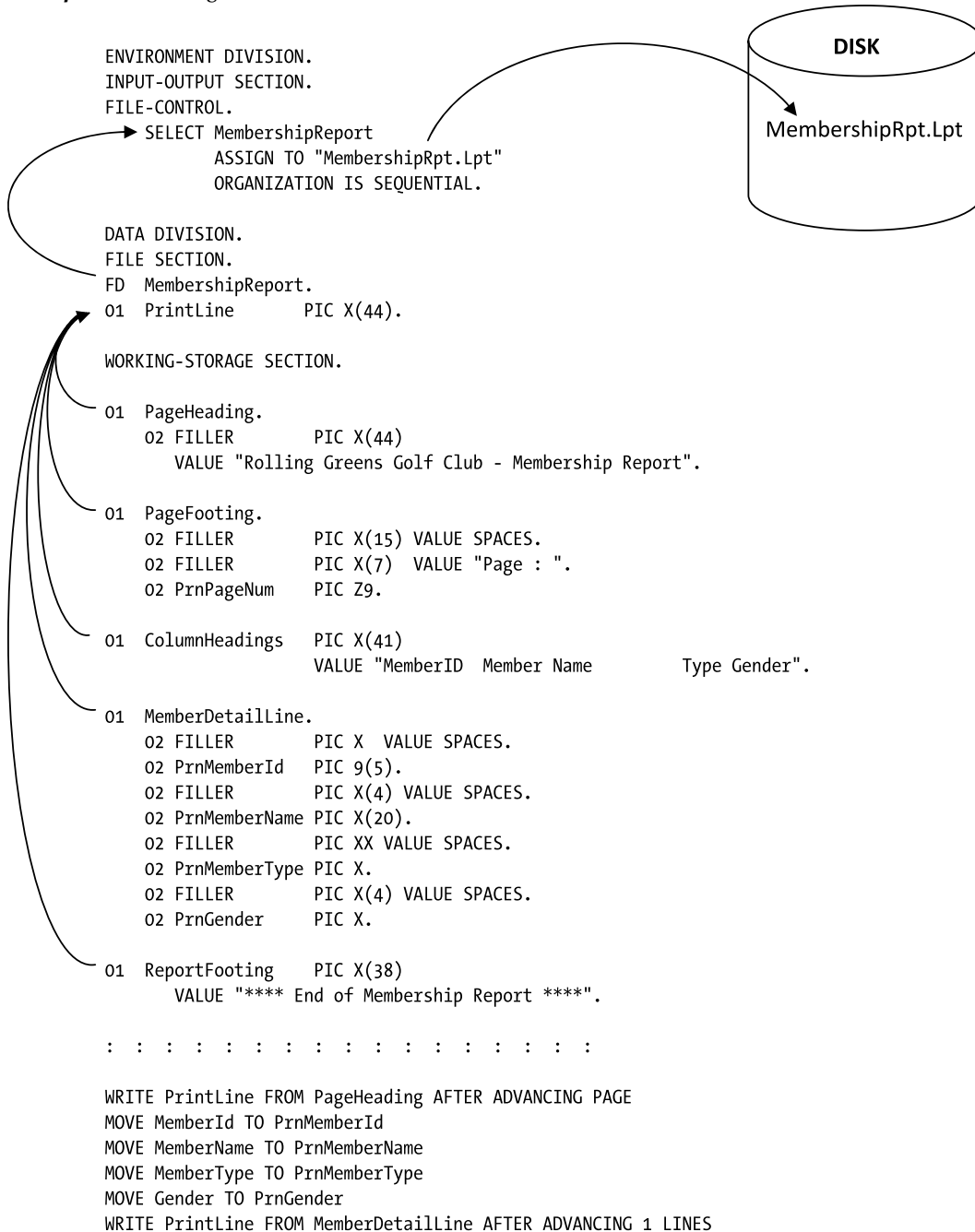
```

Problem of Multiple Print Records

When you reviewed the different types of print lines in Example 8-4, you may have realized that there is a problem. As you saw in the previous section, if a file is declared as having multiple record types, all the records map on to the same physical area of storage. This does not cause difficulties if the file is an input file, because only one type of record at a time can be in the buffer. But as you can see from the print line declarations in Example 8-4, the information in many print lines is static. It is assigned using the VALUE clause and instantiated as soon as the program starts. This means all the record values have to be in the record buffer at the same time, which is obviously impossible. In fact, to prevent the creation of print records in the FILE SECTION, there is a COBOL rule stating that, in the FILE SECTION, the VALUE clause can only be used with condition names (that is, it cannot be used to give an item an initial value).

Solution to the Multiple Print Record Problem

The solution to the problem of declaring print records is to declare the print line records in the WORKING-STORAGE SECTION and to declare a record in the file's FD entry in the FILE SECTION, which is the size of the largest print line record. You print a print line by moving it from the WORKING-STORAGE SECTION, to the record in the FILE SECTION; then that record is written to the print file. This is shown graphically in Example 8-5.

Example 8-5. Writing to a Print File

WRITE Syntax Revisited

When I discussed the WRITE statement in the previous chapter, I noted that I was postponing discussion of the ADVANCING CLAUSE until I dealt with print files. To refresh your memory, the metalanguage for the WRITE statement is given in Figure 8-9.

WRITE RecordName [FROM Identifier]

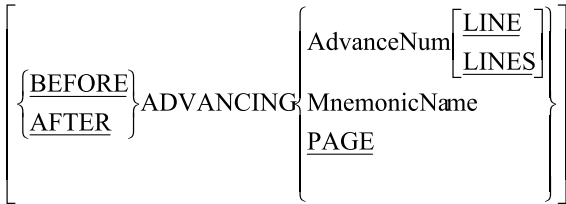


Figure 8-9. Metalinguage for the *WRITE* verb

The syntax for writing to print files is more complicated than that used for writing in ordinary sequential files because it must contain entries to allow you to control the vertical placement of the print lines. For instance, the statement `WRITE PrintLine BEFORE ADVANCING 2 LINES` sends the data in `PrintLine` to the printer, after which the printer advances two lines.

Notes on WRITE

The `ADVANCING` clause is used to position the lines on the page when writing to a print file or a printer. The `ADVANCING` clause uses the `BEFORE` or `AFTER` phrase to specify whether advancing is to occur before the line is printed or after.

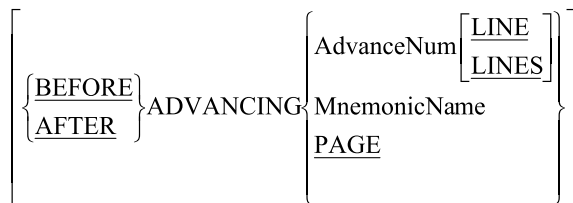
The `PAGE` option writes a form feed (goes to a new page) to the print file or printer. `MnemonicName` refers to a vendor-specific page control command. It is defined in the `SPECIAL-NAMES` paragraph.

When you write to a print file, you generally use the `WRITE . . FROM` option because the print records are described in the `WORKING-STORAGE SECTION`. When the `WRITE . . FROM` option is used, the data in the source area is moved into the record buffer and then the contents of the buffer are written to the print file. `WRITE . . FROM` is the equivalent of a `MOVE SourceItem TO RecordBuffer` statement followed by a `WRITE RecordBuffer` statement.

SOME IGNORED WRITE VERB ENTRIES

I have ignored some print-related formats of the `WRITE` verb on the basis that if you need this level of print sophistication, you should be using the Report Writer. The full `WRITE` syntax includes the `END-OF-PAGE` clause, as shown in the following illustration; this is connected to the `LINAGE` clause specified in the file's `FD` entry. The `LINAGE` clause specifies the number of lines that can fit on a page, and this in turn allows the end of the page to be automatically detected. If you want to explore this further, you should read your implementer manual.

WRITE RecordName [FROM Identifier]



$$\left[\text{AT} \left\{ \begin{array}{l} \underline{\text{END-OF-PAGE}} \\ \underline{\text{EOP}} \end{array} \right\} \text{StatementBlock} \right]$$

$$\left[\underline{\text{NOT AT}} \left\{ \begin{array}{l} \underline{\text{END-OF-PAGE}} \\ \underline{\text{EOP}} \end{array} \right\} \text{StatementBlock} \right]$$

[END-WRITE]

Example Program

Listing 8-3 contains a program that produces a simple report to show a golf club's membership list. The program keeps a count of the number of lines printed; it changes the page and prints the headings again when the line count is greater than 49. A page count is also kept, and this is printed at the bottom of each page. The report produced by running the program is shown in Figure 8-10.

Listing 8-3. Program to Print the Golf Club Membership Report

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing8-3.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT MembershipReport
        ASSIGN TO " Listing8-3-Members.rpt"
        ORGANIZATION IS SEQUENTIAL.

    SELECT MemberFile ASSIGN TO "Listing8-3Members.dat"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD MembershipReport.
01 PrintLine          PIC X(44).

FD MemberFile.
01 MemberRec.
    88 EndOfMemberFile VALUE HIGH-VALUES.
    02 MemberId        PIC X(5).
    02 MemberName     PIC X(20).
    02 MemberType     PIC 9.
    02 Gender         PIC X.

WORKING-STORAGE SECTION.
01 PageHeading.
    02 FILLER          PIC X(44)
        VALUE "Rolling Greens Golf Club - Membership Report".

01 PageFooting.
    02 FILLER          PIC X(15) VALUE SPACES.
    02 FILLER          PIC X(7) VALUE "Page : ".
    02 PrnPageNum     PIC Z9.

01 ColumnHeadings    PIC X(41)
        VALUE "MemberID  Member Name          Type Gender".

01 MemberDetailLine.
    02 FILLER          PIC X VALUE SPACES.
    02 PrnMemberId    PIC 9(5).

```

```

02 FILLER          PIC X(4) VALUE SPACES.
02 PrnMemberName  PIC X(20).
02 FILLER          PIC XX VALUE SPACES.
02 PrnMemberType  PIC X.
02 FILLER          PIC X(4) VALUE SPACES.
02 PrnGender      PIC X.

01 ReportFooting  PIC X(38)
   VALUE "**** End of Membership Report ****".

01 LineCount      PIC 99 VALUE ZEROS.
   88 NewPageRequired VALUE 40 THRU 99.

01 PageCount      PIC 99 VALUE ZEROS.

```

PROCEDURE DIVISION.

PrintMembershipReport.

```

OPEN INPUT MemberFile
OPEN OUTPUT MembershipReport
PERFORM PrintPageHeadings
READ MemberFile
   AT END SET EndOfMemberFile TO TRUE
END-READ
PERFORM PrintReportBody UNTIL EndOfMemberFile
WRITE PrintLine FROM ReportFooting AFTER ADVANCING 5 LINES
CLOSE MemberFile, MembershipReport
STOP RUN.

```

PrintPageHeadings.

```

WRITE PrintLine FROM PageHeading AFTER ADVANCING PAGE
WRITE PrintLine FROM ColumnHeadings AFTER ADVANCING 2 LINES
MOVE 3 TO LineCount
ADD 1 TO PageCount.

```

PrintReportBody.

```

IF NewPageRequired
   MOVE PageCount TO PrnPageNum
   WRITE PrintLine FROM PageFooting AFTER ADVANCING 5 LINES
   PERFORM PrintPageHeadings
END-IF.
MOVE MemberId    TO PrnMemberId
MOVE MemberName  TO PrnMemberName
MOVE MemberType  TO PrnMemberType
MOVE Gender      TO PrnGender
WRITE PrintLine FROM MemberDetailLine AFTER ADVANCING 1 LINE
ADD 1 TO LineCount
READ MemberFile
   AT END SET EndOfMemberFile TO TRUE
END-READ.

```

```

Rolling Greens Golf Club - Membership Report
Mem: Rolling Greens Golf Club - Membership Report
A1:
A1: MemberID  Member Name      Type Gender
A1: F0003     Niamh Lynch      1    F
A1: F0104     Michael Reddy    1    M
A1: F0105
A1: F0106
B0: F0107
B0: F0128     L0022           Michael O'Brien  1    M
B0: F0129     L0023           Donal O'Donoghue 1    M
B0: F0130     M0024           Mark Deasy        1    M
B0: F0131     M0025           Joseph Kiely      2    M
B0: F0132     M0026           Martin Goodwin    1    M
B0: F0133     M0027           Mary Maher        1    F
B0: G0212     M0028           David Hayes       1    M
C2: G0311     M0029           Kevin Kirwan      1    M
C2: G0410     M0030           Arthur McCormack  1    M
C2: G0509
C2: G0608
C2: G0707
C2: G0806
C2: H1234
C2: H1235     Eoghan O'Toole   2    M
D6: H1236     Hao Ming O'Connor 1    M
D7: H1237     Donald Hogan     2    M
D7: H1238     Ciara Ryan       1    F
D8: H1239     Shu Carroll      3    F
D9: H1240     Shane Reen       1    M
D9: H1241     Matthew Ryan     1    M
E1: H1242     William Carty    2    M
E1: K0012     Shane Cronin     1    M
E1: K0013     Kristofer Geraghty 2    M
E1: K0014     Padraig Webster  1    M
E1: K0015     David McWeeney  1    M
E1: K0016     Sharon Doyle     1    F
E1: K0017     Aaron Brady      1    M
F0: K0018     Jay Mc Carthy    1    M
F0: L0019     Barry Murphy     1    M
    L0020     Triona Keyes    1    F
    L0021     Patrick Gillen  3    M

**** End of Membership Report ****

Page : 2

```

Figure 8-10. Report produced by Listing 8-3

Report Writer Version

The Report Writer has been mentioned a number of times in this chapter, so it might be useful to compare the PROCEDURE DIVISION of the program in Listing 8-3 with the PROCEDURE DIVISION of the Report Writer version of the report shown in Example 8-6. How is it able to do so much work with so little PROCEDURE DIVISION code? A short answer is that that is the magic of the Report Writer and declarative programming. A detailed answer will have to wait until I examine the Report Writer in a later chapter.

Example 8-6. PROCEDURE DIVISION for Report Writer Version of the Golf Club Membership Report

```

PROCEDURE DIVISION.
PrintMembershipReport.
    OPEN INPUT MemberFile
    OPEN OUTPUT MembershipReport
    INITIATE ClubMemebershipReport
    READ MemberFile
        AT END SET EndOfMemberFile TO TRUE
    END-READ
    PERFORM UNTIL EndOfMemberFile
        GENERATE MemberLine
        READ MemberFile
            AT END SET EndOfMemberFile TO TRUE
        END-READ
    END-PERFORM
    TERMINATE ClubMemebershipReport
    CLOSE MemberFile, MembershipReport
    STOP RUN.

```

Variable-Length Records

COBOL programs normally process fixed-length records, but sometimes files contain records of different lengths. In the first section of this chapter, you saw that a file might consist of a number of different record types. But even though, taken as a whole, the records in the file vary in size, each record type is a fixed-length record. You can, however, have true variable-length records, meaning you do not know the structure or size of the records (although you have to know the maximum size and may know the minimum size). For instance, in an ordinary text file such as might be produced by MS Notepad, the lines of text have no structure and vary in size from line to line. This section demonstrates how files containing true variable-length records may be declared and processed.

FD Entries for Variable-Length Records

When the FD entry for sequential files was introduced, you only saw a simplified version that consisted of the letters *FD* followed by the file name. Actually, the FD entry can be more complex than you have seen so far, and it can have a large number of subordinate clauses (see your implementer manual or help files). Some of these clauses are not required for all computers. For instance, the `BLOCK CONTAINS` clause is only required for computers where the number of characters read or written in one I/O operation is under programmatic control. If the block size is fixed, it is not required. Other clauses are syntax retained from previous versions of COBOL and are now treated as comments. I ignore these. Some clauses are important for direct-access file organizations; I deal with these when I examine these file organizations. The `RECORD IS VARYING IN SIZE` clause allows you to specify that a file contains variable-length records. The metalanguage for the expanded FD entry is given in Figure 8-11 and Example 8-7 demonstrates how to use these new FD entries.

FD *FileName*

```

RECORD IS VARYING IN SIZE
[ [FROM SmallestSize#l ] [TO LargestSize#l ] CHARACTERS ]
[ DEPENDING ON RecordSize#i ]

```

Figure 8-11. `RECORD IS VARYING` clause for variable-length records

Notes on Varying-Length Records

The `RECORD IS VARYING IN SIZE` clause without the `DEPENDING ON` phrase is not strictly required, because the compiler can work out this information from the record sizes. That is why it was not included in the multiple record-type declarations in the first section of this chapter.

The `RecordSize#i` in the `DEPENDING ON` phrase must be an elementary unsigned integer data-item declared in the `WORKING-STORAGE SECTION`. When a record defined with the `RECORD IS VARYING IN SIZE..DEPENDING ON` phrase is read from a file, the length of the record read in to the buffer is moved into the `RecordSize#i` data item. When a record defined with `RECORD IS VARYING IN SIZE..DEPENDING ON` is written to a file, the length of the record to be written must first be moved to `RecordSize#i` data-item, and then the `WRITE` statement must be executed.

Example 8-7. FD Entries with the `RECORD IS VARYING` Phrase

```
FD Textfile
   RECORD IS VARYING IN SIZE
   FROM 1 TO 80 CHARACTERS
   DEPENDING ON TextLineLength.
```

Or we may define the file as -

```
FD Textfile
   RECORD IS VARYING IN SIZE
   DEPENDING ON TextLineLength.
```

Example Program

Listing 8-4 is an example program that demonstrates how to read a file that contains variable-length records. One problem with variable-length records is that although the records are variable length, the buffer into which they are read is fixed in size. So if only the characters that have been read from the file are required, they must be extracted from the record buffer. In this program, reference modification and `NameLength` are used to slice `NameLength` number of characters from the buffer. *Reference modification* is a COBOL string-handling facility that you explore in a later chapter. To demonstrate that you have extracted only the required characters, asterisks are used to bracket the names. Figure 8-12 is a diagrammatic representation of how reference modification is used to extract the name from the record buffer.

Listing 8-4. Processing Variable-Length Records

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing8-4.
AUTHOR. Michael Coughlan.
* This program demonstrates how to read variable length records.
* It also demonstrates how a file may be assigned its actual name
* at run time rather than compile time (dynamic vs static).
* The record buffer is a fixed 40 characters in size but the
* lengths or names vary so Reference Modification is used to extract
* only the number of characters from the record buffer.

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
   SELECT LongNameFile
      ASSIGN TO NameOfFile
      ORGANIZATION IS LINE SEQUENTIAL.
```



```

DATA DIVISION.
FILE SECTION.
FD LongNameFile
   RECORD IS VARYING IN SIZE
   DEPENDING ON NameLength.
01 LongNameRec          PIC X(40).
   88 EndOfNames        VALUE HIGH-VALUES.

```

```

WORKING-STORAGE SECTION.
01 NameLength           PIC 99.
01 NameOfFile           PIC X(20).

```

```

PROCEDURE DIVISION.
Begin.
   DISPLAY "Enter the name of the file :- "
     WITH NO ADVANCING
   ACCEPT NameOfFile.
   OPEN INPUT LongNameFile.
   READ LongNameFile
     AT END SET EndOfNames TO TRUE
   END-READ
   PERFORM UNTIL EndOfNames
     DISPLAY "****" LongNameRec(1:NameLength) "****"
     READ LongNameFile
       AT END SET EndOfNames TO TRUE
     END-READ
   END-PERFORM
   CLOSE LongNameFile
   STOP RUN.

```

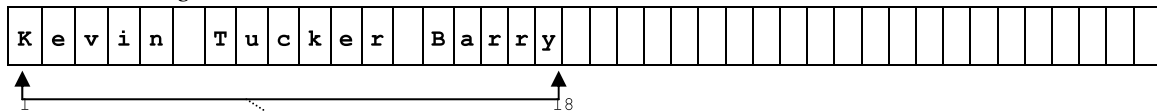
Run of Listing8-4

```

Enter the name of the file :-
longnames.dat
***Oscar Fingal O'Flahertie Wills Wilde***
***Colm Padraig Brendan Ryan***
***Kevin Tucker Barry***
***Maria Roseanna Catherine Donovan***
***Liam Sean Lorigan***
***Maeve Fitzgibbon Mencke***
***Shane Philip Adrian Cross***
***Stephen Rory Mulhall***
***Niamh Karen Ciara Lynch***
***Darren Peter Hastings***
***Aoife Triona Ryan***
***Hao Ming Barry O'Connor***

```

```
01 LongNameRec  PIC X(40).
```



```
DISPLAY "****" LongNameRec(1:NameLength) "****"
```

Figure 8-12. Using reference modification to extract the name from the record

Summary

This chapter examined how files that contain records of different lengths may be defined and used. The first section of the chapter dealt with files in which the record lengths are different because the file contains fixed-length records of different types. The last section dealt with files that contain real variable-length records. The middle section of the chapter discussed the problem of print files. It explained why the different types of print lines required when printing a report cannot be declared as different records in the file's FD entry but must instead be declared in the WORKING-STORAGE SECTION.

In the next chapter, you continue your exploration of printed output by examining edited pictures. Edited pictures allow you to format data for output. In some of the example programs in this and previous chapters, I have used edited pictures without explanation because the context made obvious what was happening. But seeing edited pictures in action and knowing how to use them are different things. The next chapter examines edited pictures in detail and discusses how to format data so that leading zeros are suppressed; so that the currency symbol floats against the non-zero digits of the number; and so that blanks, commas, zeros, and slashes are inserted where they are required. Table 8-1 gives a preview of some of the formatting that can be applied to data.

Table 8-1. *Preview of Some of the Edited Picture Formatting Effects*

Effect	Value
Original value	00014584.95
With commas inserted	00,014,584.95
With zero-suppression added	14,584.95
With check security and currency symbol added	\$***14,584.95
With floating + sign	+14,584.95
With floating currency symbol	\$14,584.95
With zeros inserted after the decimal point	\$14,584.00
With slashes inserted in the middle of the number	00/014/584.95
With three zeros inserted in the number	00014000584.95
With three blanks inserted in the number	00014 584.95

PROGRAMMING EXERCISE 1

It is exercise time again. Now, where did you put that 2B pencil? Write a program to satisfy the following specification.

University Entrants Summary Report

A program is required that will process the first-year-student entrants file (`Entrants.dat`) to produce a summary that shows the number of first-year students in each course. The summary should be displayed on the screen ordered by ascending `CourseCode`. An output template is given next.

Output Template

```

First Year Entrants Summary
Course Code   NumOfStudents
LM999         9,999
LM999         9,999
:             :
:             :
LM999         9,999
LM999         9,999

```

Total Students: 99,999

Entrants File

The entrants file (Entrants.dat) is a sequential file sequenced on ascending CourseCode. The records in the file have the following description:

Field	Type	Length	Value
StudentId	9	8	0-99999999
CourseCode	X	5	-
Gender	X	1	M/F

Some Statements You Need for Your Program

To make this programming exercise easier, some of the statements and data declarations required for your program are given next.

Executable Statements

```

DISPLAY Headingline1
DISPLAY Headingline2
DISPLAY CourseLine
DISPLAY SPACES
DISPLAY FinalTotalLine
MOVE CourseCode TO PrnCourseCode
MOVE CourseTotal TO PrnCourseTotal
MOVE FinalTotal TO PrnFinalTotal
READ EntrantsFile
    AT END SET EndOfFile TO TRUE
END-READ
OPEN INPUT EntrantsFile
CLOSE EntrantsFile
ADD 1 TO CourseTotal, FinalTotal
MOVE ZEROS TO CourseTotal
MOVE ZEROS TO FinalTotal
MOVE CourseCode TO PrevCourseCode

```

Some Data Descriptions

```

01 HeadingLine1      PIC X(31) VALUE "   First Year Entrants Summary".
01 HeadingLine2      PIC X(31) VALUE "   Course Code   NumOfStudents".
01 CourseLine.
    02 FILLER          PIC X(5) VALUE SPACES.
    02 PrnCourseCode  PIC X(5).
    02 FILLER          PIC X(10) VALUE SPACES.
    02 PrnCourseTotal PIC Z,ZZ9.
01 FinalTotalLine.
    02 FILLER          PIC X(19) VALUE "   Total Students:".
    02 PrnFinalTotal  PIC ZZ,ZZ9.
01 CourseTotal       PIC 9(4).
01 FinalTotal        PIC 9(5).
01 PrevCourseCode    PIC X(5).

```

PROGRAMMING EXERCISE 2

Change the program you wrote for Programming Exercise 1 so that it now writes the report to a print file.

The answer to this exercise is given below. Because exercise 1 is substantially the same as exercise 2, the same answer should serve both.

PROGRAMMING EXERCISES 1 AND 2: ANSWER

IDENTIFICATION DIVISION.

PROGRAM-ID. Listing8-5.

AUTHOR. Michael Coughlan.

- * This program processes the first year students entrants file to produce
- * a summary report sequenced on ascending Course Code that shows the number
- * of first year students* in each course.
- * The Entrants File is a sequential file sequenced on ascending CourseCode.

ENVIRONMENT DIVISION.

INPUT-OUTPUT SECTION.

FILE-CONTROL.

```

SELECT EntrantsFile ASSIGN TO "Listing8-5-Entrants.Dat"
    ORGANIZATION IS LINE SEQUENTIAL.

```

```

SELECT SummaryReport ASSIGN TO "Listing8-5-Summary.Rpt"
    ORGANIZATION IS SEQUENTIAL.

```

DATA DIVISION.

FILE SECTION.

FD EntrantsFile.

01 StudentRecord.

```

    88 EndOfEntrantsFile      VALUE HIGH-VALUES.
    02 StudentId              PIC 9(8).
    02 CourseCode             PIC X(5).
    02 Gender                  PIC X.

```

```

FD SummaryReport.
01 PrintLine          PIC X(35).

WORKING-STORAGE SECTION.
01 HeadingLine1      PIC X(31) VALUE "   First Year Entrants Summary".

01 HeadingLine2      PIC X(31) VALUE "   Course Code   NumOfStudents".

01 CourseLine.
  02 FILLER          PIC X(5) VALUE SPACES.
  02 PrnCourseCode   PIC X(5).
  02 FILLER          PIC X(10) VALUE SPACES.
  02 PrnCourseTotal  PIC BBZZ9.

01 FinalTotalLine.
  02 FILLER          PIC X(19) VALUE "   Total Students:".
  02 PrnFinalTotal   PIC BZ,ZZ9.

01 CourseTotal       PIC 9(4) VALUE ZEROS.
01 FinalTotal        PIC 9(5) VALUE ZEROS.
01 PrevCourseCode    PIC X(5) VALUE ZEROS.

```

PROCEDURE DIVISION.

```

ProduceSummaryReport.
  OPEN INPUT EntrantsFile
  OPEN OUTPUT SummaryReport
  WRITE PrintLine FROM HeadingLine1 AFTER ADVANCING PAGE
  WRITE PrintLine FROM HeadingLine2 AFTER ADVANCING 2 LINES
  READ EntrantsFile
  AT END SET EndOfEntrantsFile TO TRUE
  END-READ
  PERFORM UNTIL EndOfEntrantsFile
    MOVE CourseCode TO PrnCourseCode, PrevCourseCode
    MOVE ZEROS TO CourseTotal
    PERFORM UNTIL CourseCode NOT = PrevCourseCode
      ADD 1 TO CourseTotal, FinalTotal
      READ EntrantsFile
      AT END SET EndOfEntrantsFile TO TRUE
    END-READ
  END-PERFORM
  MOVE CourseTotal TO PrnCourseTotal
  WRITE PrintLine FROM CourseLine AFTER ADVANCING 1 LINE
  END-PERFORM
  MOVE FinalTotal TO PrnFinalTotal
  WRITE PrintLine FROM FinalTotalLine AFTER ADVANCING 2 LINES
  CLOSE EntrantsFile, SummaryReport

```

STOP RUN.

CHAPTER 9



Edited Pictures

In the previous chapter, you saw how a printed report may be created by sending data directly to the printer or to a print file. In this chapter, you continue your exploration of printed output by examining how data may be formatted for output.

Most users of the data produced by a COBOL report program are not content with the simple raw, unformatted data. Unformatted data is difficult to read, so users want it presented in a way that makes it easier to understand. This is especially true of numeric data. Users may want numeric values separated into thousands, and they may want leading zeros to be suppressed. If the report contains currency values, then users may want the currency symbol to be printed, and they may want the symbol floated up against the first non-zero digit. In COBOL, all these effects and more can be achieved using edited pictures.

Edited Pictures

Edited pictures are picture clauses that format data intended for output to a screen or a printer. To enable the data items to be formatted, special symbols are embedded in the picture clause. These symbols supplement the basic 9, X, A, V, and S picture clause symbols. The additional symbols are referred to as *edit symbols*, and picture clauses that include edit symbols are called *edited Pictures*. The term *edit* is used because the edit symbols cause the data in the edited item to be changed or “edited.”

When numeric data is moved into an edited numeric data item, it obeys the rules for numeric moves, with decimal-point alignment and zero-filling or truncation as necessary. Although an edited numeric data item cannot be used as an active operand in a computation, it may be used as the receiving field of a computation. That is, it may be used to the right of the word GIVING.

Formatting Output

The last chapter ended with an example that showed a number of the formatting effects that may be applied to a data value. The example did not show how those effects were achieved. You start this chapter by revisiting that example and examining a program that shows how edited pictures were used to achieve those effects. After you have seen how edited pictures are used in a program, this chapter explores the topic of edited pictures in detail. You examine the different kinds of editing that may be applied to data, and you expand your knowledge of the special symbols used to create edited pictures.

Table 9-1 restates the example given in Table 8-1 in the previous chapter. This example shows some of the different kinds of formatting that may be applied to a data value. Among the effects are numeric values divided into thousands by commas, suppression of leading zeros, and the plus sign and the currency symbol floating up against the first non-zero value.

Table 9-1. Edited Picture Formatting Effects

Effect	Value
Original value	00014584.95
With commas inserted	00,014,584.95
With zero-suppression added	14,584.95
With check security and currency symbol added	\$\$\$14,584.95
With floating + sign	+14,584.95
With floating currency symbol	\$14,584.95
With zeros inserted after the decimal point	\$14,584.00
With slashes inserted in the middle of the number	00/014/584.95
With three zeros inserted in the number	00014000584.95
With three blanks inserted in the number	00014 584.95

Immediate Editing

The most important thing to know about an edited picture is that the data formatting is not done when the edited data is output to a printer or a computer screen; it is immediate. The moment data is moved into an edited item, the data itself is modified according to the formatting instructions specified by the edited picture.

It can be very useful to know that when a data value is moved into an edited item, it is immediately formatted; once you know that, you can think of a number of manipulations that you can do to the edited data to achieve interesting effects. For instance, you could use COBOL string-handling to replace the floating dollar sign with the Euro, Yen, or other currency symbol; or you might replace the slash symbol in a date with the hyphen or some other separator. Later, this chapter returns to this idea and looks at some examples.

Example Program

Listing 9-1 is a simple program that shows how the formatting effects of Table 9-1 were achieved. This program has been pared down to its essential elements so that you can concentrate on the editing effects. The program uses the DISPLAY statement to output the edited data to the screen.

Listing 9-1. Using Edited Pictures to Format Data for Output

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing9-1.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 NumericValue PIC 9(8)V99 VALUE 00014584.95.
01 Edit1 PIC 99,999,999.99.
01 Edit2 PIC ZZ,ZZZ,ZZ9.99.
01 Edit3 PIC $*,***,**9.99.
01 Edit4 PIC ++,+++,**9.99.
01 Edit5 PIC $$,$$$,$$9.99.
01 Edit6 PIC $$,$$$,$$9.00.
```

```

01 Edit7    PIC 99/999/999.99.
01 Edit8    PIC 99999000999.99.
01 Edit9    PIC 99999BBB999.99.

```

```
PROCEDURE DIVISION.
```

```
Begin.
```

```
MOVE NumericValue TO Edit1
```

```
DISPLAY "Edit1 = " Edit1
```

```
MOVE NumericValue TO Edit2
```

```
DISPLAY "Edit2 = " Edit2
```

```
MOVE NumericValue TO Edit3
```

```
DISPLAY "Edit3 = " Edit3
```

```
MOVE NumericValue TO Edit4
```

```
DISPLAY "Edit4 = " Edit4
```

```
MOVE NumericValue TO Edit5
```

```
DISPLAY "Edit5 = " Edit5
```

```
MOVE NumericValue TO Edit6
```

```
DISPLAY "Edit6 = " Edit6
```

```
MOVE NumericValue TO Edit7
```

```
DISPLAY "Edit7 = " Edit7
```

```
MOVE NumericValue TO Edit8
```

```
DISPLAY "Edit8 = " Edit8
```

```
MOVE NumericValue TO Edit9
```

```
DISPLAY "Edit9 = " Edit9
```

```
STOP RUN.
```

Listing 9-1 Output

```

Edit1 = 00,014,584.95
Edit2 =   14,584.95
Edit3 = $***14,584.95
Edit4 =  +14,584.95
Edit5 =  $14,584.95
Edit6 =  $14,584.00
Edit7 = 00/014/584.95
Edit8 = 00014000584.95
Edit9 = 00014  584.95

```

The data item `NumericValue` is a decimal number. The `V` in the picture clause indicates the position of the assumed decimal point; but the actual decimal point, which is a text character, is not held in the data item. To display or print an actual decimal point, you must use an edited picture containing the decimal-point editing symbol. If you examine the `Edit1` data item in Listing 9-1, you see that the `V`, which normally indicates the position of the decimal point, has been replaced by the actual decimal-point character.

When the value in `NumericValue` is moved into the edited item, the data is immediately modified according to the formatting specified by the edit symbols. A brief explanation of the effect of moving data from `NumericValue` to each of the edited items is given next:

- When `NumericValue` is moved to `Edit1`, the assumed decimal point in `NumericValue` aligns with the actual decimal point in `Edit1`, and the actual decimal-point character is inserted. In addition, commas are inserted where they are specified in the edited picture.

- The zero-suppression symbol **Z** in `Edit2` modifies the data so that leading zeros are replaced with spaces.
- In `Edit3`, the edit symbols cause the dollar sign to be inserted and the leading zeros to be replaced with asterisks.
- The plus-sign symbols in `Edit4` cause the sign to float up against the first non-zero digit.
- The data in `Edit5` is similarly modified, but using the dollar sign.
- The editing specified for `Edit6` inserts two zeros after the decimal point. This means when the data is moved into `Edit6` and there is alignment along the decimal point, there is no room for the digits 9 and 5, which are truncated.
- `Edit7` shows how the slash character can be inserted into a number. The slash is used to good effect when formatting dates, but it is used here to show that it is not restricted to date values.
- In `Edit8`, the zero edit symbol is used to insert zeros into the middle of the number.
- In `Edit9`, the blank symbol **B** is used to insert spaces or blanks into the middle of the number. This can be useful for formatting dates or for aligning report headings or values.

Types of Editing

There are two basic types of editing in COBOL: insertion editing, and suppression and replacement editing. Insertion editing modifies the data value by inserting additional characters into the data. This type of editing has the following subcategories:

- Simple insertion
- Special insertion
- Fixed insertion
- Floating insertion

Suppression and replacement editing modifies the data value by suppressing leading zeros and replacing them with a replacement character. This type of editing has the following subcategories:

- Zero-suppression and replacement with spaces
- Zero-suppression and replacement with asterisks (*)

■ **COBOL Detail** Zero-suppression and replacement with spaces can also be achieved by using the `BLANK WHEN ZERO` clause. This clause can sometimes be useful because it may be used with a picture clause that contains editing symbols (except the asterisk [*] replacement symbol). For instance, `01 BlankedNumber PIC +$$$,$$9 BLANK WHEN ZERO`.

Editing Symbols

Special picture symbols are used in an edited-picture clause to specify the formatting required. Table 9-2 shows the special picture clause symbols used in edited pictures and categorizes them by the type of editing they are used for.

Table 9-2. *Editing Symbols*

Edit Symbol	Editing Type
, B 0 /	Simple insertion
.	Special insertion
+ - CR DB \$	Fixed insertion
+ - \$	Floating insertion
Z *	Suppression and replacement

Insertion Editing

Insertion editing is so named because the edit symbol is inserted into the data value at the same position it occupies in the picture clause. As mentioned earlier, there are four types of insertion editing: simple insertion, special insertion, fixed insertion, and floating insertion. The following sections explore these types of editing in more detail.

Simple-Insertion Editing

A simple-insertion edited picture consists of a PICTURE string that specifies the relevant insertion character(s) in the required character position. When a data value is moved into the edited item, the insertion characters are inserted into the item at the position specified in the PICTURE. Simple insertion may be used with both numeric-edited and alphanumeric-edited data items.

As shown in Table 9-2, the comma, the blank or space, the zero, and the slash are the simple-insertion editing symbols. In simple insertion, all the inserted characters count toward the number of characters printed or displayed. For instance, an item described as PIC 9999/99/99 occupies ten character positions when printed. You need to be aware of this when designing report layouts.

How the Symbols Work

The comma symbol (,) instructs the computer to insert a comma at the character position where the symbol occurs. The comma counts toward the size of the printed item. When used with zero-suppression and replacement or floating insertion, the comma operates in a special way: if all characters to the left of the comma are zeros, the comma is replaced with the appropriate character (currency symbol, asterisk, or space).

The space or blank (B), slash (/), and zero (0) symbols instruct the computer to insert the appropriate character at the position where the symbol occurs in the PICTURE string.

Simple-Insertion Examples

Table 9-3 gives some simple-insertion example PICTURE strings, shows the formatting that these edited pictures apply to data values, and provides a comment that explains what is done.

Table 9-3. Simple-Insertion Examples

Sending		Receiving		Comments
Picture	Data	Picture	Result	
PIC X(8)	MikeRyan	PIC X(4)BBX(4)	Mike□□Ryan	Spaces are inserted. Size = 10 characters.
PIC X(9)	10Jan2013	PIC XX/XXX/(4)	10/Jan/2013	Slashes are inserted. Size = 11 characters.
PIC 9(6)	123456	PIC 999,999	123,456	Comma is inserted. Size = 7 characters.
PIC 9(6)	000045	PIC 9(3),9(3)	000,045	Comma is inserted. Note the leading zeros. Size = 7 characters.
PIC 9(6)	000045	PIC ZZZ,ZZZ	□□□□45	Leading zeros are replaced with spaces (represented by □). Because there is a zero to the left of the comma, it is replaced by a space. Size = 7 characters.
PIC 9(6)	000345	PIC ***,***	****345	Zero-suppression and the zero to the left of the comma cause the comma to be replaced by an asterisk. Size = 7 characters.
PIC 9(6)	002345	PIC ***,***	**2,345	Zero-suppression is used, but there is a non-zero to the left of the comma, so the comma is inserted. Size = 7 characters.
PIC 9(8)	12252013	PIC 99B99B9999	12□25□2013	Spaces are inserted. Size = 10 characters.
PIC 9(8)	12252013	PIC 99/99/9999	12/25/2013	Slashes are inserted. Size = 10 characters.
PIC 9(6)	7654329	PIC 990099	430029	No explicit decimal point in either the sending or receiving field means each is treated as if it had a decimal point in the rightmost position. The zero characters are inserted, so there is only room in the data for four of the sending field's digits. After decimal-point alignment, digits 765 are truncated. Size = 6 characters.
PIC 9(4)V999	7654329	PIC 999.009	654.003	The assumed decimal point aligns with the actual decimal point in the receiving field, causing the most significant digit (7) to be truncated. The zero characters are inserted after the decimal point, which only leaves room for one digit; so the digits 29 are truncated on the left. Size = 7 characters.

Special-Insertion Editing

The only special-insertion symbol is the decimal point. The decimal-point insertion symbol has the effect of inserting an actual decimal point into the edited item. This type of editing is called *special insertion* because of the effect on data moved into the edited item. Data sent to the edited field is aligned along the decimal point, with zero-filling or truncation as required. The decimal point is inserted in the character position where the symbol occurs, and there may be only one decimal point. The decimal-point symbol cannot be mixed with either the V (assumed decimal point) or the P (scaling position) symbol. The purpose and operation of the P symbol is explored later in this chapter.

Special-Insertion Examples

Table 9-4 gives some special-insertion example picture strings and shows the formatting that these edited pictures apply to data values. You probably noticed that the last example in Table 9-3 was an example of special insertion as well as simple insertion.

Table 9-4. *Special-Insertion Editing Examples*

Sending		Receiving		Comments
Picture	Data	Picture	Result	
PIC 9(3)V99	63485	PIC 9999.99	0634.85	The decimal point is inserted; and after alignment, the digits of the sending item are inserted to the left and right of the decimal point, with the result that there is zero-filling on the left. Size = 7 characters.
		<td></td>		
PIC 9(4)V99	063485	PIC 9999.9	0634.8	The decimal point is inserted; and after alignment, the digits of the sending item are inserted to the left and right of the decimal point, with the result that there is truncation on the right (5). Size = 6 characters.
		<td></td>		
PIC 9(4)V99	363485	PIC 999.99	634.85	The decimal point is inserted; and after alignment, the digits of the sending item are inserted to the left and right of the decimal point with the result that there is truncation on the left (3). Size = 6 characters.
		<td></td>		
PIC 9(4)	3485	PIC 999.99	485.00	The decimal point is inserted. The sending field is treated as if it had a decimal point in the rightmost position. After alignment, there is truncation of the leftmost digit (3) and zero-filling on the left. Size = 6 characters.
		<td></td>		

Fixed-Insertion Editing

Fixed-insertion editing is so named because it inserts the edit symbol in a fixed position at the beginning or end of the edited item. The fixed insertion editing symbols are as follows:

- The plus (+) and minus (-) signs
- The letters CR and DB, representing credit and debit
- The currency symbol (usually the \$ sign)

Like the other insertion edit symbols, the fixed-insertion symbols count toward the size of the printed item.

Plus and Minus Symbols

The plus (+) and minus (-) symbols must be placed in the first or last character position of the PICTURE string. The operation of the plus and minus edit symbols is not as straightforward as it may appear. The rules governing their operation are as follows:

- If the plus symbol is specified, then a minus sign is inserted if the value is negative and a plus sign is inserted if the value is positive.
- If the minus symbol is specified, then a minus sign is inserted if the value is negative but a *space* is inserted if the value is positive. So the minus symbol is only used to highlight negative values. If you always want the appropriate sign to be inserted, use the plus symbol.

CR and DB

CR and DB stand for credit and debit, respectively. But what a credit is and what a debit is depends on which side of the balance sheet you are on. Therefore, the rule with the CR and DB symbols is that both are inserted only if the value is negative. CR and DB count toward the data-item size, occupy two character positions, and may only appear in the last character position of the edit PICTURE string.

The Currency Symbol

The currency symbol (usually \$) must be one of the leading characters of the edit PICTURE string. It may be preceded by a plus or a minus sign.

The default currency symbol is the dollar sign (\$); but as shown in Listing 9-2, it may be changed to a different symbol by the CURRENCY SIGN IS clause, in the SPECIAL-NAMES paragraph, CONFIGURATION SECTION, ENVIRONMENT DIVISION.

Listing 9-2. Using the CURRENCY SIGN Clause to Change the Currency Symbol

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing9-2.
AUTHOR. Michael Coughlan.
```

```
ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SPECIAL-NAMES.
```

CURRENCY SIGN IS "£".

```
DATA DIVISION.
WORKING-STORAGE SECTION.
01 Edit1      PIC $$$,ff9.99.
```

```
PROCEDURE DIVISION.
```

```
Begin.
```

```
  MOVE 12345.95 TO Edit1
  DISPLAY "Edit1 = " Edit1
  STOP RUN.
```

Listing 9-2 Output

```
Edit1 = £12,345.95
```

In Listing 9-3, multiple currency sign declarations are used to create a currency converter program. Several CURRENCY SIGN declarations are made (note that while there are several clauses there is only one sentence and hence one period) and then each edited picture uses the appropriate currency symbol.

Listing 9-3. Using Multiple CURRENCY SIZE clauses

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing9-3.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SPECIAL-NAMES.
  CURRENCY SIGN IS "£"
  CURRENCY SIGN IS "$"
  CURRENCY SIGN IS "¥".
DATA DIVISION.
WORKING-STORAGE SECTION.
01 DollarValue      PIC 9999V99.

01 PrnDollarValue   PIC $$$,$$9.99.
01 PrnYenValue      PIC ¥¥¥,¥¥9.99.
01 PrnPoundValue    PIC $$$,ff9.99.

01 Dollar2PoundRate PIC 99V9(6) VALUE 0.640138.
01 Dollar2YenRate   PIC 99V9(6) VALUE 98.6600.

PROCEDURE DIVISION.
Begin.
  DISPLAY "Enter a dollar value to convert :- " WITH NO ADVANCING
  ACCEPT DollarValue
  MOVE DollarValue TO PrnDollarValue

  COMPUTE PrnYenValue ROUNDED = DollarValue * Dollar2YenRate

  COMPUTE PrnPoundValue ROUNDED = DollarValue * Dollar2PoundRate
```

```

DISPLAY "Dollar value   = " PrnDollarValue
DISPLAY "Yen value     = " PrnYenValue
DISPLAY "Pound value  = " PrnPoundValue

```

Listing 9-3 Output	
Enter a dollar value to convert :-	123.45
Dollar value =	\$123.45
Yen value =	¥12,179.58
Pound value =	£79.03

Fixed-Insertion Examples

Table 9-5 gives examples of fixed insertion using the plus and minus edit symbols. Table 9-6 does the same for the CR and DB edit symbols.

Table 9-5. Fixed-Insertion Editing with the Plus and Minus Symbols

Sending		Receiving		Comments
Picture	Data	Picture	Result	
PIC S9(4)	-4174	PIC -9999	-4174	A negative value moved into an item edited with a minus sign inserts the minus sign. Size = 5 characters.
PIC S9(4)	-4174	PIC 9999-	4174-	When the minus sign is in the last character position, the minus is inserted into the last character position. Size = 5 characters.
PIC S9(4)	+4174	PIC -9999	□4174	A positive value moved into an item edited with a minus sign inserts a space character in the position of the minus symbol. Size = 5 characters.
PIC S9(4)	+4174	PIC +9999	+4174	A positive value moved into an item edited with a plus sign inserts a plus sign. Size = 5 characters.
PIC S9(4)	-174	PIC +9999	-0174	A negative value moved into an item edited with a plus sign inserts a minus sign. Size = 5 characters.
PIC S9(4)	-174	PIC 9999+	0174-	A negative value moved into an item edited with a plus sign inserts a minus sign in the character position of the plus symbol. Size = 5 characters.

Table 9-6. *Fixed-Insertion Editing with CR, DB, and the Currency Symbol*

Sending		Receiving		Comments
Picture	Data	Picture	Result	
PIC 999	174	PIC \$9999	\$0174	The \$ sign is inserted. Size = 5 characters.
PIC S999	-174	PIC -\$9999	-\$0174	The minus symbol is used before the \$ and the value is negative, so both are inserted. Size = 6 characters.
PIC S999	-174	PIC -\$9999CR	-\$0174CR	The minus symbol is used at the start of the edit string and CR at the end. The value is negative, so the minus and CR are both inserted. Size = 8 characters.
PIC S999	+174	PIC +\$9999CR	+\$0174□□	A plus sign is used before the \$ and the value is positive, so a plus sign is inserted. The CR symbol is used; but because the value is positive, spaces are inserted. Size = 8 characters.
PIC S9(4)	-4174	PIC 9999CR	4174CR	The value is negative, so CR is inserted. Size = 6 characters.
PIC S9(4)	+4174	PIC 9999CR	4174□□	The value is positive, so spaces are inserted. Size = 6 characters.
PIC S9(4)	-4174	PIC 9999DB	4174DB	The value is negative, so DB is inserted. Size = 6 characters.
PIC S9(4)	+4174	PIC 9999DB	4174□□	The value is positive, so spaces are inserted. Size = 6 characters.
PIC S9(4)	-174	PIC 9999+	0174-	A negative value moved into an item edited with a plus sign inserts a minus sign in the character position of the plus symbol. Size = 5 characters.

Floating Insertion

The problem with fixed-insertion editing is that data formatted using it can be somewhat unsightly. Values like \$00019,825.75 and -0000135 are more acceptably presented as \$19,825.75 and -135. What makes these formats more presentable is that the leading zeros have been suppressed and the editing symbol has been “floated” up against the first non-zero digit. In COBOL, this effect can be achieved using floating insertion. Floating insertion can only be applied to numeric-edited data items.

The floating-insertion symbols are the plus and minus signs and the currency symbol. Floating insertion suppresses leading zeros and floats the insertion symbol up against the first non-zero digit. Every floating symbol counts toward the size of the printed item. Each floating-insertion symbol—with the exception of the leftmost symbol, which is always inserted—is a placeholder that may be replaced by a space or a digit. This means at least one symbol is always inserted, even though this may be at the cost of truncating the number.

Floating-Insertion Examples

The examples in Table 9-7 show how you can use floating-insertion editing. You should pay particular attention to how floating insertion deals with the comma when this symbol is combined with the floating-insertion symbols (see the second example).

Table 9-7. *Floating-Insertion Editing with Plus, Minus, and the Currency Symbol*

Sending		Receiving		Comments
Picture	Data	Picture	Result	
PIC 9(4)V99	000000	PIC \$\$,\$\$9.99	****\$0.00	The currency symbol floats against the digit in the leftmost numeric position. The zeros to the left of the currency symbol are replaced by spaces. Size = 9 characters.
PIC 9(4)V99	174.75	PIC \$\$,\$\$9.99	**\$174.75	The currency symbol replaces the comma because there are no digits to the left of the comma (rule prevents \$,174.75). Size = 9 characters.
PIC 9(4)V99	4174.75	PIC \$\$,\$\$9.99	\$4,174.75	A comma is inserted. Size = 9 characters.
PIC 9(4)V99	4174.75	PIC \$\$,\$\$9.00	\$4,174.00	The zeros are inserted to the right of the decimal point. After decimal-point alignment, the least significant digits (75) of the value are lost. Size = 9 characters.
PIC 9(5)V99	34174.75	PIC \$\$,\$\$9.99	\$4,174.75	The leftmost currency symbol cannot be replaced by a digit, which means after alignment the most significant digit (3) is lost. Size = 9 characters.
PIC S9(3)	-26	PIC +++9	*-26	The character positions to the left of the currency symbol are occupied by spaces. Size = 4 characters.
PIC S9(3)	+426	PIC +++9	+426	Size = 4 characters.
PIC S9(3)	-426	PIC ---9	-426	Size = 4 characters.
PIC S9(3)	+426	PIC ---9	□426	A positive value and the minus symbol mean the symbol is replaced by space. Size = 4 characters.
PIC S9(4)	+6426	PIC +++9	+426	The leftmost plus symbol cannot be replaced by a digit, which means after alignment the most significant digit (6) is lost. Size = 4 characters.

Suppression-and-Replacement Editing

Suppression-and-replacement editing is used to replace leading zeroes from the value to be edited with the replacement symbol. Like floating insertion, suppression and replacement can only be applied to numeric-edited data items. There are two varieties of suppression-and-replacement editing:

- Suppression of leading zeros and replacement with spaces
- Suppression of leading zeros and replacement with asterisks

The suppression and replacement symbols are the letter Z and the asterisk (*). Using Z in an edited picture instructs the computer to suppress a leading zero in that character position and replace it with a space. Using * in an edited picture instructs the computer to replace a leading zero with an asterisk. The picture clause symbol 9 cannot appear to the left of the replacement symbols (Z or *). If all the character positions in a data item are Z editing symbols and the sending item is 0, then only spaces will be printed. Replacement with spaces is done for aesthetic reasons, but replacement with asterisks is often done as a security measure on checks.

Suppression-and-Replacement Examples

Table 9-8 shows how you can use suppression and replacement. As with the examples in Table 9-7, you should pay particular attention to how suppression-and-replacement editing deals with the comma when this symbol is combined with the replacement symbols.

Table 9-8. *Suppression-and-Replacement Editing Examples*

Sending		Receiving		Comments
Picture	Data	Picture	Result	
PIC 9(4)	0000	PIC Z,ZZZ	□□□□□	The value is zero, and the edit string instructs the computer to replace the leading zeros with spaces. Size= 5 characters.
PIC 9(4)	8317	PIC Z,Z99	8,317	If there are no leading zeros, there is no replacement. Size= 5 characters.
PIC 9(4)	0317	PIC Z,Z99	□□317	When there are only zeros to the left of the comma, the comma is replaced with the replacement symbol. Size= 5 characters.
PIC 9(4)	0007	PIC Z,Z99	□□□07	The edited value is 07 because the edit picture does not require replacement for the last two digits. Size= 5 characters.
PIC 9(4)	0000	PIC ****	****	The value is zero, and the edit string instructs the computer to replace the leading zeros with asterisks. Size= 4 characters.
PIC 9(4)	0083	PIC ****	**83	Leading zeros are replaced with asterisks. Size= 4 characters.

(continued)

Table 9-8. (continued)

Sending		Receiving		Comments
Picture	Data	Picture	Result	
PIC 9(4)	8317	PIC \$*,**9.00	\$8,317.00	No replacement occurs, but the currency symbol, comma, and zeros are inserted. Size = 9 characters.
PIC 9(4)	0317	PIC \$*,**9.00	***317.00	The comma is replaced with an asterisk. Size = 9 characters.
PIC 9(4)	0017	PIC \$*,999.00	***017.00	The comma is replaced with an asterisk. Size = 9 characters.

Example Print Lines

Example 9-1 shows some print lines. Note how the edit symbol B is used for spacing. If this were not done, additional data items filled with spaces, as shown in Example 9-2, would have to be used.

Example 9-1. Example Print Lines Containing Edited Pictures

```

01 Cust-Sales-Line.
02 Prn-Cust-Name      PIC X(20).
02 Prn-Cust-Id       PIC BBB9(5).
02 Prn-Cust-Sales    PIC B(5)ZZ9.
02 Prn-Qty-Sold      PIC B(5)ZZ,ZZ9.
02 Prn-Sales-Value   PIC BBBB$$$,$$9.99.

01 Total-Sales-Line.
02 FILLER             PIC X(33) VALUE SPACES.
02 FILLER             PIC X(19) VALUE "TOTAL SALES      :".
02 Prn-Total-Sales   PIC B(6)ZZ,ZZ9.

```

Example 9-2. Spacing with Space-Filled Data Items

```

01 Cust-Sales-Line.
02 Prn-Cust-Name      PIC X(20).
02 FILLER             PIC XXX VALUE SPACES.
02 Prn-Cust-Id       PIC 9(5).
02 FILLER             PIC X(5) VALUE SPACES.
02 Prn-Cust-Sales    PIC ZZ9.
02 FILLER             PIC X(5) VALUE SPACES.
02 Prn-Qty-Sold      PIC ZZ,ZZ9.
02 FILLER             PIC X(4) VALUE SPACES.
02 Prn-Sales-Value   PIC $$$,$$9.99.

```

Immediate Editing

I noted earlier that the moment a value is placed into an edited data item, the value is modified according to the formatting specified by the edit string. This section examines examples that show some of the interesting effects you can achieve by taking advantage of the way editing works.

In Figure 9-1, the data item SouthAfricanPay uses the dollar sign as the floating-insertion symbol. Obviously, this is a problem. The currency of South Africa is the Rand, which is represented by the character *R*. What you want is a floating *R* character rather than a floating dollar sign. Unfortunately, you cannot change the currency symbol to *R* using the CURRENCY SIGN clause: restrictions are placed on the characters that can be used with that clause, and *R* is one of the restricted characters. So what can you do? Immediate editing gives you the answer. You replace the dollar sign that has floated against the number, with an *R*.

```
01 SouthAfricanPay PIC $$$,$$9.99.
```

```
:: :: :: :: :: :: :: :: ::
```

```
MOVE 12345.67 TO SouthAfricanPay.
INSPECT SouthAfricanPay REPLACING ALL "$" BY "R".
DISPLAY SouthAfricanPay
```

	01 SouthAfricanPay PIC \$\$\$,\$\$9.99.
After MOVE	\$12,345.67
After INSPECT	R12,345.67

Figure 9-1. The floating Rand symbol

Example Program

Listing 9-4 uses zero suppression and replacement by asterisks to create a starred rating system. In this system, a rating of 5 is shown as 5 asterisks, 4 is shown as 4 asterisks, and so on. The COMPUTE statement produces the values 10000, *1000, **100, ***10, ****1, and *****. The INSPECT replaces each 1 and each 0 in Stars with a space. INSPECT Stars CONVERTING "10" TO SPACES is a shorthand way of writing - INSPECT Stars REPLACING ALL "1" BY SPACE, ALL "0" BY SPACE. You'll examine INSPECT in detail in Chapter 15.

Listing 9-4. Starred Rating System

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing9-4.
AUTHOR. Michael Coughlan.

DATA DIVISION.
WORKING-STORAGE SECTION.
01 Stars          PIC *****.
01 NumOfStars     PIC 9.
```

PROCEDURE DIVISION.

Begin.

```
PERFORM VARYING NumOfStars FROM 0 BY 1 UNTIL NumOfStars > 5
  COMPUTE Stars = 10 ** (4 - NumOfStars)
  INSPECT Stars CONVERTING "10" TO SPACES
  DISPLAY NumOfStars " = " Stars
END-PERFORM
STOP RUN.
```

Listing 9-4 Output

0 =

1 = *

2 = **

3 = ***

4 = ****

5 = *****

PICTURE String Restrictions

Some combinations of picture symbols are not permitted. Table 9-9 shows the combinations of symbols that are allowed. You should now be familiar with all these PICTURE symbols except P: the P symbol is a scaling symbol.

Table 9-9. PICTURE String Restrictions

Character	May Be Followed By
P	P B 0 / , + - CR DB 9 V
B	P B 0 / , . + - CR DB 9 V
0	P B 0 / , . + - CR DB 9 V
/	P B 0 / , . + - CR DB 9 V
,	P B 0 / , . + - CR DB 9 V
.	B 0 / , . + - CR DB 9
+	P B 0 / , . + \$ 9 V
-	P B 0 / , . - \$ 9 V
CR or DB	Nothing at all
\$	P B 0 / , . + - CR DB \$ 9 V
9	P B 0 / , . + - CR DB 9 V
V	B 0 / , + - CR DB 9

The PICTURE Clause Scaling Symbol

The P symbol in a PICTURE clause specifies a decimal-point scaling position. It is used to save storage when the magnitude of a number is significantly larger than the required precision. For instance, suppose you are required to store numbers that contain whole billions. You could use a declaration such as PIC 9(12), which requires 12 characters, or you could use the scaling symbol P to define the item as PIC 999P(9). This definition requires only three characters and can store a value between 001,000,000,000 and 999,000,000,000.

The P symbol is not often used, but a description of how it operates is included here for completeness. By default, when no assumed decimal point is explicitly defined, the data item is treated as if it had a decimal point in the rightmost position. The P symbol allows you to change that by defining the assumed decimal point to be to the left or right of the digits, depending on where the P symbol is placed. Each P symbol represents one decimal scaling position.

In Example 9-3, LargeScaledNumber occupies only three characters of storage but can hold a value as high as 99,900,000. Similarly, ScaledBillions occupies only three characters of storage but can hold a number as large as 999,000,000,000, while SmallScaledNumber can hold a number as small as 0.00000001.

Example 9-3. Scaling, Which Allows Numbers to Be Defined Using Less Storage

```
01 SmallScaledNumber PIC P(5)999 VALUE .00000423.
01 LargeScaledNumber PIC 999P(5) VALUE 45600000.00.
01 ScaledBillions    PIC 999P(9)    VALUE ZEROS.
```

Rules

If the symbol P is used more than once, it can only occur as a contiguous string of Ps at the leftmost or rightmost end of the PICTURE string. The assumed decimal point symbol (V) can be used for clarity, but it has no semantic effect, and when used it must appear to the left of the leftmost P or to the right of the rightmost P. For instance, to clarify where the decimal point is, you could define the Example 9-3 data items as follows:

```
01 SmallScaledNumber PIC VPPPPP999 VALUE .00000423.
01 LargeScaledNumber PIC 999PPPPPV VALUE 45600000.00.
01 ScaledBillions    PIC 999PPPPPPPPV VALUE ZEROS.
```

The P symbols do not count toward the size of the item. However, each P counts toward the maximum number of digit positions (18) in a numeric item.

The P symbol cannot be used if the explicit decimal-point edit symbol is used in the PICTURE string.

All computations and other operations performed against scaled data items behave as if the decimal point were in the scaled position. For instance, as shown in Listing 9-5, the result of adding `LargeScaledNumber` to the data item containing the value 11,111,111.00 is 56,711,111.00.

Listing 9-5. Using the Scaling Symbol P

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing9-5.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 SmallScaledNumber PIC VP(5)999 VALUE .00000423.
01 LargeScaledNumber PIC 999P(5)V VALUE 45600000.00.
01 ScaledBillions PIC 999P(9) VALUE ZEROS.

01 SmallNumber PIC 9V9(8) VALUE 1.11111111.
01 LargeNumber PIC 9(8)V9 VALUE 11111111.

01 PrnSmall PIC 99.9(8).
01 PrnLarge PIC ZZ,ZZZ,ZZ9.99.
01 PrnBillions PIC ZZZ,ZZZ,ZZZ,ZZ9.

PROCEDURE DIVISION.
Begin.
MOVE SmallScaledNumber TO PrnSmall
MOVE LargeScaledNumber TO PrnLarge
DISPLAY "Small scaled = " PrnSmall
DISPLAY "Large scaled = " PrnLarge

ADD SmallScaledNumber TO SmallNumber
ADD LargeScaledNumber TO LargeNumber
MOVE SmallNumber TO PrnSmall
MOVE LargeNumber TO PrnLarge
DISPLAY "Small = " PrnSmall
DISPLAY "Large = " PrnLarge

MOVE 123456789012 TO ScaledBillions
MOVE ScaledBillions TO PrnBillions
DISPLAY "Billions = " PrnBillions
STOP RUN.
```

Listing 9-5 Output

```
Small scaled = 00.00000423
Large scaled = 45,600,000.00
Small = 01.11111534
Large = 56,711,111.00
Billions = 123,000,000,000
```

Summary

This chapter continued the exploration of printed output that began in the last chapter. You discovered how data can be formatted for output using edited pictures. You explored the different kinds of editing supported by COBOL, from simple insertion of the comma, the currency symbol, and the plus and minus signs; to the more sophisticated floating insertion, which floats these last symbols against the number being displayed or printed; to zero-suppression and replacement with asterisks or spaces. You learned that the editing effect is immediate, and you saw some of the interesting post-edit manipulations you can do on the edited data item. Finally, you examined how the PICTURE symbol P may be used to store a very large or very small value in only a few characters of storage.

The next chapter examines some of the problems of processing sequential files. In particular, you look at some of the difficulties of the file-update problem and learn how to write control-break programs.

LANGUAGE KNOWLEDGE EXERCISE

The time has come once more to unlimber those 2B pencils and answer some exercise questions.

1. For each part, examine the formatted results produced for the various data values. Deduce what the edited picture would have to be to produce the formatted results shown from the data values given.

a.

Sending	Data	Result	Edited Picture
PIC 9(5)	12345	12345	
	01234	*1234	
	00123	**123	
	00012	**012	

b.

Sending	Data	Result	Edited Picture
PIC 9(6)	412345	\$12345	
	000123	**\$123	
	000001	****\$1	
	000000	*****	

c.

Sending	Data	Result	Edited Picture
PIC 9(6)V99	012345	\$123.00	
	000123	\$**1.00	
	000025	**0.00	
	000000	**0.00	

d.

Sending	Data	Result	Edited Picture
PIC S9(4)	1234	+1234	
	-0012	**_12	
	0004	***+4	
	0000	*****	

2. Show the formatted result that will be produced when the data value is moved to the edited picture.

Sending	Data	Result	Edited Picture
9(6)	000321		PIC ZZZ,999
9(6)	004321		PIC ZZZ,999
9(6)	000004		PIC ZZZ,999
9(6)	654321		PIC ZZZ,ZZZ.00
9999V99	654321		PIC ZZZ,ZZZ.ZZ
9999V99	004321		PIC \$\$,\$\$9.99
9999V99	000078		PIC \$\$,\$\$9.99
9999V99	000078		PIC \$Z,ZZ9.99
S9999V99	000078		PIC \$Z,ZZ9.99CR
S9999V99	-045678		PIC \$Z,ZZ9.99CR
S9(6)	-123456		PIC -999,999
S9(6)	123456		PIC -999,999
S9(6)	123456		PIC +999,999
S9(6)	-123456		PIC +999,999
S9(6)	001234		PIC +++++,++9
9(6)	123456		PIC 99B99B99
9(6)	001234		PIC Z(6).00
9(6)	000092		PIC ZZZZZZ00
X(5)	123GO		PIC XBXBXBBXX
9999V99	000123		PIC \$\$\$,**9.99
99999V99	24123.45		PIC \$\$,\$\$9.99

PROGRAMMING EXERCISE 1

The Genealogists Society of Ireland wishes to discover the most popular surname used in each of the 26 counties in the Irish Republic. In order to obtain this information, the society has acquired a file containing a subset of data from the most recent census.

Write a program that will process the census file and produce a report that shows, for each county, the most popular surname and the number of times it occurs.

The census file is a standard sequential file with fixed-length fields. Each record contains a census number, a surname, and a county name. The file has been sorted and is now ordered on ascending `Surname` within ascending `CountyName`. Each record in the file has the following description:

Field	Type	Length	Value
CensusNumber	N	8	00000001-99999999
Surname	X	20	-
CountyName	X	9	-

The report should take the format shown in the following report template. The `Count` field is a count of the number of times the surname occurs in the county. In the `Count` field, thousands should be separated using a comma; and the field should be zero-suppressed up to, but not including, the last digit:

```

      Popular Surname Report
CountyName Surname          Count
Carlow     XXXXXXXXXXXXXXXXXXXX XXX,XXX
Cavan      XXXXXXXXXXXXXXXXXXXX XXX,XXX
Clare      XXXXXXXXXXXXXXXXXXXX XXX,XXX
:: :: ::  :: :: ::  :: :: ::  :: ::
Westmeath  XXXXXXXXXXXXXXXXXXXX XXX,XXX
Wicklow    XXXXXXXXXXXXXXXXXXXX XXX,XXX
Wexford    XXXXXXXXXXXXXXXXXXXX XXX,XXX
***** end of report *****

```

LANGUAGE KNOWLEDGE EXERCISES: ANSWERS

The time has come once more to unlimber those 2B pencils and answer the following exercise questions.

1. For each part, examine for formatted results produced for the various data values. Deduce what the edited picture would have to be to produce the formatted results from the data values given.

a.

Sending	Data	Result	Edited Picture
PIC 9(5)	12345	12345	PIC ZZ999
	01234	*1234	
	00123	**123	
	00012	**012	

b.

Sending	Data	Result	Edited Picture
PIC 9(6)	412345	\$12345	PIC \$(6) or \$\$\$\$\$\$
	000123	**\$123	
	000001	****\$1	
	000000	*****	

c.

Sending	Data	Result	Edited Picture
PIC 9(6)V99	012345	\$123.00	PIC \$ZZ9.00
	000123	**1.00	
	000025	**0.00	
	000000	**0.00	

d.

Sending	Data	Result	Edited Picture
PIC S9(4)	1234	+1234	PIC +(5) or +++++
	-0012	** - 12	
	0004	***+4	
	0000	*****	

2. Show the formatted result that will be produced when the data value is moved to the edited picture.

Sending	Data	Result	Edited Picture
9(6)	000321	***321	PIC ZZZ,999
9(6)	004321	**4,321	PIC ZZZ,999
9(6)	000004	****004	PIC ZZZ,999
9(6)	654321	654,321.00	PIC ZZZ,ZZZ.00
9999V99	654321	**6,543.21	PIC ZZZ,ZZZ.ZZ
9999V99	004321	***\$43.21	PIC \$\$,\$\$9.99
9999V99	000078	****\$0.78	PIC \$\$,\$\$9.99
9999V99	000078	\$****0.78	PIC \$Z,ZZ9.99
S9999V99	000078	\$****0.78	PIC \$Z,ZZ9.99CR
S9999V99	-045678	**456.78CR	PIC \$Z,ZZ9.99CR
S9(6)	-123456	-123,456	PIC -999,999
S9(6)	123456	*123,456	PIC -999,999
S9(6)	123456	+123,456	PIC +999,999
S9(6)	-123456	-123,456	PIC +999,999
S9(6)	001234	**+1,234	PIC ++++,++9
9(6)	123456	12*34*56	PIC 99B99B99
9(6)	001234	**1234.00	PIC Z(6).00
9(6)	000092	****9200	PIC ZZZZZZ00
X(5)	123GO	1*2*3**GO	PIC XBXXBBXX
9999V99	000123	\$*****1.23	PIC \$**,**9.99
99999V99	24123.45	\$4,123.45	PIC \$\$,\$\$9.99

PROGRAMMING EXERCISE 1: ANSWER

The answer to this exercise is found in the next chapter, where it appears as an example.



Processing Sequential Files

Previous chapters introduced the mechanics of creating and reading sequential files. This chapter introduces the two most important sequential-file processing problems: control breaks and the file update problem.

Both control breaks and the file update problem involve manipulating ordered sequential files so the chapter begins with a discussion of how sequential files are organized and the difference between ordered and unordered sequential files.

The next section discusses control-break problems. These normally occur when a hierarchically structured printed report has to be produced. But control breaks are not limited to printed reports. Any problem that processes a stream of ordered data and requires action to be taken when one of the items on which the stream is ordered changes, is a control-break problem.

The final section introduces the file-update problem. This involves the thorny difficulty of how to apply a sequential file of ordered transaction records to an ordered sequential master file. This section starts gently by showing how transaction files containing updates of only a single type may be applied to a master file. I then discuss the record buffer implications of transaction files that contain different types of records and introduce a simplified version of the file-update problem. Finally, I discuss and demonstrate an algorithm, based on academic research, which addresses the full complexity of the file-update problem.

File Organization vs. Method of Access

Two important characteristics of files are data organization and method of access. *Data organization* refers to the way the file's records are organized on the backing storage device. COBOL recognizes three main types of file organization:

- *Sequential*: Records are organized serially.
- *Relative*: A direct-access file is used and is organized on relative record number.
- *Indexed*: A direct-access file is used and has an index-based organization.

Method of access refers to the way in which records are accessed. Some approaches to organization are more versatile than others. A file with indexed or relative organization may still have its records accessed sequentially; but the records in a sequential file can only be accessed sequentially.

To understand the difference between file organization and method of access, consider them in the context of a library with a large book collection. Most of the books in the library are organized by Dewey Decimal number; but some, awaiting shelving, are organized in the order in which they were purchased. A reader looking for a book in the main part of the library might find it by looking up its Dewey Decimal number in the library index or might just go the particular section and browse through the books on the shelves. Because the books are organized by Dewey Decimal number, the reader has a choice regarding the method of access. But if the desired book is in the newly acquired section, the reader has no choice. They have to browse through all the titles to find the one they want. This is the difference between direct-access files and sequential files. Direct-access files offer a choice of access methods. Sequential files can only be processed sequentially.

Sequential Organization

Sequential organization is the simplest type of file organization. In a sequential file, the records are arranged serially, one after another, like cards in a dealing shoe. The only way to access a particular record is to start at the first record and read all the succeeding records until the required record is found or until the end of the file is reached.

Ordered and Unordered Files

Sequential files may be ordered or unordered (they should really be called *serial* files). In an ordered file, the records are sequenced (see Table 10-1) on a particular field in the record, such as `CustomerId` or `CustomerName`. In an unordered file, the records are not in any particular order.

Table 10-1. *Ordered and Unordered Files*

Ordered File	Unordered File
Record-KeyA	Record-KeyM
Record-KeyB	Record-KeyH
Record-KeyD	Record-KeyO
Record-KeyG	Record-KeyB
Record-KeyH	Record-KeyN
Record-KeyK	Record-KeyA
Record-KeyM	Record-KeyT
Record-KeyO	Record-KeyK
Record-KeyT	Record-KeyG

The ordering of the records in a file has a significant impact on the way in which it is processed and the processing that can be applied to it.

Control-Break Processing

Control-break processing is a technique generally applied to an ordered sequential file in order to create a printed report. But it can also be used for other purposes such as creating a summary file. For control-break processing to work, the input file must be sorted in the same order as the output to be produced.

A control-break program works by monitoring one or more *control items* (fields in the record) and taking action when the value in one of the control items changes (the *control break*). In a control-break program with multiple control-break items, the control breaks are usually hierarchical, such that a break in a major control item automatically causes a break in the minor controls even if the actual value of the minor item does not change. For instance, Figure 10-1 partially models a file that holds details of magazine sales. When the major control item changes from England to Ireland, this also causes the minor control item to break even though its value is unchanged. You can see the logic behind this: it is unlikely that the same individual (Maxwell) lives in both countries.

MagazineSales file

CountryName	CustomerName
England	Abbot
England	Abbot
England	Lowe
England	Lyon
England	Lyon
England	Maxwell
England	Maxwell
Ireland	Maxwell
Ireland	Maxwell
Ireland	Maxwell
Ireland	Molloy
Ireland	Molloy
Ireland	Power
Scotland	Campbell
Scotland	Campbell
Scotland	MacDonald
Scotland	MacKenzie
Scotland	MacKenzie
Scotland	Stewart

Figure 10-1. Partial model of a file containing details of magazine sales. A major control break also causes a break of the minor control item

Specifications that Require Control Breaks

To get a feel for the kinds of problems that require a control-break solution, consider the following specifications.

Specification Requiring a Single Control Break

Write a program to process the UnemploymentPayments file to produce a report showing the annual Social Welfare unemployment payments made in each county in Ireland. The report must be printed and sequenced on ascending CountyName. The UnemploymentPayments file is a sequential file ordered on ascending CountyName.

In this specification, the control-break item is the CountyName. The processing required is to sum the payments for a particular county and then, when the county names changes, to print the county name and the total unemployment payments for that county.

Specification Requiring Two Control Breaks

A program is required to process the MagazineSales file to produce a report showing the total spent by customers in each country on magazines. The report must be printed on ascending CustomerName within ascending CountryName. The MagazineSales file is a sequential file ordered on ascending CustomerName within ascending CountryName.

Figure 10-1 models the MagazineSales file and shows what is meant by “ordered on ascending CustomerName within ascending CountryName.” Notice how the records are in order of ascending country name, but all the records for a particular country are in order of ascending customer name.

In this specification, the control-break items are the CountryName (major) and the CustomerName (minor).

Specification Requiring Three Control Breaks

Electronics2Go has branches in a number of American states. A program is required to produce a report showing the total sales made by each salesperson, the total sales for each branch, the total sales for each state, and a final total of sales for the entire United States. The report must be printed on ascending SalespersonId within ascending BranchId within ascending StateName.

The report is based on the CompanySales file. This file holds details of sales made in all the branches of the company. It is a sequential file, ordered on ascending SalespersonId, within ascending BranchId, within ascending StateName.

In this specification, the control-break items are the StateName (major), the BranchId (minor), and the SalespersonId (most minor).

Detecting the Control Break

A major consideration in a control-break program is how to detect the control break. If you examine the data in Figure 10-1, you can see the control breaks quite clearly. When the country name changes from England to Ireland, a major control break has occurred. When the customer surname changes from Molloy to Power, a minor control break has occurred. It is easy for *you* to see the control breaks in the data file, but how can you detect these control breaks programmatically?

The way you do this is to compare the value of the control field in the record against the previous value of the control field. How do you know the previous value of the control field? You must store it in a data item specifically set up for the purpose. For instance, if you were writing a control-break program for the data in Figure 10-1, you might create the data items PrevCountryName and PrevCustomerName to store the control-break values. Detecting the control break then simply becomes a matter of comparing the values in these fields with the values in the fields of the current record.

Writing a Control-Break Program

The first instinct programmers seem to have when writing a control-break program is to code the solution as a single loop and to use IF statements (often nested IF statements) to handle the control breaks. This approach results in a cumbersome solution. A better technique is to recognize the structure of the data in the data file and in the report and to create a program that echoes that structure. This echoed structure uses a hierarchy of loops to process the control breaks. This idea is not original; it is essentially that advocated by Michael Jackson in Jackson Structured Programming (JSP).¹

When you use this approach, the code for processing each control item becomes

```
Initialize control items (Totals and PrevControlItems)
Loop Until control break
Finalize control items (Print Totals)
```

¹Michael Jackson. Principles of Program Design. Academic Press, 1975.

Control-Break Program Template

Example 10-1 gives a template for writing a control-break program. The program structure echoes the structure of the input and output data. The control breaks are processed by a hierarchy of loops, where the inner loop processes the most minor control break.

Example 10-1. Template for Control-Break Programs

```

OPEN File
Read next record from file
PERFORM UNTIL EndOfFile
    MOVE ZEROS TO totals of ControlItem1
    MOVE ControlItem1 TO PrevControlItem1
    PERFORM UNTIL ControlItem1 NOT EQUAL TO PrevControlItem1
        OR EndOfFile
        MOVE ZEROS TO totals of ControlItem2
        MOVE ControlItem2 TO PrevControlItem2
        PERFORM UNTIL ControlItem2 NOT EQUAL TO PrevControlItem2
            OR ControlItem1 NOT EQUAL TO PrevControlItem1
            OR EndOfFile
            Process record
            Read next record from file
        END-PERFORM
        Process totals of ControlItem2
    END-PERFORM
    Process totals of ControlItem1
END-PERFORM
Process final totals
CLOSE file

```

Three-Level Control Break

Let's see how all this works in an actual example. As the basis for the example, let's use a modified version of the three-control-break specification given earlier.

Electronics2Go has branches in a number of American states. A program is required to produce a summary report showing the total sales made by each salesperson, the total sales for each branch, the total sales for each state, and a final total of sales for the entire United States. The report must be printed on ascending SalespersonId in ascending BranchId in ascending StateName.

The report is based on the Electronics2Go sales file. This file holds details of sales made in all the branches of the company. It is a sequential file, ordered on ascending SalespersonId, within ascending BranchId, within ascending StateName. Each record in the sales file has the following description:

Field	Type	Length	Value
StateName	X	14	-
BranchId	X	5	-
SalespersonId	X	6	99999X (M/F)
ValueOfSale	9	6	0000.00-9999.99

The report format should follow the template in Figure 10-2. In the report template, the `SalesTotal` field is the sum of the sales made by this salesperson. The `Branch Total` is the sum of the sales made by each branch. The `State Total` is the sum of the sales made by all the branches in the state. The `Final Total` is the sum of the sales made in the United States.

```

      Electronics2Go Sales Report
State Name      Branch  SalesId  SalesTotal
XXXXXXXXXXXXXXX XXXXX   XXXXXX  XXXXXXXXX
                XXXXX   XXXXXXXX
                XXXXX   XXXXXXXX
                Branch Total:  XXXXXXXXX

                XXXXX   XXXXXXXX
                XXXXX   XXXXXXXX
                XXXXX   XXXXXXXX
                XXXXX   XXXXXXXX
                Branch Total:   XXXXXXXXX
                State Total:  XXXXXXXXX

XXXXXXXXXXXXXXX XXXXX   XXXXXX  XXXXXXXXX
                XXXXX   XXXXXXXX
                XXXXX   XXXXXXXX
                Branch Total:   XXXXXXXXX

XXXXXXXXXXXXXXX XXXXXX  XXXXXX  XXXXXXXXX
                XXXXX   XXXXXXXX
                XXXXX   XXXXXXXX
                Branch Total:   XXXXXXXXX
                State Total:  XXXXXXXXX
                Final Total: XXXXXXXXX

```

Figure 10-2. Template for the Electronics2Go sales report

In all sales value fields, leading zeros should be suppressed and the dollar symbol should float against the value. The `State Name` and the `Branch` should be suppressed after their first occurrence. For simplicity, the headings are only printed once, so no page count or line numbers need be tracked.

■ **Note** The full state name is used in every record of the sales file. This is a waste of space. Normally a code representing the state would be used, and the program would convert this code into a state name by means of a lookup table. Because you have not yet encountered lookup tables, I have decided to use the full state name in the file.

Three-Level Control-Break Program

Listing 10-1 shows a program that implements the Electronics2Go Sales Report specification.

Listing 10-1. Three-Control-Break Electronics2Go Sales Report

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing10-1.
AUTHOR. Michael Coughlan.
* A three level Control Break program to process the Electronics2Go
* Sales file and produce a report that shows the value of sales for
* each Salesperson, each Branch, each State, and for the Country.
* The SalesFile is sorted on ascending SalespersonId within BranchId
* within Statename.
* The report must be printed in the same order

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
SELECT SalesFile ASSIGN TO "Listing10-1TestData.Dat"
    ORGANIZATION IS LINE SEQUENTIAL.

SELECT SalesReport ASSIGN TO "Listing10-1.RPT"
    ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD SalesFile.
01 SalesRecord.
    88 EndOfSalesFile VALUE HIGH-VALUES.
    02 StateName          PIC X(14).
    02 BranchId          PIC X(5).
    02 SalesPersonId     PIC X(6).
    02 ValueOfSale       PIC 9(4)V99.

FD SalesReport.
01 PrintLine            PIC X(55).

WORKING-STORAGE SECTION.
01 ReportHeading.
    02 FILLER            PIC X(35)
    VALUE "              Electronics2Go Sales Report".

01 SubjectHeading.
    02 FILLER            PIC X(43)
    VALUE "State Name   Branch SalesId SalesTotal".

01 DetailLine.
    02 PrnStateName     PIC X(14).
    88 SuppressStateName VALUE SPACES.
    02 PrnBranchId      PIC BBX(5).
    88 SuppressBranchId VALUE SPACES.
    02 PrnSalespersonId PIC BBBBX(6).
    02 PrnSalespersonTotal PIC BB$$,$$9.99.

```

```

01 BranchTotalLine.
   02 FILLER          PIC X(43)
      VALUE "          Branch Total:  ".
   02 PrnBranchTotal PIC $$$,$$9.99.

01 StateTotalLine.
   02 FILLER          PIC X(40)
      VALUE "          State Total :  ".
   02 PrnStateTotal  PIC $$,$$$,$$9.99.

01 FinalTotalLine.
   02 FILLER          PIC X(39)
      VALUE "          Final Total :".
   02 PrnFinalTotal  PIC $$$,$$$,$$9.99.

01 SalespersonTotal PIC 9(4)V99.
01 BranchTotal      PIC 9(6)V99.
01 StateTotal       PIC 9(7)V99.
01 FinalTotal       PIC 9(9)V99.

01 PrevStateName    PIC X(14).
01 PrevBranchId     PIC X(5).
01 PrevSalespersonId PIC X(6).

```

PROCEDURE DIVISION.

Begin.

```

OPEN INPUT SalesFile
OPEN OUTPUT SalesReport
WRITE PrintLine FROM ReportHeading AFTER ADVANCING 1 LINE
WRITE PrintLine FROM SubjectHeading AFTER ADVANCING 1 LINE

READ SalesFile
  AT END SET EndOfSalesFile TO TRUE
END-READ
PERFORM UNTIL EndOfSalesFile
  MOVE StateName TO PrevStateName, PrnStateName
  MOVE ZEROS TO StateTotal
  PERFORM SumSalesForState
    UNTIL StateName NOT = PrevStateName
    OR EndOfSalesFile
  MOVE StateTotal TO PrnStateTotal
  WRITE PrintLine FROM StateTotalLine AFTER ADVANCING 1 LINE
END-PERFORM

MOVE FinalTotal TO PrnFinalTotal
WRITE PrintLine FROM FinalTotalLine AFTER ADVANCING 1 LINE

CLOSE SalesFile, SalesReport
STOP RUN.

```

```

SumSalesForState.
  WRITE PrintLine FROM SPACES AFTER ADVANCING 1 LINE
  MOVE BranchId TO PrevBranchId, PrnBranchId
  MOVE ZEROS TO BranchTotal
  PERFORM SumSalesForBranch
    UNTIL BranchId NOT = PrevBranchId
      OR StateName NOT = PrevStateName
      OR EndOfSalesFile
  MOVE BranchTotal TO PrnBranchTotal
  WRITE PrintLine FROM BranchTotalLine AFTER ADVANCING 1 LINE.

```

```

SumSalesForBranch.
  MOVE SalespersonId TO PrevSalespersonId, PrnSalespersonId
  MOVE ZEROS TO SalespersonTotal
  PERFORM SumSalespersonSales
    UNTIL SalespersonId NOT = PrevSalespersonId
      OR BranchId NOT = PrevBranchId
      OR StateName NOT = PrevStateName
      OR EndOfSalesFile
  MOVE SalespersonTotal TO PrnSalespersonTotal
  WRITE PrintLine FROM DetailLine AFTER ADVANCING 1 LINE
  SET SuppressBranchId TO TRUE
  SET SuppressStateName TO TRUE.

```

```

SumSalespersonSales.
  ADD ValueOfSale TO SalespersonTotal, BranchTotal, StateTotal, FinalTotal
  READ SalesFile
    AT END SET EndOfSalesFile TO TRUE
  END-READ.

```

Program Notes

The program in Listing 10-1 is fairly straightforward, once you understand that its structure mirrors the structure of the data and the report. It is interesting to contrast this program with a similar program given on the web site *The American Programmer*². That program uses the single loop and IF statement approach mentioned earlier. One objection to this approach is that the three control items are tested for every record in the file.

I draw your attention to the way in which the `StateName` and `BranchId` are suppressed after their first occurrence in Listing 10-1. This is done to make the report look less cluttered. To implement the suppression, the condition-name technique that you have seen in a number of other example programs is used. I could have implemented the suppression using a statement such as `MOVE SPACES TO PrnStateName`, but it would not have been obvious why the data item was being filled with spaces. The purpose of the statement `SET SuppressStateName TO TRUE` is easier to understand.

Test Data and Results

Due to space constraints, Figure 10-3 shows only a portion of the test data file and the report produced from that data is shown.

²The Three Level Subtotal (Control Break) COBOL Program, *TheAmericanProgrammer.Com*, <http://theamericanprogrammer.com/programming/08-brklv3.shtml>.

Electronics2Go Sales Report				Test Data		
State Name	Branch	SalesId	SalesTotal			
Arkansas	KA123	12344M	\$111.11	Arkansas	KA12312344M011111	
		12345F	\$222.22	Arkansas	KA12312345F011111	
		12347M	\$333.33	Arkansas	KA12312345F011111	
		12348F	\$444.44	Arkansas	KA12312347M033333	
		12349M	\$555.55	Arkansas	KA12312348F022222	
		Branch Total:		\$1,666.65	Arkansas	KA12312348F022222
	KA124	23456F	\$666.66	Arkansas	KA12423456F022222	
		23457F	\$777.77	Arkansas	KA12423456F022222	
		23456F	\$888.88	Arkansas	KA12423457F077777	
		Branch Total:		\$2,333.31	Arkansas	KA12423456F044444
	KA128	11345F	\$33.54	Arkansas	KA12423456F044444	
		44444M	\$1,711.16	Arkansas	KA12811345F001117	
		55555M	\$166.75	Arkansas	KA12811345F001118	
		Branch Total:		\$1,911.45	Arkansas	KA12811345F001119
	KA411	00123F	\$4,133.32	Arkansas	KA12844444M055555	
		11111F	\$6,177.90	Arkansas	KA12844444M055555	
		22222M	\$3,157.05	Arkansas	KA12844444M055555	
		Branch Total:		\$13,468.27	Arkansas	KA12844444M002225
		State Total :		\$19,379.68	Arkansas	KA12844444M002226
	Florida	LF111	00123F	\$188.15	Arkansas	KA12855555M003333
33123F			\$39.45	Arkansas	KA12855555M003334	
55123F			\$66.55	Arkansas	KA12855555M003335	
Branch Total:				\$294.15	Arkansas	KA12855555M003336
					Arkansas	KA12855555M003337
				Arkansas	KA41100123F104443	
				Arkansas	KA41100123F204444	
				Arkansas	KA41100123F104445	
				Arkansas	KA41111111F304446	
				Arkansas	KA41111111F104447	
				Arkansas	KA41111111F104448	
				Arkansas	KA41111111F104449	
				Arkansas	KA41122222M100234	
				Arkansas	KA41122222M110235	
				Arkansas	KA41122222M105236	

Figure 10-3. Fragment of the report produced and part of the test data file

An Atypical Control Break

The program in Listing 10-1 is a typical control-break program, but control-break problems come in a variety of shapes and sizes. For instance, you have probably realized by now that Exercise 1 at the end of the last chapter is a control-break problem but not a typical one. I didn't provide a solution at the time because I wanted you discover for yourself some of the difficulties with this kind of problem and how easy it is to get dragged into a convoluted solution. Before I present my solution, let's look at the specification again.

Specification

The Genealogists Society of Ireland wishes to discover the most popular surname used in each of the 26 counties in the Irish Republic. In order to obtain this information, the society has acquired a file containing a subset of data from the most recent census.

A program is required that will process the census file and produce a report that shows, for each county, the most popular surname and the number of times it occurs.

The census file is a standard sequential file with fixed-length fields. Each record contains a census number, a surname, and a county name. The file has been sorted and is now ordered on ascending Surname in ascending CountyName. Each record in the file has the following description:

Field	Type	Length	Value
CensusNumber	9	8	00000001-99999999
Surname	X	20	-
CountyName	X	9	-

The report should take the format shown in the following report template. The Count field is a count of the number of times the Surname occurs in the county. In the Count field, thousands should be separated using a comma, and the field should be zero-suppressed up to, but not including, the last digit:

```

        Popular Surname Report
CountyName Surname                Count
Carlow     XXXXXXXXXXXXXXXXXXXXXXXX   XXX,XXX
Cavan      XXXXXXXXXXXXXXXXXXXXXXXX   XXX,XXX
Clare      XXXXXXXXXXXXXXXXXXXXXXXX   XXX,XXX
:: :: :: :: :: :: :: :: :: ::
Westmeath  XXXXXXXXXXXXXXXXXXXXXXXX   XXX,XXX
Wicklow   XXXXXXXXXXXXXXXXXXXXXXXX   XXX,XXX
Wexford    XXXXXXXXXXXXXXXXXXXXXXXX   XXX,XXX

***** end of report *****

```

Atypical Control-Break Program

This is not a typical control-break program (see Listing 10-2). Instead of printing the total number of occurrences of the surname when there is a change of surname (as a classic control-break program would do), there is a check to see if this surname is the most popular. A line is printed only when the major control item (the county name) changes. When that happens, the county name and the most popular surname are printed. There is a trap here for the unwary: when the control break occurs, it is too late to move the county name to the print line, because at this point the county name in the buffer is the next county. The solution is to move PrevCountyName to the print line or to, as is done in this program, prime the print line with the correct county name before entering the loop that processes all the surnames in that county.

Listing 10-2. Two-Level Control-Break Program Showing the Most Popular Surnames in the Counties of Ireland

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing10-2.
AUTHOR. Michael Coughlan.
* Control Break program to process the Census file and produce
* a report that shows, for each county, the most popular surname
* and the number of times it occurs.
* The Records in the sequential Census file are ordered on
* ascending Surname within ascending CountyName.
* The report must be printed in ascending CountyName order

```

```

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
SELECT CensusFile ASSIGN TO "Listing10-2TestData.Dat"
    ORGANIZATION IS LINE SEQUENTIAL.

```

```

SELECT SurnameReport ASSIGN TO "Listing10-2.RPT"
    ORGANIZATION IS LINE SEQUENTIAL.

```

```

DATA DIVISION.
FILE SECTION.
FD CensusFile.
01 CensusRec.
    88 EndOfCensusFile VALUE HIGH-VALUES.
    02 CensusNum          PIC 9(8).
    02 Surname           PIC X(20).
    02 CountyName        PIC X(9).

```

```

FD SurnameReport.
01 PrintLine            PIC X(45).

```

```

WORKING-STORAGE SECTION.
01 ReportHeading.
    02 FILLER            PIC X(13) VALUE SPACES.
    02 FILLER            PIC X(22)
        VALUE "Popular Surname Report".

01 SubjectHeading.
    02 FILLER            PIC X(42)
        VALUE "CountyName Surname Count".

01 CountySurnameline.
    02 PrnCountyName     PIC X(9).
    02 FILLER            PIC X(3) VALUE SPACES.
    02 PrnSurname        PIC X(20).
    02 PrnCount          PIC BBBZZZ,ZZ9.

01 ReportFooter         PIC X(43)
    VALUE "***** end of report *****".

01 PrevCountyName       PIC X(9).
01 PrevSurname          PIC X(20).
01 MostPopularSurname   PIC X(20).
01 MostPopularCount     PIC 9(6).
01 SurnameCount         PIC 9(6).

```

```

PROCEDURE DIVISION.
Begin.
    OPEN INPUT CensusFile
    OPEN OUTPUT SurnameReport
    WRITE PrintLine FROM ReportHeading AFTER ADVANCING 1 LINE
    WRITE PrintLine FROM SubjectHeading AFTER ADVANCING 1 LINE

```



```

READ CensusFile
  AT END SET EndOfCensusFile TO TRUE
END-READ
PERFORM UNTIL EndOfCensusFile
  MOVE CountyName TO PrevCountyName, PrnCountyName
  MOVE ZEROS TO MostPopularCount
  MOVE SPACES TO MostPopularSurname
  PERFORM FindMostPopularSurname
    UNTIL CountyName NOT EQUAL TO PrevCountyName
      OR EndOfCensusFile
  MOVE MostPopularCount TO PrnCount
  MOVE MostPopularSurname TO PrnSurname
  WRITE PrintLine FROM CountySurnameLine AFTER ADVANCING 1 LINE
END-PERFORM

WRITE PrintLine FROM ReportFooter AFTER ADVANCING 2 LINES
CLOSE CensusFile, SurnameReport
STOP RUN.

```

```

FindMostPopularSurname.
  MOVE Surname TO PrevSurname
  PERFORM CountSurnameOccurs VARYING SurnameCount FROM 0 BY 1
    UNTIL Surname NOT EQUAL TO PrevSurname
      OR CountyName NOT EQUAL TO PrevCountyName
      OR EndOfCensusFile

  IF SurnameCount > MostPopularCount
    MOVE SurnameCount TO MostPopularCount
    MOVE PrevSurname TO MostPopularSurname
  END-IF.

```

```

CountSurnameOccurs.
  READ CensusFile
    AT END SET EndOfCensusFile TO TRUE
  END-READ.

```

Program Notes

The census file is ordered on ascending Surname in ascending CountyName, and that is the same order required for the printed report. The control items are CountyName and Surname. The data items PrevSurname and PrevCountyName are used to detect the control breaks. Similar to Listing 10-1, the structure of this program echoes the structure of the input file and the output report.

Test Data and Results

Figure 10-4 shows the report produced by the program and a small portion of the test data file used.

Popular Surname Report			Test Data	
CountyName	Surname	Count		
CARLOW	BOURKE	32	00660861AGNEW	CARLOW
CAVAN	DOHERTY	1,296	04358072AGNEW	CARLOW
CLARE	O'NEILL	36	04418761AHERN	CARLOW
CORK	COLLINS	10	08311181AHERN	CARLOW
DONEGAL	BROWN	5	07778114AHERN	CARLOW
DUBLIN	SAVAGE	5	06863734AHERN	CARLOW
GALWAY	LYONS	36	04402884AMBROSE	CARLOW
KERRY	COLLINS	6	08685554AMBROSE	CARLOW
KILDARE	BUCKELY	5	07792108ANDREWS	CARLOW
KILKENNY	COLLINS	6	00444018APPLEBY	CARLOW
LAOIS	COAKLEY	7	01057045APPLEBY	CARLOW
LIMERICK	MACDONAGH	40	05662481ASHE	CARLOW
LONGFORD	FINE	5	01031598ASHE	CARLOW
LOUTH	COLLINS	5	00655862ASHE	CARLOW
MAYO	BERRY	4	02988155ASHTON	CARLOW
MEATH	BERRY	5	07726846BAKER	CARLOW
MONAGHAN	WHEALAN	5	07112469BAKER	CARLOW
ROSCOMMON	COLLINS	7	07148094BAKER	CARLOW
SLIGO	ASHTON	4	03879251BARKER	CARLOW
TIPPERARY	COLLINS	6	09206688BARKER	CARLOW
WATERFORD	COUGHLAN	10	09590803BARKER	CARLOW
WESTMEATH	AGNEW	5	01843122BARKER	CARLOW
WEXFORD	BOLGER	6	07123677BARON	CARLOW
WICKLOW	RUTLAND	6	00495541BARR	CARLOW
***** end of report *****			06897641BARRY	CARLOW
			03609815BEGLEY	CARLOW
			04659971BERMINGHAM	CARLOW
			02865489BERMINGHAM	CARLOW

Figure 10-4. The report produced by the program, and part of the test data file

Updating Sequential Files

It is easy to add records to an unordered sequential file because you can simply add them to the end of the file by opening the file for EXTEND. For instance:

```
OPEN EXTEND UnorderedFile
WRITE UnorderedRec
```

When a file is OPENed for EXTEND, the Next Record Pointer is positioned at the end of the file. When records are written to the file, they are appended to the end.

Although you can add records to an unordered sequential file, the records in a sequential file cannot be deleted or updated *in situ*. The only way to delete records from a sequential file is to create a *new file*, which does not contain them; and the only way to update records is to create a *new file* that contains the updated records. A record update involves changing the value of one or more of its fields. For instance, you might change the value of the CustomerAddress or CustomerPhoneNumber field of a customer record, or you might change the value of the QtyInStock or ReorderLevel field of a stock record.

■ **COBOL Detail** Although, in standard COBOL, sequential files cannot be deleted or updated *in situ* many vendors, including Micro Focus, allow this for disk-based files.

Because updating or deleting records in a sequential file requires you to read all the records in the file and to create a new file that has the changes applied to it, it is computationally too expensive to apply these operations to the file one at a time. Updates to sequential files are normally done in batch mode. That is, all the updates are gathered together into what is often referred to as the *transaction file* and then applied to the target file in one go or *batch*. The target file is often referred to as the *master file*.

As you have seen, you can add records to an unordered sequential file by opening the file for EXTEND and writing the records to the end of it. But if you want to update or delete records, you must have a way of identifying the record you want to update or delete. A *key field* is normally used to achieve this. A key field is a field in the record whose value can be used to identify that record. For instance, in a stock record, the `StockNumber` might be used as the key field. When you apply transaction records to a master file, you compare the key field in the transaction record with that in the master file record. If there is a match, you can apply the delete or update to that master file record. This key-comparison operation is called *record matching*.

For record matching to work correctly, the transaction file and the master file must be ordered on the same key value. Record matching does not work if either file is unordered or if the files are ordered on different key fields. If you need convincing of this, PERFORM (that is, go there, do the exercise, and then come back) the Language Knowledge Exercise at the end of the chapter. That exercise will help you understand the problems of trying to apply batched transactions to an unordered master file.

Applying Transactions to an Ordered Sequential File

You start this section by looking at programming templates that show how to apply each type of transaction (insertion, deletion, and update) to an ordered sequential file. To complicate matters, most transaction files consist of a mixture of transaction types. Therefore, this section considers the data-declaration implications of mixed transaction types, and you examine an example program that applies a variety of transaction types to an ordered sequential file.

Inserting Records in an Ordered Sequential File

When you want to add records to an unordered sequential file, you just OPEN the file for EXTEND and then write the records to the file. You can't do that with an ordered sequential file because if you do, the records will no longer be in order.

When you insert records into an ordered sequential file, a major consideration must be to preserve the ordering. To insert records, you must create a new file that consists of all the records of the old file with the new records inserted into their correct key-value positions. When you are inserting records into an ordered file, you also have to be aware of the possibility that the record you are trying to insert will have the same key value as one already in the file. This is an error condition. For instance, you can't have two customer records with the same `CustomerId` value.

Figure 10-5 is a template that outlines the algorithm required to insert records from an ordered transaction file into their correct positions in an ordered master file. There are three files. The *transaction file* (TF) contains the three records you want to insert. The *master file* (MF) is the file into which you wish to insert these records. Because the MF is a sequential file, the only way to insert the records is to create a new file that contains the inserted records. This is the *new master file* (NMF).

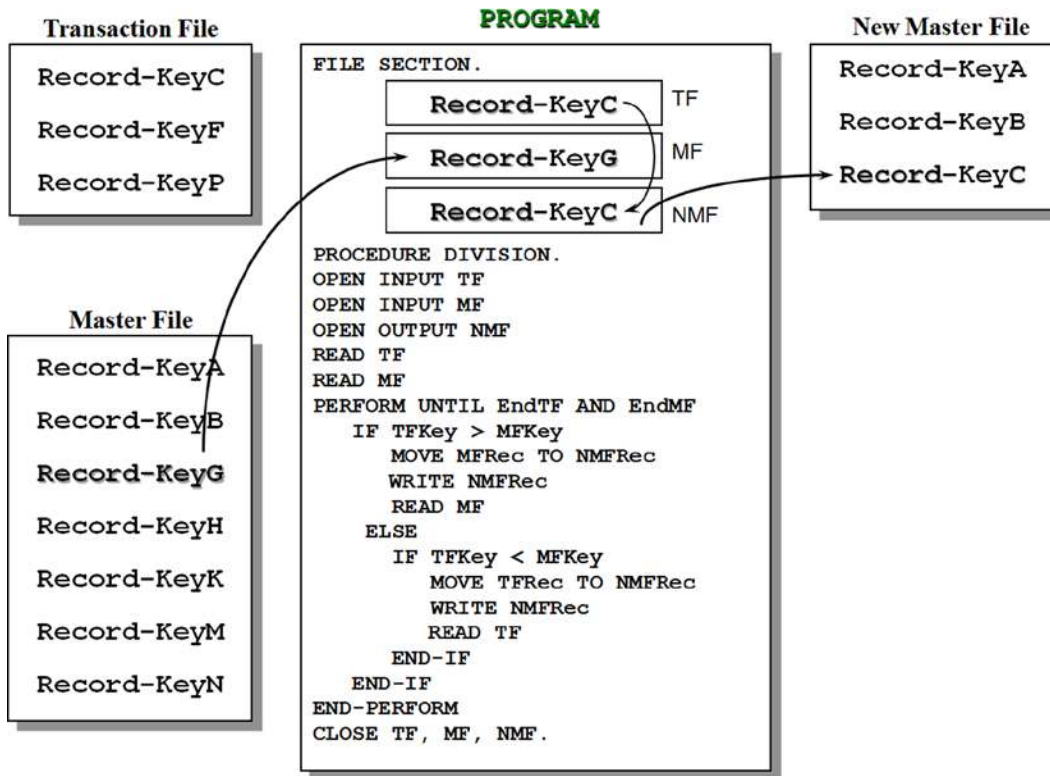


Figure 10-5. Inserting records into an ordered sequential file

The program starts by opening the files and reading a record from each of the two input files. This is the equivalent of the read-ahead technique that you saw in Chapter 5. Before you enter the loop that processes the files, you start with a record in each file buffer. The loop is executed until the end of both files, because regardless of which file ends first, the remaining records of the other must be written to the NMF.

With Record-KeyC in one buffer (TF) and Record-KeyA in the other (MF), the key field values are compared. When the transaction is greater than the master (as is the case here), the condition indicates that the position where the transaction record must be inserted has not yet been reached, so the MF record is written to the NMF. Because the MF record in the buffer has been dealt with (consumed), you read the MF to get a new record. This is the record: Record-KeyB.

When the key values are compared, the transaction key is still greater the master, so this record too is written to the NMF and another is read from the MF. This is the record: Record-KeyG.

Now you have reached the point in the program captured by Figure 10-5. This time, the key value in the TF is less than that of the MF, so the transaction record is written to the NMF. Because the record in the TF buffer has been consumed, a new record is read into the buffer, and the process continues until both files end.

To simplify the template, the condition where the key values are equal has been omitted. If this condition occurs, then a transaction error has occurred, because for record-matching purposes, the key values must be unique.

If you examine the algorithm provided, you might be puzzled that there appears to be no code to write out the remaining records to the NMF when one file ends before the other. The explanation for this lies in the end-of-file condition name associated with each file. These might be described as in Example 10-2.

Example 10-2. Partial Record Descriptions for the Transaction and Master Files

```

FD TransactionFile
01 TFRec.
   88 EndTF  VALUE HIGH-VALUES.
   02 TFKey   PIC X(?).
      etc

FD MasterFile
01 MFRec.
   88 EndMF  VALUE HIGH-VALUES.
   02 MFKey   PIC X(?).
      etc

```

When the end of either file is encountered, its associated condition name is set to true; this has the side effect of filling its record area (including its key field) with HIGH-VALUES (the highest possible character value). Subsequent key comparisons cause the remaining records to be written to the NMF. For instance, from the test data in Figure 10-1, it is clear that the TF will end first. When the EndTF condition name is set to true, TFkey contains HIGH-VALUES. In the key comparison, TFKey is greater than MFKey, and this results in the master record being written to the NMF. If the MF ends first, MFKey is filled with HIGH-VALUES, and the key comparisons then causes the remaining transaction records to be written to the NMF.

Updating Records in an Ordered Sequential File

The template for updating records in an ordered sequential file is shown in Figure 10-6. The diagram captures the program action at the point where Record-KeyH has been read into the TF record buffer and the MF record buffer. Both records are combined to produce the updated record Record-KeyH+, which is then sent to the NMF.

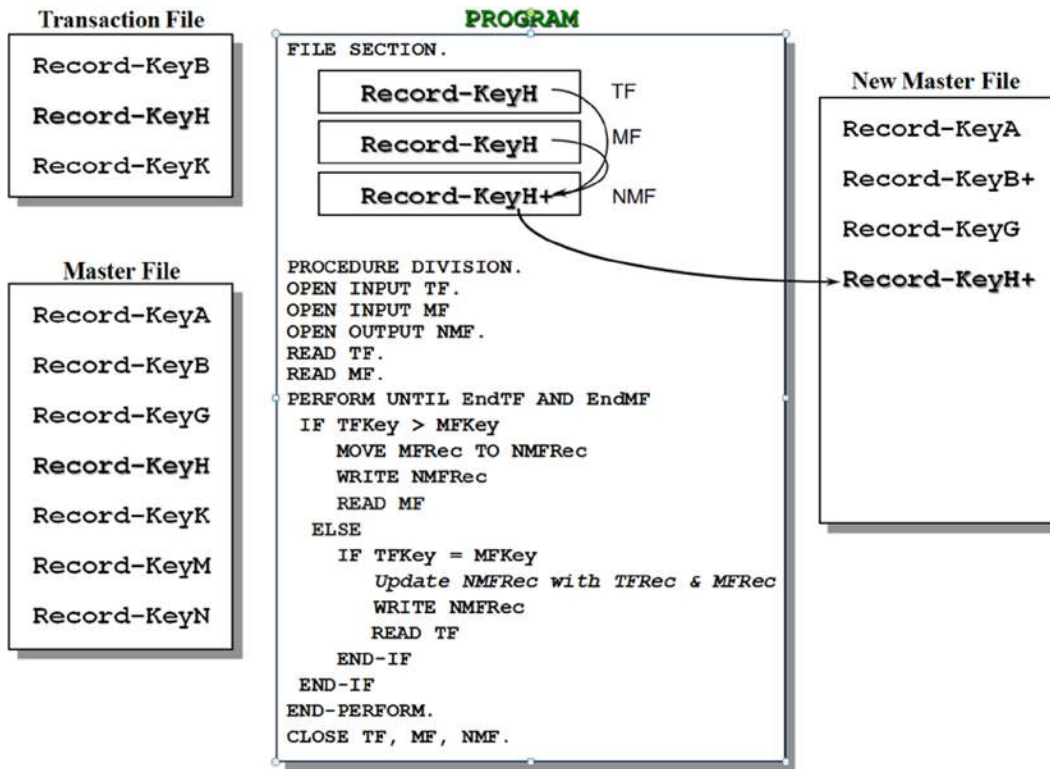


Figure 10-6. Updating records in an ordered sequential file

When you apply an update to the MF, you combine the records from the TF and the MF because the transaction record only consists of the key field and the field(s) to be updated. For instance, in a stock-file update, the update record in the TF might contain the fields shown in Example 10-3, whereas the MF might contain those shown in Example 10-4.

Example 10-3. Fields in the Update Record of a Transaction File

```

FD TransactionFile.
01 TFRec.
  02 StockId-TF      PIC X(?).
  02 QtyInStock-TF  PIC 9(?).

```

Example 10-4. Fields in the Record of a Stock Master File

```

FD StockMasterFile.
01 StockMFRec.
  02 StockId-MF      PIC X(?).
  02 Description-MF  PIC X(?).
  02 ManfId-MF       PIC X(?).
  02 ReorderLevel-MF PIC 9(?).
  02 ReorderQty-MF   PIC 9(?).
  02 QtyInStock-MF   PIC 9(?).

```

The template in Figure 10-6 does not check for the error condition where the record to be updated does not exist in the MF. This condition is detected when the value in TFKey is less than that in MFKey. You can test this yourself by including the record Record-KeyD in the transaction file and then applying the transactions manually.

Deleting Records from an Ordered Sequential File

Figure 10-7 shows the template for deleting records from an ordered sequential file. The diagram captures the action just after Record-KeyK has been read into the MF record buffer. When the keys are equal, you have found the MF record to be deleted. So what action do you take to delete it? No action! You just don't send it to the NMF. Because both the transaction record and the master record have been consumed, you need to get the next record from each file.

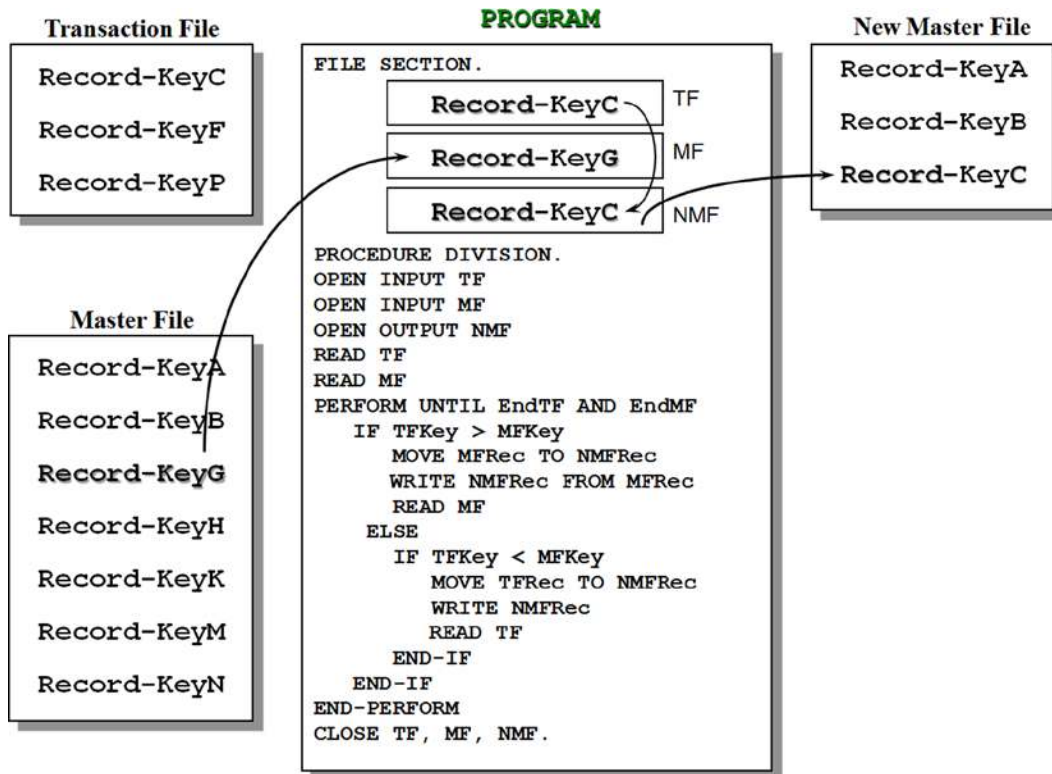


Figure 10-7. Deleting records from an ordered sequential file

When I discussed how to update an ordered sequential file, I noted that the transaction record contained fewer fields than the MF record. The delete operation takes this even further. To delete a record, the transaction record only needs the key field.

As before, the template does not check for the error condition where the record to be deleted does not exist in the MF. Just like the update operation, this condition is detected when the value in TFKey is less than that in MFKey. You can test this yourself by adding the record Record-KeyC to the records in the TF and then applying the transactions manually.

The File-Update Problem: Simplified

The previous section showed how various types of updates can be applied to an ordered sequential file. But you considered each of these types of updates in isolation. The TF consisted of records of only one type; it contained a batch of deletions, or a batch of insertions, or a batch of updates. In reality, all these different kinds of transaction records would be gathered together into one transaction file. Having multiple record types in the transaction file is good for processing efficiency, but it considerably complicates the update logic.

The problem of how to update an ordered sequential file is known as the *file-update problem*. The file-update problem is much more difficult than it appears on the surface and has been the subject of some research. Of particular interest is Barry Dwyer's paper "One More Time—How to Update a Master File."³ The algorithm described in his paper is implemented in Listing 10-2.

This section considers a simplified version of updating a file containing multiple record types. In this version, multiple updates for a particular master record are allowed, but an insertion record cannot be followed by any other operation for the same record. That restriction reveals the further levels of complexity of the file-update problem. Obviously, in a stock file, there might be a number of stock movements (additions and subtractions from stock) for a particular stock item. But in some cases, there might be an insertion for a particular stock item followed by stock movements and other updates for that item. In such a situation, the order in which the transactions are applied is important, because obviously you want to insert the record before you apply updates to it. These and other issues considerably complicate the file-update problem.

Updating a Stock File: Problem Specification

To explore some of the complexities of applying transactions of different types to a master file, consider the following problem specification.

A stock file holds details of gadgets sold by Gadget Shop (GadgetShop.Com). It is a sequential file sorted on ascending GadgetId. Each record in the file has the following description:

Field	Type	Length	Value
GadgetId	9	6	000001-999999
GadgetName	X	30	-
QtyInStock	9	4	0000-9999
Price	9	6	0000.00-9999.99

To update the stock file, a number of different kinds of update records have been gathered together into a sequential transaction file.

The records in transaction file have been sorted into ascending GadgetId order. Within GadgetId, the transactions are sorted by the order in which they were submitted. There are three different types of transaction records: insertion records to add a new line of stock, deletion records to delete a line of stock, and price-change records change the Price of a line of stock. Obviously, you could also have stock-movement records to add and subtract inventory from the QtyInStock field, but that would needlessly complicate this example.

Because there are three different types of records in the transaction file, you need to have three different record descriptions. But as you discovered in Chapter 8, when a file contains multiple types of records, you must have some way of identifying which record type has been read into the record buffer. To distinguish one type of record from

³Barry Dwyer. 1981. One more time—how to update a master file. *Commun. ACM* 24, 1 (January 1981), 3-8. DOI=10.1145/358527.358534 <http://doi.acm.org/10.1145/358527.358534>.

another, a special field called a *type code* is inserted into each transaction record. In the transaction file used to update Gadget Shop's stock file, a type code value of 1 is used to represent insertions, 2 represents deletions, and 3 represents a price change. The records in the transaction file have the following descriptions:

Insertion Record

Field	Type	Length	Value
TypeCode	9	1	1
GadgetId	9	6	000001-999999
GadgetName	X	30	-
QtyInStock	9	4	0000-9999
Price	9	6	0000.00-9999.99

Deletion Record

Field	Type	Length	Value
TypeCode	9	1	2
GadgetId	9	6	000001-999999

Price Change Record

Field	Type	Length	Value
TypeCode	9	1	3
GadgetId	9	6	000001-999999
Price	9	6	0000.00-9999.99

Because there are three different types of records in the file, you must have three record descriptions in the FD entry for the transaction file (see Example 10-5).

Example 10-5. Record Descriptions for the Transaction File

FD TransactionFile.

01 InsertionRec.

02 TypeCode PIC 9.
 02 GadgetId PIC 9(6).
 02 GadgetName PIC X(30).
 02 QtyInStock PIC 9(4).
 02 Price PIC 9(4)V99.

01 DeletionRec.

02 TypeCode PIC 9.
 02 GadgetID PIC 9(6).

01 PriceChangeRec.

02 TypeCode PIC 9.
 02 GadgetID PIC 9(6).
 02 Price PIC 9(4)V99.

Buffer Implications of Multiple Record Types

You discovered in Chapter 8 that when a file contains multiple record types, a record declaration (starting with a 01 level number) must be created for each type of record. But even though there are different types of records in the file, and there are separate record declarations for each record type, only a *single record buffer* is created for the file. All the record descriptions map on to this area of storage, which is the size of the largest record. Figure 10-8 shows the mapping of the transaction records on to the record buffer. All the identifiers in all the mapped records are current/active at the same time, but only one set of identifiers makes sense for the particular record in the buffer. In Figure 10-8, the record in the buffer is an insertion record (TypeCode = 1), so even though you *could* execute the statement `MOVE Price TO PrnPrice`, it wouldn't make sense to do so. Because there is an insertion record in the buffer, Price has the value "Ice Cr."

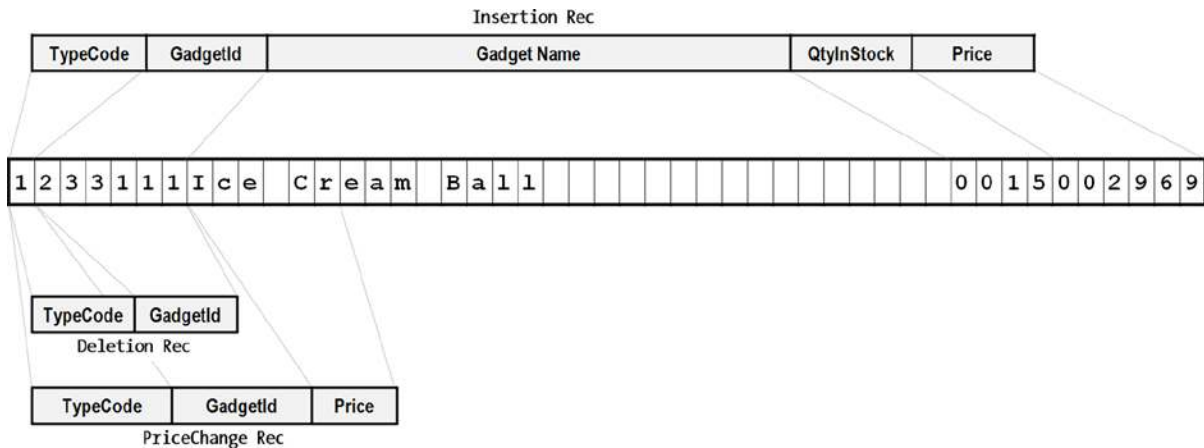


Figure 10-8. Schematic showing the mapping of records on to the record buffer

When you examine the record descriptions in Example 10-5 and the record schematic in Figure 10-8, you may notice that both TypeCode and GadgetId occur in all three record descriptions. You may wonder if it is permitted to use the same data name in different records. And if it is permitted, how can the data name be referenced uniquely?

Although it is legal to use the same data name in different records (but not in the same group item), in order to uniquely identify the record you want, you must qualify it with the record or group name. For instance, you can refer to the GadgetId in PriceChangeRec by using the form `GadgetId OF PriceChangeRec`.

But even though it is *legal* to declare GadgetId in all the records, and even though you must declare the storage for GadgetId in all the records, you don't actually *need* to use the name GadgetId in all the records. Because all the records map on to the same area of storage, it does not matter which GadgetId you refer to—they all access the same value in the record. So no matter which record is in the buffer, a statement that refers to `GadgetId OF InsertRec` will still access the correct value.

The same logic applies to the TypeCode. The TypeCode is in the same place in all three record types, so it doesn't matter which one you use—they all access the same area of memory. When an area of storage must be declared, but you don't care what name you give it, you don't have to make up a dummy name. You use the special name FILLER.

Example 10-6 shows a revised version of the three record descriptions. In this version, only the items that have to be named are given data names. The record schematic for this revised version is shown in Figure 10-9.

Example 10-6. Revised Record Descriptions

FD TransactionFile.

01 InsertionRec.

```

02 TypeCode          PIC 9.
02 GadgetId          PIC 9(6).
02 GadgetName        PIC X(30).
02 QtyInStock        PIC 9(4).
02 Price             PIC 9(4)V99.

```

01 DeletionRec.

```

02 FILLER            PIC 9(7).

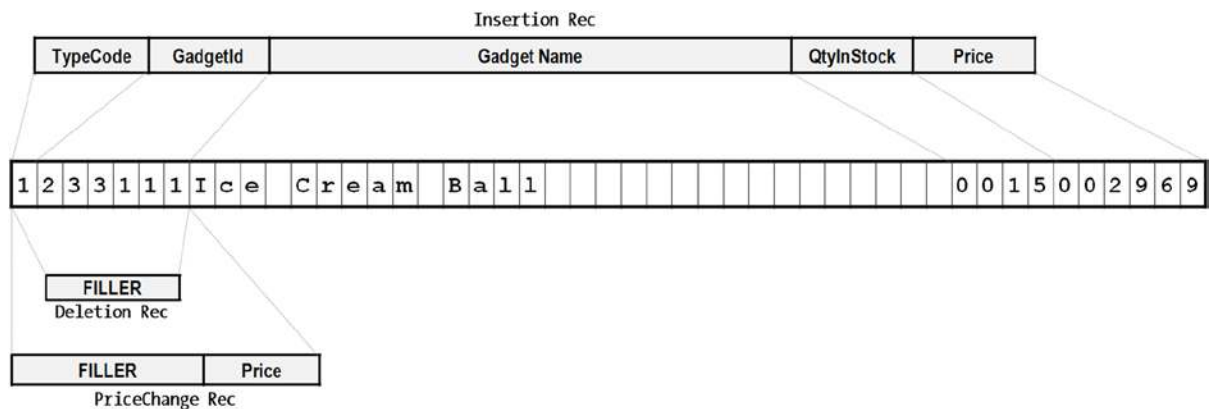
```

01 PriceChangeRec.

```

02 FILLER            PIC 9(7).
02 Price             PIC 9(4)V99.

```

**Figure 10-9.** Mapping of transaction records on to the record buffer

File Update Program

The program required to apply the transaction file to the gadget stock file is shown in Listing 10-3.

Listing 10-3. File Update—Insert not followed by updates to inserted record

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing10-3.
AUTHOR. Michael Coughlan
* Applies the transactions ordered on ascending GadgetId-TF to the
* MasterStockFile ordered on ascending GadgetId-MF.
* Assumption: Insert not followed by updates to inserted record
*           Multiple updates per master record permitted

```

ENVIRONMENT DIVISION.

INPUT-OUTPUT SECTION.

FILE-CONTROL.

```
SELECT MasterStockFile ASSIGN TO "Listing10-3Master.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

```
SELECT NewStockFile ASSIGN TO "Listing10-3NewMast.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

```
SELECT TransactionFile ASSIGN TO "Listing10-3Trans.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

DATA DIVISION.

FILE SECTION.

FD MasterStockFile.

01 MasterStockRec.

```
88 EndOfMasterFile      VALUE HIGH-VALUES.
02 GadgetId-MF          PIC 9(6).
02 GadgetName-MF        PIC X(30).
02 QtyInStock-MF        PIC 9(4).
02 Price-MF             PIC 9(4)V99.
```

FD NewStockFile.

01 NewStockRec.

```
02 GadgetId-NSF         PIC 9(6).
02 GadgetName-NSF       PIC X(30).
02 QtyInStock-NSF       PIC 9(4).
02 Price-NSF            PIC 9(4)V99.
```

FD TransactionFile.

01 InsertionRec.

```
88 EndOfTransFile      VALUE HIGH-VALUES.
02 TypeCode-TF          PIC 9.
   88 Insertion         VALUE 1.
   88 Deletion           VALUE 2.
   88 UpdatePrice        VALUE 3.
02 GadgetId-TF          PIC 9(6).
02 GadgetName-IR        PIC X(30).
02 QtyInStock-IR        PIC 9(4).
02 Price-IR             PIC 9(4)V99.
```

01 DeletionRec.

```
02 FILLER               PIC 9(7).
```

01 PriceChangeRec.

```
02 FILLER               PIC 9(7).
02 Price-PCR            PIC 9(4)V99.
```

WORKING-STORAGE SECTION.

01 ErrorMessage.

```
02 PrnGadgetId          PIC 9(6).
02 FILLER               PIC XXX VALUE " - ".
```

```

02 FILLER          PIC X(45).
   88 InsertError  VALUE "Insert Error - Record already exists".
   88 DeleteError  VALUE "Delete Error - No such record in Master".
   88 PriceUpdateError VALUE "Price Update Error - No such record in Master".

```

PROCEDURE DIVISION.

Begin.

```

OPEN INPUT  MasterStockFile
OPEN INPUT  TransactionFile
OPEN OUTPUT NewStockFile
PERFORM ReadMasterFile
PERFORM ReadTransFile
PERFORM UNTIL EndOfMasterFile AND EndOfTransFile
    EVALUATE TRUE
        WHEN GadgetId-TF > GadgetId-MF PERFORM CopyToNewMaster
        WHEN GadgetId-TF = GadgetId-MF PERFORM TryToApplyToMaster
        WHEN GadgetId-TF < GadgetId-MF PERFORM TryToInsert
    END-EVALUATE
END-PERFORM

CLOSE MasterStockFile, TransactionFile, NewStockFile
STOP RUN.

```

CopyToNewMaster.

```

WRITE NewStockRec FROM MasterStockRec
PERFORM ReadMasterFile.

```

TryToApplyToMaster.

```

EVALUATE TRUE
    WHEN UpdatePrice MOVE Price-PCR TO Price-MF
    WHEN Deletion    PERFORM ReadMasterFile
    WHEN Insertion   SET InsertError TO TRUE
                    DISPLAY ErrorMessage
END-EVALUATE
PERFORM ReadTransFile.

```

TryToInsert.

```

IF Insertion  MOVE GadgetId-TF TO GadgetId-NSF
              MOVE GadgetName-IR TO GadgetName-NSF
              MOVE QtyInStock-IR TO QtyInStock-NSF
              MOVE Price-IR TO Price-NSF
              WRITE NewStockRec
ELSE
    IF UpdatePrice
        SET PriceUpdateError TO TRUE
    END-IF
    IF Deletion
        SET DeleteError TO TRUE
    END-IF
    DISPLAY ErrorMessage
END-IF
PERFORM ReadTransFile.

```

ReadTransFile.

```

READ TransactionFile
  AT END SET EndOfTransFile TO TRUE
END-READ
MOVE GadgetId-TF TO PrnGadgetId.
```

ReadMasterFile.

```

READ MasterStockFile
  AT END SET EndOfMasterFile TO TRUE
END-READ.
```

Program Notes

Three files are used in the program. The master file, the transaction file and the new master file. The gadget stock file is known as the MasterStockFile, the transaction file is called the TransactionFile, and the new master file, produced by applying the transactions to the master file is known as the NewStockFile.

Applying the updates requires a considerable amount of data movement from fields in one stock record to another. To avoid the tedium of having to qualify each field reference, a suffix has been applied to the relevant fields to distinguish them from one another. The suffix MF (master File) is applied to records of the MasterStockFile, NSF is applied to records of the NewStockFile, and TF is applied to the common fields (TypeCode and GadgetId) of the TransactionFile.

Reading the TransactionFile and the MasterStockFile are operations that occur in a number of places. To avoid having to write out the READ statement in full each time, I have placed them in a paragraph which I then invoke by means of a PERFORM. While this makes the program textually shorter, you should be aware that performance will be impacted. Similarly, I have placed the statement MOVE GadgetId-TF TO PrnGadgetId in the ReadTransFile paragraph where it sets the GadgetId into the ErrorMessage every time a record is read. This placement means only one instance of this statement is required but again this saving is achieved at the cost of a slight impact on performance (because you really only need to do this if there is an error).

The GadgetId is moved into the ErrorMessage area every time a transaction record is read but you may be wondering how the actual error message gets into the ErrorMessage area. I won't go into a full explanation here but I will remind you that when a condition name is set to TRUE it pushes its value item into the associated data item. If that isn't a sufficient hint, then you may need to review Chapter 5 where condition names were discussed.

The paragraph CopyToNewMaster copies the MasterStockFile record to the NewStockFile when there are no transactions to be applied to the MasterStockFile record (GadgetId-TF > GadgetId-MF) but it is also the paragraph that writes the MasterStockRec after updates have been applied to it. How does this happen? Consider this sequence of events happening in the program:

GadgetId-TF = GadgetId-MF and an update is applied to the MasterStockRec

The next transaction record is read

GadgetId-TF = GadgetId-MF and another update is applied to the MasterStockRec

The next transaction record is read (because the transaction records are in ascending sequence this transaction must be equal to or greater than the master)

GadgetId-TF > GadgetId-MF and the updated MasterStockRec is written to the NewStockFile

When the keys are equal, the update is applied to the MasterStockRec, when eventually the transaction key is greater than the master file key (the only possible condition because the files are ordered), the updated record is written to the new master file.

Test Data and Results

The test data files for the program are given Figure 10-10. As usual, I've kept them short because of space constraints and to make them easy to understand. For the transaction file, I have taken advantage of the fact the record buffer is the size of the largest record, to add text that identifies the purpose of each test. For instance, a delete record in a real transaction file would only consist of the type code and the key.

TransactionFile	MasterStockFile (record to be deleted in bold)
1113111Valid Insert @ start of file 1111004149	113434Mini Retro Popcorn Maker 1111004149
3234567033333 Valid Price Update	123456SoundDisk MP3 Player 4GB 0650003095
1266111Valid Insert @ middle of file 1111002379	234567BioLite Camp Stove 0057029550
2334222 Invalid Delete	266999The Original Bacon Kit 1111002379
1345678 Invalid Insert 0155002590	345678Collapsible Kettle - Green 0155002590
3345678003333 Valid Update	456789Digital Measuring Jug 0325000895
2567890 Valid Delete MicroLiteLEDTorch	567890MicroLite LED Torch 0512000745
3578901001799 Invalid Update	678901Pocket Sized Fishing Rod 0055001799
3789111003333 First update to 789111	789111Ice Cream Ball 1111002969
3789111009393 Second update to 789111	
1888111Valid Insert @ end of file 1111002969	

Figure 10-10. Test data and results

The results from running the program are shown in Figure 10-11.

NewStockFile (inserts & updates in bold)	Listing 10-3 Output
113111Valid Insert @ start of file 1111004149	334222 - Delete Error - No such record in Master
113434Mini Retro Popcorn Maker 1111004149	345678 - Insert Error - Record already exists
123456SoundDisk MP3 Player 4GB 0650003095	578901 - Price Update Error - No such record in Master
234567BioLite Camp Stove 0057 033333	
266111Valid Insert @ middle of file 1111002379	
266999The Original Bacon Kit 1111002379	
345678Collapsible Kettle - Green 0155 003333	
456789Digital Measuring Jug 0325000895	
678901Pocket Sized Fishing Rod 0055001799	
789111Ice Cream Ball 1111 009393	
888111Valid Insert @ end of file 1111002969	

Figure 10-11. Listing 10-3 results

The Full File Update Problem

Listing 10-3 provides a gentle introduction to the file update problem but the algorithm used in that program only works for a limited form of the problem. The algorithm does not work when an insert can be followed by updates to the record to be inserted. The reason the algorithm does not work for the extended version of problem is that now the updates can be applied to either the master file or the transaction file. In the Listing 10-3 algorithm, the updates are applied only to the master file. This seemingly small change makes the task a very slippery fish indeed. The moment you think you have solved the problem by placing a read here or a write there some other difficulty rears its ugly head. The best way to get a feel for the complications that this simple specification change causes, is to try it yourself. Using Listing 10-3 as the basis for your program, attempt to change the program so that it also allows an insertion to be followed by updates to the inserted record.

Fortunately, you don't have to rely on your own resources to come up with a solution. People have gone before you, and you can stand on their shoulders. Listing 10-4 demonstrates a solution to the problem based on the algorithm described by Barry Dwyer in "One More Time - How to Update a Master File."³

The main elements of the algorithm are the ChooseNextKey and SetInitialStatus paragraphs, the RecordInMaster and RecordNotInMaster condition names, and the loop PERFORM ProcessOneTransaction UNTIL GadgetID-TF NOT = CurrentKey.

ChooseNextKey allows the program to decide if the transaction file or the master file will be the focus of updates. The key of whichever file is the focus is recorded in CurrentKey.

SetInitialStatus uses the condition names RecordInMaster and RecordNotInMaster to record whether or not the record is currently included in the master file. Later the RecordInMaster condition name is used to decide whether the record is to be included in the new master file.

The ProcessOneTransaction loop applies all the transactions that apply to the record of focus while the keys are equal. When the loop exits, the RecordInMaster condition name is tested to see if the record of focus should be included in the new master file.

Full File Update Program

Listing 10-4 is the final program.

Listing 10-4. Caption

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing10-4.
AUTHOR. Michael Coughlan
* File Update program based on the algorithm described by Barry Dwyer in
* "One more time - How to update a Master File"
* Applies the transactions ordered on ascending GadgetId-TF to the
* MasterStockFile ordered on ascending GadgetId-MF.
* Within each key value records are ordered on the sequence in which
* events occurred in the outside world.
* All valid, real world, transaction sequences are accommodated

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT MasterStockFile ASSIGN TO "Listing10-4Master.dat"
        ORGANIZATION IS LINE SEQUENTIAL.
```



```
SELECT NewStockFile ASSIGN TO "Listing10-4NewMast.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

```
SELECT TransactionFile ASSIGN TO "Listing10-4Trans.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

```
DATA DIVISION.
```

```
FILE SECTION.
```

```
FD MasterStockFile.
```

```
01 MasterStockRec.
```

```
88 EndOfMasterFile      VALUE HIGH-VALUES.
02 GadgetID-MF          PIC 9(6).
02 GadgetName-MF        PIC X(30).
02 QtyInStock-MF        PIC 9(4).
02 Price-MF             PIC 9(4)V99.
```

```
FD NewStockFile.
```

```
01 NewStockRec.
```

```
02 GadgetID-NSF         PIC 9(6).
02 GadgetName-NSF       PIC X(30).
02 QtyInStock-NSF       PIC 9(4).
02 Price-NSF            PIC 9(4)V99.
```

```
FD TransactionFile.
```

```
01 InsertionRec.
```

```
88 EndOfTransFile      VALUE HIGH-VALUES.
02 TypeCode-TF          PIC 9.
88 Insertion            VALUE 1.
88 Deletion              VALUE 2.
88 UpdatePrice          VALUE 3.
02 RecordBody-IR.
03 GadgetID-TF          PIC 9(6).
03 GadgetName-IR        PIC X(30).
03 QtyInStock-IR        PIC 9(4).
03 Price-IR             PIC 9(4)V99.
```

```
01 DeletionRec.
```

```
02 FILLER                PIC 9(7).
```

```
01 PriceChangeRec.
```

```
02 FILLER                PIC 9(7).
02 Price-PCR             PIC 9(4)V99.
```

```
WORKING-STORAGE SECTION.
```

```
01 ErrorMessage.
```

```
02 PrnGadgetId          PIC 9(6).
02 FILLER                PIC XXX VALUE " - ".
02 FILLER                PIC X(45).
88 InsertError          VALUE "Insert Error - Record already exists".
88 DeleteError          VALUE "Delete Error - No such record in Master".
88 PriceUpdateError     VALUE "Price Update Error - No such record in Master".
```

```

01 FILLER                PIC X VALUE "n".
   88 RecordInMaster     VALUE "y".
   88 RecordNotInMaster  VALUE "n".

01 CurrentKey           PIC 9(6).

```

PROCEDURE DIVISION.

Begin.

```

OPEN INPUT MasterStockFile
OPEN INPUT TransactionFile
OPEN OUTPUT NewStockFile
PERFORM ReadMasterFile
PERFORM ReadTransFile
PERFORM ChooseNextKey
PERFORM UNTIL EndOfMasterFile AND EndOfTransFile
    PERFORM SetInitialStatus
    PERFORM ProcessOneTransaction
        UNTIL GadgetID-TF NOT = CurrentKey
*   CheckFinalStatus
    IF RecordInMaster
        WRITE NewStockRec
    END-IF
    PERFORM ChooseNextKey
END-PERFORM

CLOSE MasterStockFile, TransactionFile, NewStockFile
STOP RUN.

```

ChooseNextKey.

```

IF GadgetID-TF < GadgetID-MF
    MOVE GadgetID-TF TO CurrentKey
ELSE
    MOVE GadgetID-MF TO CurrentKey
END-IF.

```

SetInitialStatus.

```

IF GadgetID-MF = CurrentKey
    MOVE MasterStockRec TO NewStockRec
    SET RecordInMaster TO TRUE
    PERFORM ReadMasterFile
ELSE SET RecordNotInMaster TO TRUE
END-IF.

```

ProcessOneTransaction.

```

* ApplyTransToMaster
EVALUATE TRUE
    WHEN Insertion PERFORM ApplyInsertion
    WHEN UpdatePrice PERFORM ApplyPriceChange
    WHEN Deletion PERFORM ApplyDeletion
END-EVALUATE.
PERFORM ReadTransFile.

```

```

ApplyInsertion.
  IF RecordInMaster
    SET InsertError TO TRUE
    DISPLAY ErrorMessage
  ELSE
    SET RecordInMaster TO TRUE
    MOVE RecordBody-IR TO NewStockRec
  END-IF.

```

```

ApplyDeletion.
  IF RecordNotInMaster
    SET DeleteError TO TRUE
    DISPLAY ErrorMessage
  ELSE SET RecordNotInMaster TO TRUE
  END-IF.

```

```

ApplyPriceChange.
  IF RecordNotInMaster
    SET PriceUpdateError TO TRUE
    DISPLAY ErrorMessage
  ELSE
    MOVE Price-PCR TO Price-NSF
  END-IF.

```

```

ReadTransFile.
  READ TransactionFile
    AT END SET EndOfTransFile TO TRUE
  END-READ
  MOVE GadgetID-TF TO PrnGadgetId.

```

```

ReadMasterFile.
  READ MasterStockFile
    AT END SET EndOfMasterFile TO TRUE
  END-READ.

```

Program Notes

I have incorporated an optimization in Listing 10-4 that might welcome some explanation. Before you write an insert record to the master file in Listing 10-3, the fields in the record are transferred one by one to the `NewStockRec`. You couldn't just move the `InsertionRec` to the `NewStockRec` because the `InsertionRec` also includes the `TypeCode` field. In Listing 10-4, this problem has been solved by restructuring the `Insertion` records so that the fields you have to move to the `NewStockRec` are subordinate to a group item called `RecordBody-IR`. This means in Listing 10-4, instead of moving the contents of the insertion record to the new master record field by field, you just `MOVE RecordBody-IR TO NewStockRec`. The record schematic for this restructured record is shown in Figure 10-12. The record remains the same size. But now you have an additional data name with which to manipulate the data in the record.

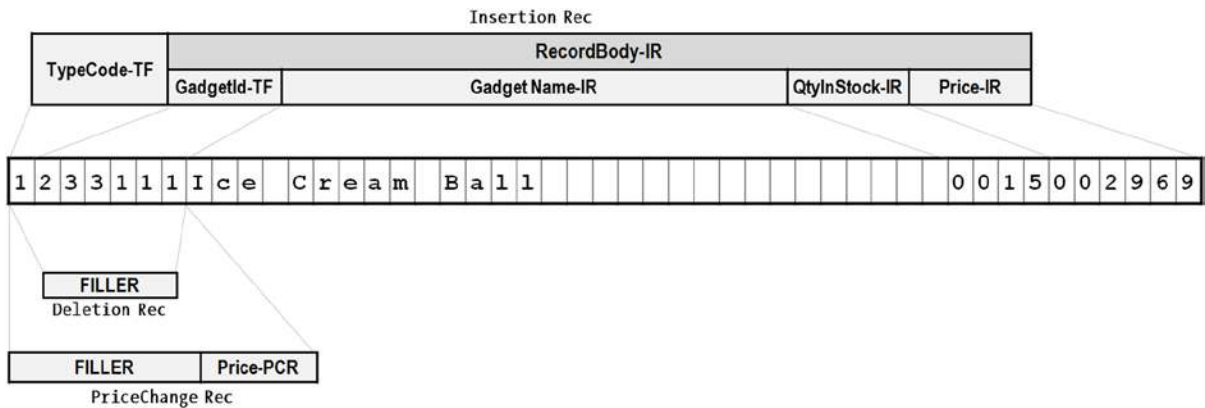


Figure 10-12. Revised record schematic showing the restructured Insertion record

Test Data and Results

The test data for the program is shown in Figure 10-13.

TransactionFile	MasterStockFile (record to be deleted shown in bold)
1113111Valid Insert @ start of file 1111004149	113434Mini Retro Popcorn Maker 1111004149
3234567033333 Valid Price Update	123456SoundDisk MP3 Player 4GB 0650003095
1266111Valid Insert @ middle of file 1111002379	234567BioLite Camp Stove 0057029550
2334222 Invalid Delete	266999The Original Bacon Kit 1111002379
1333333Valid Insert & updates 1111003333	345678Collapsible Kettle - Green 0155002590
3333333006666 First update to 333333	456789Digital Measuring Jug 0325000895
3333333009999 Second update to 333333	567890MicroLite LED Torch 0512000745
1345678 Invalid Insert 0155002590	678901Pocket Sized Fishing Rod 0055001799
3345678003333 Valid Update	789111Ice Cream Ball 1111002969
2567890 Valid Delete MicroLiteLEDTorch	
3578901001799 Invalid Update	
3789111003333 First update to 789111	
3789111009393 Second update to 789111	
1888111Valid Insert @ end of file 1111002969	

Figure 10-13. Test data for Listing 10-4

The result of running the program against that test data is shown in Figure 10-14.

```

NewStockFile (inserts & updates in bold)

113111Valid Insert @ start of file 1111004149
113434Mini Retro Popcorn Maker      1111004149
123456SoundDisk MP3 Player 4GB     0650003095
234567BioLite Camp Stove           0057033333
266111Valid Insert @ middle of file 1111002379
266999The Original Bacon Kit       1111002379
333333Valid Insert & updates 1111009999
345678Collapsible Kettle - Green   0155003333
456789Digital Measuring Jug        0325000895
678901Pocket Sized Fishing Rod     0055001799
789111Ice Cream Ball               1111009393
888111Valid Insert @ end of file 1111002969

```

Figure 10-14. Results of running Listing 10-4

Summary

This chapter introduced two of the most important sequential file processing problems. The chapter began by examining how sequential files are organized and discussing the difference between ordered and unordered sequential files. The next section introduced the class of problems known as control-break problems. The final section introduced the thorny problem of the sequential File Update.

The section that discussed control-break problems included an example program to produce a printed report involving a three level control break. A second example program implemented an atypical control break problem and was intended to show that a control break solution may be applied to a number of different types of problem.

In the final section, I discussed how to apply updates to an ordered sequential file and included two examples programs. The first example implemented a solution to a simplified version of the file update problem while the second applied the algorithm described by Dwyer³ and Dijkstra.⁴

In the specification for Listing 10-1, I mentioned that using the full state name in every record was very wasteful and that a more realistic scenario would use a state code instead of the full name. I noted that in that case you would have to convert the state code to a state name by means of a lookup table. In the next chapter, which will discuss how tabular data is implemented in COBOL, you revisit the Listing 10-1 specification to create a more realistic scenario that will require you to incorporate a state lookup table into the program.

LANGUAGE KNOWLEDGE EXERCISE

Unleash your 2B pencil once more. It is time for some exercises. These exercises are designed to allow you to prove to yourself that it is not possible to update an unordered sequential file.

No answers are provided for these questions.

1. The transaction file and the master file in Figure 10-15 are unordered sequential files. Using the algorithm outlined in Figure 10-15 manually attempt to update the master file records to produce a new master file that contains the updated records.

⁴Dijkstra, E.W. A Discipline of Programming. Prentice-Hall, Englewood Cliffs, N.J.,1976.

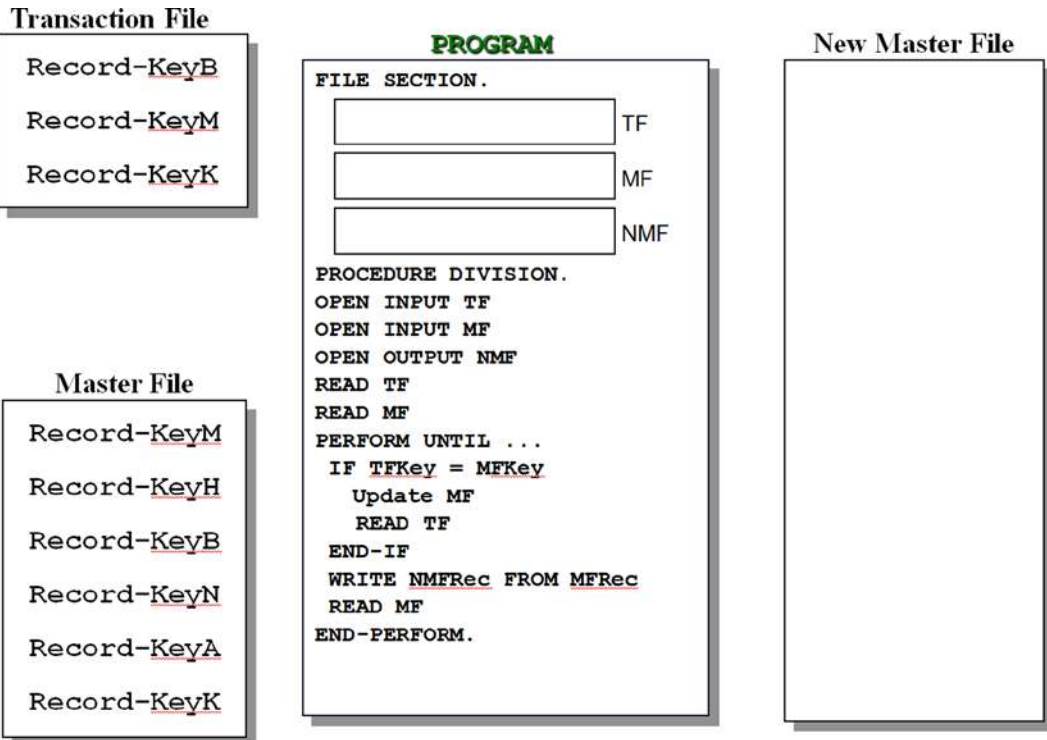


Figure 10-15. Attempting to update an unordered sequential file

2. The transaction file and the master file in Figure 10-15 are unordered sequential files. Using the algorithm outlined in Figure 10-16 manually attempt to delete the master file records to produce a new master file that does not contain the deleted records.

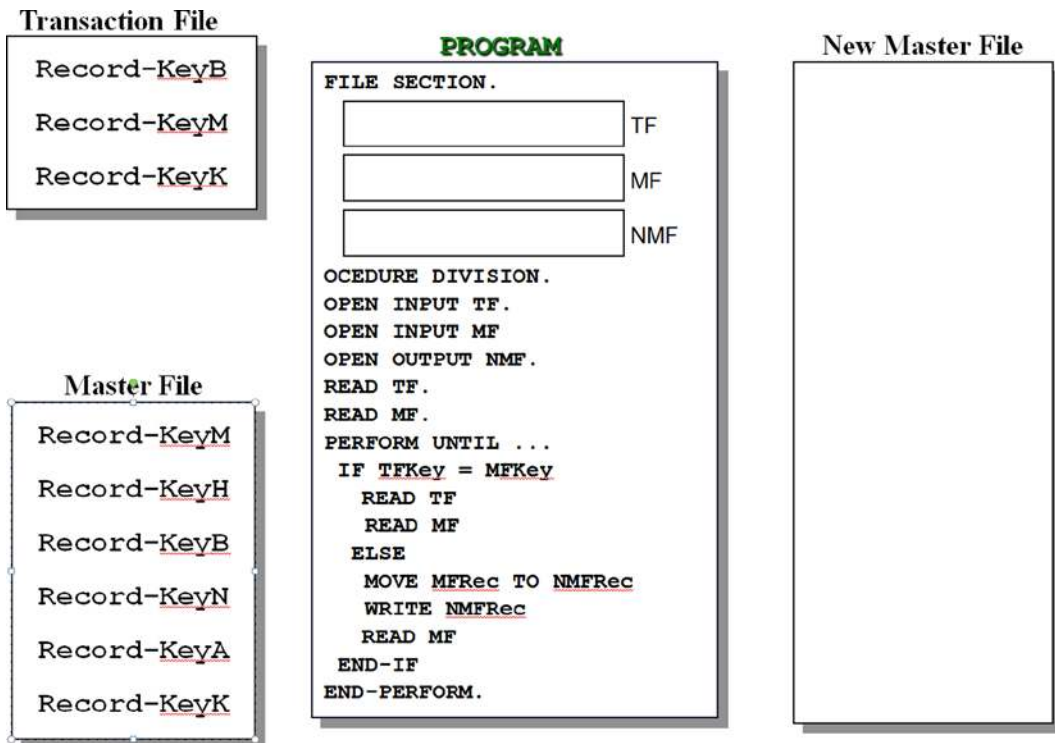


Figure 10-16. Attempting to delete from an unordered sequential file

PROGRAMMING EXERCISE

Listing 10-4 applies the File Update algorithm described by Dwyer³ to implement an update of the Gadget Shop's Stock MF. However, in that implementation only the Price field is updated. Now you need to modify that program so that it can also update the QtyInStock field.

Change the program in Listing 10-4 so that it handle stock movement updates as well as price change updates. To accommodate this change in the specification two new record types will have to be added to the transaction file. These new transaction records are the AddToStock record indicated by a type code of 4 and the SubtractFromStock record indicated by a type code of 5.

The record descriptions for the MF and the new version of the TF are given here.

The Stock MF is a sequential file ordered on ascending GadgetId. Each record has the following description.

StockMaster Record

Field	Type	Length	Value
GadgetId	9	6	000001-999999
GadgetName	X	30	-
QtyInStock	9	4	0000-9999

Field	Type	Length	Value
Price	9	6	0000.00–9999.99

The TF is a sequential file ordered on ascending `GadgetId`. In each set of records with the same `GadgetId` the records are ordered in sequence in which the transactions occurred in the real world. Records in the TF have the following descriptions:

Insertion record

Field	Type	Length	Value
TypeCode	9	1	1
GadgetId	9	6	000001–999999
GadgetName	X	30	-
QtyInStock	9	4	0000–9999
Price	9	6	0000.00–9999.99

Deletion record

Field	Type	Length	Value
TypeCode	9	1	2
GadgetId	9	6	000001–999999

PriceChange record

Field	Type	Length	Value
TypeCode	9	1	3
GadgetId	9	6	000001–999999
Price	9	6	0000.00–9999.99

AddToStock record

Field	Type	Length	Value
TypeCode	9	1	4
GadgetId	9	6	000001–999999
QtyToAdd	9	4	0000–9999

SubtractFromStock record

Field	Type	Length	Value
TypeCode	9	1	5
GadgetId	9	6	000001–999999
QtyToSubtract	9	4	0000–9999

TestData

To test your program you can use the test data shown below in Figure 10-17.

TransactionFile	MasterStockFile (record to be deleted shown in bold)
1113111Valid Insert @ start of file 1111004149	113434Mini Retro Popcorn Maker 1111004149
3234567033333 Valid Price Update	123456SoundDisk MP3 Player 4GB 0650003095
1266111Valid Insert @ middle of file 1111002379	234567BioLite Camp Stove 0057029550
52669991111 Valid Subtract from stock	266999The Original Bacon Kit 1111002379
52669990003 Invalid subtract - not enough	345678Collapsible Kettle - Green 0155002590
42669994444 Valid Add to stock	456789Digital Measuring Jug 0325000895
52669990404 Valid Subtract from stock	567890MicroLite LED Torch 0512000745
2334222 Invalid Delete	678901Pocket Sized Fishing Rod 0055001799
1333333Valid Insert & updates 1111003333	789111Ice Cream Ball 1111002969
3333333006666 First update to 333333	
3333333009999 Second update to 333333	
1345678 Invalid Insert 0155002590	
3345678003333 Valid Update	
2567890 Valid Delete MicroLiteLEDTorch	
3578901001799 Invalid Update	
3789111003333 First update to 789111	
3789111009393 Second update to 789111	
1888111Valid Insert @ end of file 1111002969	

Figure 10-17. Test data including add and subtract from stock transactions

Notes

There is an additional error conditions to be noted. If the GadgetId-TF < GadgetId-MF and the type code is 4 or 5 then an error has occurred (no matching master file record) but it is also an error if the transaction is a SubtractFromStock record but the QtyInStock in the MF is less than the QtyToSubtract in the SubtractFromStock record

PROGRAMMING EXERCISE - ANSWER

Listing 10-5. Update with added AddToStock and SubtractFromStock transactions

IDENTIFICATION DIVISION.

PROGRAM-ID. Listing10-5.

AUTHOR. Michael Coughlan

* File Update program based on the algorithm described by Barry Dwyer in

* "One more time - How to update a Master File"

* Applies the transactions ordered on ascending GadgetId-TF to the

* MasterStockFile ordered on ascending GadgetId-MF.

* Within each key value records are ordered on the sequence in which

- * events occurred in the outside world.
- * All valid, real world, transaction sequences are accommodated
- * This version includes additions and subtractions from QtyInStock

ENVIRONMENT DIVISION.

INPUT-OUTPUT SECTION.

FILE-CONTROL.

```
SELECT MasterStockFile ASSIGN TO "Listing10-5Master.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

```
SELECT NewStockFile ASSIGN TO "Listing10-5NewMast.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

```
SELECT TransactionFile ASSIGN TO "Listing10-5Trans.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

DATA DIVISION.

FILE SECTION.

FD MasterStockFile.

01 MasterStockRec.

```
88 EndOfMasterFile      VALUE HIGH-VALUES.
02 GadgetID-MF          PIC 9(6).
02 GadgetName-MF        PIC X(30).
02 QtyInStock-MF        PIC 9(4).
02 Price-MF              PIC 9(4)V99.
```

FD NewStockFile.

01 NewStockRec.

```
02 GadgetID-NSF          PIC 9(6).
02 GadgetName-NSF        PIC X(30).
02 QtyInStock-NSF        PIC 9(4).
02 Price-NSF              PIC 9(4)V99.
```

FD TransactionFile.

01 InsertionRec.

```
88 EndOfTransFile      VALUE HIGH-VALUES.
02 TypeCode-TF          PIC 9.
   88 Insertion          VALUE 1.
   88 Deletion            VALUE 2.
   88 UpdatePrice         VALUE 3.
   88 StockAddition       VALUE 4.
   88 StockSubtraction    VALUE 5.
```

02 RecordBody-IR.

```
03 GadgetID-TF          PIC 9(6).
03 GadgetName-IR        PIC X(30).
03 QtyInStock-IR        PIC 9(4).
03 Price-IR              PIC 9(4)V99.
```

01 DeletionRec.

```
02 FILLER                PIC 9(7).
```

```

01 PriceChangeRec.
  02 FILLER                PIC 9(7).
  02 Price-PCR             PIC 9(4)V99.

01 AddToStock.
  02 FILLER                PIC 9(7).
  02 QtyToAdd             PIC 9(4).

01 SubtractFromStock.
  02 FILLER                PIC 9(7).
  02 QtyToSubtract       PIC 9(4).

WORKING-STORAGE SECTION.
01 ErrorMessage.
  02 PrnGadgetId          PIC 9(6).
  02 FILLER                PIC XXX VALUE " - ".
  02 FILLER                PIC X(46).
  88 InsertError         VALUE "Insert Error - Record already exists".
  88 DeleteError         VALUE "Delete Error - No such record in Master".
  88 PriceUpdateError    VALUE "Price Update Error - No such record in Master".
  88 QtyAddError          VALUE "Stock Add Error - No such record in Master".
  88 QtySubtractError    VALUE "Stock Subtract Error - No such record in Master".
  88 InsufficientStock   VALUE "Stock Subtract Error - Not enough stock".

01 FILLER                PIC X VALUE "n".
  88 RecordInMaster      VALUE "y".
  88 RecordNotInMaster   VALUE "n".

01 CurrentKey            PIC 9(6).

PROCEDURE DIVISION.
Begin.
  OPEN INPUT  MasterStockFile
  OPEN INPUT  TransactionFile
  OPEN OUTPUT NewStockFile
  PERFORM ReadMasterFile
  PERFORM ReadTransFile
  PERFORM ChooseNextKey
  PERFORM UNTIL EndOfMasterFile AND EndOfTransFile
    PERFORM SetInitialStatus
    PERFORM ProcessOneTransaction
      UNTIL GadgetID-TF NOT = CurrentKey
  *   CheckFinalStatus
    IF RecordInMaster
      WRITE NewStockRec
    END-IF
  PERFORM ChooseNextKey
  END-PERFORM

  CLOSE MasterStockFile, TransactionFile, NewStockFile
  STOP RUN.

```

ChooseNextKey.

```
IF GadgetID-TF < GadgetID-MF
  MOVE GadgetID-TF TO CurrentKey
ELSE
  MOVE GadgetID-MF TO CurrentKey
END-IF.
```

SetInitialStatus.

```
IF GadgetID-MF = CurrentKey
  MOVE MasterStockRec TO NewStockRec
  SET RecordInMaster TO TRUE
  PERFORM ReadMasterFile
ELSE SET RecordNotInMaster TO TRUE
END-IF.
```

ProcessOneTransaction.

```
* ApplyTransToMaster
EVALUATE TRUE
  WHEN Insertion           PERFORM ApplyInsertion
  WHEN UpdatePrice        PERFORM ApplyPriceChange
  WHEN Deletion           PERFORM ApplyDeletion
  WHEN StockAddition      PERFORM ApplyAddToStock
  WHEN StockSubtraction   PERFORM ApplySubtractFromStock
END-EVALUATE.
PERFORM ReadTransFile.
```

ApplyInsertion.

```
IF RecordInMaster
  SET InsertError TO TRUE
  DISPLAY ErrorMessage
ELSE
  SET RecordInMaster TO TRUE
  MOVE RecordBody-IR TO NewStockRec
END-IF.
```

ApplyDeletion.

```
IF RecordNotInMaster
  SET DeleteError TO TRUE
  DISPLAY ErrorMessage
ELSE SET RecordNotInMaster TO TRUE
END-IF.
```

ApplyPriceChange.

```
IF RecordNotInMaster
  SET PriceUpdateError TO TRUE
  DISPLAY ErrorMessage
ELSE
  MOVE Price-PCR TO Price-NSF
END-IF.
```

ApplyAddToStock.

```
IF RecordNotInMaster
  SET QtyAddError TO TRUE
  DISPLAY ErrorMessage
ELSE
  ADD QtyToAdd TO QtyInStock-NSF
END-IF.
```

ApplySubtractFromStock.

```
IF RecordNotInMaster
  SET QtySubtractError TO TRUE
  DISPLAY ErrorMessage
ELSE
  IF QtyInStock-NSF < QtyToSubtract
    SET InsufficientStock TO TRUE
    DISPLAY ErrorMessage
  ELSE
    SUBTRACT QtyToSubtract FROM QtyInStock-NSF
  END-IF
END-IF.
```

ReadTransFile.

```
READ TransactionFile
  AT END SET EndOfTransFile TO TRUE
END-READ
MOVE GadgetID-TF TO PrnGadgetId.
```

ReadMasterFile.

```
READ MasterStockFile
  AT END SET EndOfMasterFile TO TRUE
END-READ.
```

CHAPTER 11



Creating Tabular Data

This chapter and the next return to the DATA DIVISION to explore more data-declaration concepts. In this chapter, I discuss how to create and manipulate tabular data. I compare and contrast COBOL tables with the arrays used in many other programming languages. Chapter 12 covers more advanced data declaration using the USAGE, REDEFINES, and RENAMES clauses.

The chapter starts with a discussion of the similarities and differences between arrays and tables. You then see how COBOL tables are declared using the OCCURS clause and manipulated using subscripts. I introduce a scenario to explain why tabular data is required and end the scenario with an example program that uses a simple one-dimensional table as part of the solution.

The middle section of the chapter introduces the concept of group items as table elements and demonstrates this in an example program. Multidimensional tables are then introduced. You learn the best way to depict a multidimensional COBOL table graphically; and I again address the contrast between arrays and tables, which is more pronounced with multidimensional tables. I present an example program using a two-dimensional table as part of its solution and introduce a scenario requiring a three-dimensional table.

In the chapter's final section, I show how to create prefilled tables using the REDEFINES clause. You see this demonstrated in an example program that uses a table prefilled with the names of the American states. I also discuss some of the table declaration changes introduced with the ANS 85 standard.

Tables vs. Arrays

Most programming languages have a facility to create tabular information. Tabular information consists of multiple occurrences of a homogeneous data item.

Most programming languages use the term *array* to describe these multiple-occurrence data items, but COBOL uses the term *table*. This is not just a difference of nomenclature. In most languages (including Basic, Pascal, Java, FORTRAN, and Ada), arrays look and work similarly; but COBOL tables, although they have some similarities to arrays, have a number of minor and major differences.

Table/Array Definition

Tables and arrays are so similar that you can use the same definition for them. A table/array may be defined as a contiguous sequence of memory locations that all have the same name and that are uniquely identified by that name and by their position in the sequence. The position index is called a *subscript*, and the individual components of the table/array are referred to as *elements*.

Table/Array Differences

If the same definition can be used for tables and arrays, what is the difference between them? The first difference affects the C language derivatives (C++, Java, and C#). In these languages, arrays start at element 0 and go to the maximum size of the array minus one. This arrangement is a rich source of programming errors for beginner programmers who have difficulty coming to grips with this displaced referencing: for instance, `element[9]` is the *tenth* element in the array. In COBOL, tables start at element 1 (not 0) and go to the maximum size of the table. In a COBOL table, `element(9)` is the *ninth* element of the table.

A major difference between COBOL tables and arrays is that COBOL tables are declared using record descriptions. The nature of a record description is that there is a hierarchical relationship between the items in the record. Consequently, one item in a multidimensional table must always be subordinate to another. Arrays have no such hierarchical relationship. An array is simply a matrix of cells that are referenced using row and column subscripts. The hierarchical structuring of COBOL tables allows data-manipulation opportunities that are not available to languages that use arrays.

Declaring Tables

Tables are declared using an extension to the PICTURE clause, called the OCCURS clause. The metalanguage for the basic OCCURS clause is as follows:

```
OCCURS TableSize#1 TIMES
```

To declare a table, you define the type and size of the table element, and then you use the OCCURS clause to specify how many times the element occurs. In the following NFL-Stadium example, the type and size of the element are defined by its subordinate data items. Each element is alphanumeric and 35 characters (30 + 5) in size:

```
01 SoccerStadiumName    PIC X(25) OCCURS 20 TIMES.
01 NFL-Stadium OCCURS 31 TIMES.
   02 NFL-StadiumName    PIC X(30).
   02 NFL-StadiumCapacity PIC 9(5).
```

OCCURS Clause Rules

Here are the rules for the OCCURS clause:

- Any data item whose description includes an OCCURS clause must be subscripted when referred to. For example:

```
DISPLAY SoccerStadiumName(15)
MOVE NFL-Stadium(12) TO NFL-Stadium(7)
```

- Any data item that is subordinate to a group item whose description contains an OCCURS clause must be subscripted when referred to. For example:

```
DISPLAY NFL-StadiumName(7)
DISPLAY NFL-StadiumCapacity(7)
```

Subscript Rules

Now let's look at the subscript rules:

- A subscript is a bracketed numeric index (or something that evaluates to one) that points to a particular element (or part of an element) of the table. The subscript immediately follows the element name.
- The numeric index must be a positive integer, a data name that represents one, or a simple expression that evaluates to one.
- The numeric index is a value between one and the number of elements in the table, inclusive.
- When more than one subscript is used, they must be separated from one another by commas.
- One subscript must be specified for each dimension of the table. There must be one subscript for a one-dimensional table, two subscripts for a two-dimensional table, and three for a three-dimensional table.
- The first subscript applies to the first OCCURS clause, the second applies to the second OCCURS clause, and so on.
- Subscripts must be enclosed in rounded brackets: ().

Here are some examples:

```
MOVE ZEROS TO StateSalesTotal(35)
ADD BranchSales TO StateSalesTotal(StateNum)
ADD BranchSales TO StateSalesTotal(StateNum + 1)
ADD BranchSales TO StateSalesTotal(StateNum - 2)
ADD MonthlyBranchSales TO StateSalesTotal(StateNum, MonthNum)
DISPLAY "Stadium Name is " StadiumName(24)
DISPLAY "Stadium Capacity is " StadiumCapacity(24)
```

Why Use Tabular Data?

Let's start this introduction to tabular data by setting up a hypothetical problem. In the course of exploring the problem and a number of variations, I will show how tables are defined and used in COBOL.

First Specification

YoreCandyShoppe is a franchise that sells old-time candy at branches all over the United States. A program is required that will sum the candy sales for all the YoreCandyShoppe branches in the country. The sales data is obtained from a sales file containing the candy sales for each branch. The sales file is a sequential file sequenced on ascending BranchId. Each record of the file may be described using the following record description:

```
01 BranchSalesRec.
  88 EndOfSalesFile VALUE HIGH-VALUES.
  02 BranchId PIC 9(7).
  02 StateNum PIC 99.
  02 CandySales PIC 9(7)V99.
```

To save file space, a two-digit numeric value is used to represent the state instead of a state name.

The program to perform this task is very simple. All you have to do is set up a variable to hold the total candy sales and then add `CandySales` from each record to `TotalCandySales`. A fragment of the program required to do this is given in Example 11-1.

Example 11-1. PROCEDURE DIVISION of a Program to Sum Total Candy Sales

```
PROCEDURE DIVISION.
Begin.
  OPEN INPUT SalesFile
  READ SalesFile
  AT END SET EndOfSalesFile TO TRUE
END-READ
PERFORM UNTIL EndOfSalesFile
  ADD CandySales TO TotalCandySales
  READ SalesFile
  AT END SET EndOfSalesFile TO TRUE
END-READ
END-PERFORM.
DISPLAY "Total candy sales for the US : ", TotalCandySales
CLOSE SalesFile
STOP RUN.
```

Second Specification

The program to solve the problem set in the first specification is simple. But suppose the specification is changed so that instead of being asked for the country's total candy sales, you are asked to calculate the total sales for each state.

One approach to this new problem would be to sort the file on `StateNum`. This would turn the requirement into a simple control-break problem (that is, process all the records for one state, output the result, and then go on to the next). But the issue with this solution is that sorting is a comparatively slow, disk-intensive procedure. You want to avoid having to adopt this solution if possible. Is there any other way to solve the problem?

You could create 50 variables (one for each state) to hold the sales totals. Then, in the program, you could use an `EVALUATE` statement to add `CandySales` to the appropriate total. For example:

```
EVALUATE StateNum
  WHEN 1 ADD CandySales TO State1SalesTotal
  WHEN 2 ADD CandySales TO State2SalesTotal
  WHEN 3 ADD CandySales TO State3SalesTotal
  ..... 47 more WHEN branches
END-EVALUATE
```

This solution is not very satisfactory. You need a specific `WHEN` branch to process each state, and you have to declare 50 data items to hold the sales totals. And when you want to display the results, you must use 50 `DISPLAY` statements:

```
DISPLAY "State 1 total is ", State1SalesTotal
DISPLAY "State 2 total is ", State2SalesTotal
DISPLAY "State 3 total is ", State3SalesTotal
  ..... 47 more DISPLAY statements
```

But this poor attempt at a solution does contain the germ of an idea of how to solve the problem. It is interesting to note that the processing of each WHEN branch is the same: CandySales is added to the sales total for a particular state. You could replace all 50 WHEN branches with one statement if you could generalize to something like this:

ADD the CandySales to the StateSalesTotal location indicated by the StateNum.

There is also something interesting about the 50 data items. They all have exactly the same PICTURE, and they all have, more or less, the same name: StateSalesTotal. The only way you can distinguish between one StateSalesTotal and another is by attaching a number to the name: State1SalesTotal, State2SalesTotal, State3SalesTotal, and so on.

When you see a group of data items that all have the same name and the same description and are only distinguished from one another by a number attached to the name, you know that you have a problem crying out for a table-based solution.

Using a Table for the State Sales Totals

In COBOL, you declare a table by specifying the type (or structure) of a single item (element) of the table and then specifying that the data item is to be repeated a given number of times. For instance, StateSalesTable may be defined as follows:

```
01 StateSalesTable.
   02 StateSalesTotal      PIC 9(8)V99 OCCURS 50 TIMES.
```

StateSalesTable can be represented diagrammatically as shown in Figure 11-1. All the elements of the table have the name StateSalesTotal; you can refer to a specific one by using that name followed by an integer value in brackets. So, StateSalesTotal(3) refers to the third element of the table, and StateSalesTotal(13) refers to the thirteenth element.

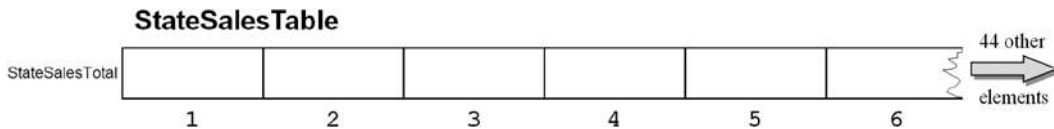


Figure 11-1. Diagrammatic representation of StateSalesTable

But when you refer to an element, you don't have to use a numeric literal. You can use anything that evaluates to a numeric value between 1 and the size of the table—even a simple arithmetic expression.

So the solution to the problem of summing the candy sales for each state is to use a table to hold a StateSalesTotal for each state and to use StateNum to access the correct element in the table.

Once you realize that you can use a table to hold the sales totals and StateNum as an index into the table, the solution to the problem becomes very simple. A program to read the sales file, sum the sales, and display the results is given in Listing 11-1. In this example, to keep the program simple and focus on table creation and handling, I chose to display the results rather than write them to a print file.

Listing 11-1. Summing Candy Sales for Each State

IDENTIFICATION DIVISION.

PROGRAM-ID. Listing11-1.

AUTHOR. Michael Coughlan

* Program to sum the CandySales for each branch of YoreCandyShoppe

* and display the results in StateNum order

* Using as input the Sequential BranchSalesFile ordered on ascending BranchId

ENVIRONMENT DIVISION.

INPUT-OUTPUT SECTION.

FILE-CONTROL.

```

SELECT BranchSalesFile ASSIGN TO "Listing11-1BranchSales.dat"
      ORGANIZATION IS LINE SEQUENTIAL.

```

DATA DIVISION.

FILE SECTION.

FD BranchSalesFile.

01 BranchSalesRec.

```

      88 EndOfSalesFile VALUE HIGH-VALUES.
      02 BranchId       PIC 9(7).
      02 StateNum       PIC 99.
      02 CandySales     PIC 9(7)V99.

```

WORKING-STORAGE SECTION.

01 StateSalesTable.

```

      02 StateSalesTotal PIC 9(8)V99 OCCURS 50 TIMES.

```

01 StateIdx PIC 99.

01 PrnStateSales PIC \$\$\$,\$\$\$,\$\$9.99.

PROCEDURE DIVISION.

Begin.

MOVE ZEROS TO StateSalesTable

OPEN INPUT BranchSalesFile

READ BranchSalesFile

AT END SET EndOfSalesFile TO TRUE

END-READ

PERFORM UNTIL EndOfSalesFile

ADD CandySales TO StateSalesTotal(StateNum)

READ BranchSalesFile

AT END SET EndOfSalesFile TO TRUE

END-READ

END-PERFORM

DISPLAY " YoreCandyShoppe Sales by State"

DISPLAY " -----"

PERFORM VARYING StateIdx FROM 1 BY 1

UNTIL StateIdx GREATER THAN 50

MOVE StateSalesTotal(StateIdx) TO PrnStateSales

```

        DISPLAY "State ", StateIdx
           " sales total is " PrnStateSales
END-PERFORM
CLOSE BranchSalesFile
STOP RUN.

```

Third Specification: Group Items as Table Elements

The elements of a table do not have to be elementary items. An element can be a group item. In other words, each element can be subdivided into two or more subordinate items.

Suppose the specification of the YoreCandyShoppe sales-report program changes so that in addition to summing the candy sales for each state, the program should count the number of branches and compute the average sales for the state. Final country totals should also be produced, showing Total-US-Sales, US-BranchCount, and Average-US-Sales.

One solution to this problem would be to set up two separate tables: one to hold state sales and another to hold the count of the number of branches in the state (see Example 11-2).

Example 11-2. The Two-Table Solution

```

01 StateSalesTable.
   02 StateSalesTotal      PIC 9(8)V99  OCCURS 50 TIMES.

01 StateBranchesTable.
   02 StateBranchCount    PIC 9(5)  OCCURS 50 TIMES.

```

Then all that would be required to calculate the average sales for the state would be a statement such as

```
COMPUTE AverageStateSales = StateSalesTotal(StateNum) / StateBranchCount(StateNum)
```

This is probably the way you would solve the problem in most languages. But in COBOL you can also set up a single table in which each element is defined as a group item that consists of the StateSalesTotal and the StateBranchCount (see Example 11-3).

Example 11-3. Solution Using the Group Item as a Table Element

```

01 StateSalesTable.
   02 StateTotals OCCURS 50 TIMES.
      03 StateSalesTotal PIC 9(8)V99.
      03 StateBranchCount PIC 9(5).

```

To calculate the average sales, you can use the same COMPUTE statement as before:

```
COMPUTE AverageStateSales = StateSalesTotal(StateNum) / StateBranchCount(StateNum)
```

A diagrammatic representation of this table description is shown in Figure 11-2. Each element of the table now consists of two parts: StateSalesTotal and StateBranchCount. These are subordinate to the StateTotals element. Data-manipulation opportunities abound. All these data names allow you to manipulate the data in the table at different levels of granularity. You can use the following commands:

- MOVE ZEROS TO StateSalesTable: See Figure 11-2. Fills the whole table with zeros.
- MOVE StateTotals(2) TO StateTotals(5): See Figure 11-2. Copies the contents of one element, including both subordinate items, to another element.

- `DISPLAY StateBranchCount(3)`: Displays the contents of the `StateBranchCount` part of element 3.
- `ADD CandySales TO StateSalesTotal(3)`: Adds `CandySales` to the contents of the `StateSalesTotal` part of element 3.

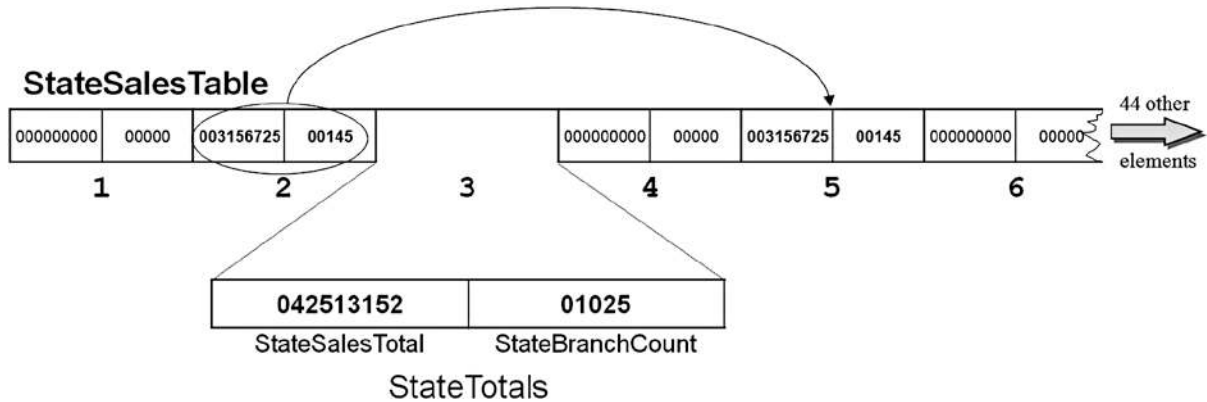


Figure 11-2. Table elements as group items. Element 3 is exploded to show details

Tabular Data Program

Listing 11-2 is a solution to the problem posed by the changed specification. It uses the table defined in Example 11-3.

Listing 11-2. Table Elements as Group Items

IDENTIFICATION DIVISION.

PROGRAM-ID. Listing11-2.

AUTHOR. Michael Coughlan

* Program that for each state and for the whole US

* sums the CandySales for each branch of YoreCandyShoppo

* counts the number of branches

* calculates the average sales per state and displays the results in StateNum order

* Uses as input the Sequential BranchSalesFile ordered on ascending BranchId

ENVIRONMENT DIVISION.

INPUT-OUTPUT SECTION.

FILE-CONTROL.

```
SELECT BranchSalesFile ASSIGN TO "Listing11-2BranchSales.dat"
    ORGANIZATION IS LINE SEQUENTIAL.
```

DATA DIVISION.

FILE SECTION.

FD BranchSalesFile.

01 BranchSalesRec.

```
88 EndOfSalesFile VALUE HIGH-VALUES.
```

```
02 BranchId PIC 9(7).
```

```
02 StateNum PIC 99.
```

```
02 CandySales PIC 9(7)V99.
```

WORKING-STORAGE SECTION.

```

01 StateSalesTable.
    02 StateTotals OCCURS 50 TIMES.
        03 StateSalesTotal PIC 9(8)V99.
        03 StateBranchCount PIC 9(5).

01 StateIdx PIC 99.

01 ReportHeading1 PIC X(35)
    VALUE " YoreCandyShoppe Sales by State".
01 ReportHeading2 PIC X(35)
    VALUE " -----".
01 ReportHeading3 PIC X(47)
    VALUE "State Branches StateSales AverageSales".

01 DetailLine.
    02 PrnStateNum PIC BZ9.
    02 PrnBranchCount PIC B(3)ZZ,ZZ9.
    02 PrnStateSales PIC B(5)$$,$$$,$$9.99.
    02 PrnAveageSales PIC BB$$$$,$$$,$$9.99.

01 US-Totals.
    02 US-TotalSales PIC 9(9)V99.
    02 US-BranchCount PIC 9(6).
    02 PrnUS-TotalSales PIC $,$$$,$$$,$$9.99.
    02 PrnUS-BranchCount PIC B(9)ZZZ,ZZ9.
    02 PrnUS-AverageSales PIC BBBB$$$$,$$$,$$9.99.

```

PROCEDURE DIVISION.

Begin.

```

MOVE ZEROS TO StateSalesTable
OPEN INPUT BranchSalesFile
READ BranchSalesFile
    AT END SET EndOfSalesFile TO TRUE
END-READ
PERFORM UNTIL EndOfSalesFile
    ADD CandySales TO StateSalesTotal(StateNum), US-TotalSales
    ADD 1 TO StateBranchCount(StateNum), US-BranchCount
    READ BranchSalesFile
        AT END SET EndOfSalesFile TO TRUE
    END-READ
END-PERFORM
PERFORM PrintResults

CLOSE BranchSalesFile
STOP RUN.

```

PrintResults.

```

DISPLAY ReportHeading1
DISPLAY ReportHeading2

```

```

DISPLAY ReportHeading3
PERFORM VARYING StateIdx FROM 1 BY 1
    UNTIL StateIdx GREATER THAN 50
    MOVE StateIdx TO PrnStateNum
    MOVE StateSalesTotal(StateIdx) TO PrnStateSales
    MOVE StateBranchCount(StateIdx) TO PrnBranchCount
    COMPUTE PrnAveageSales = StateSalesTotal(StateIdx) / StateBranchCount(StateIdx)
    DISPLAY DetailLine
END-PERFORM
MOVE US-TotalSales TO PrnUS-TotalSales
MOVE US-BranchCount TO PrnUS-BranchCount
COMPUTE PrnUS-AverageSales = US-TotalSales / US-BranchCount
DISPLAY "YoreCandyShoppe branches in the US = " PrnUS-BranchCount
DISPLAY "YoreCandyShoppe sales in the US    = " PrnUS-TotalSales
DISPLAY "YoreCandyShoppe average US sales  = " PrnAveageSales.

```

Multidimensional Tables

Listing 11-2 uses a table in which each element is a group item that consists of the `StateSalesTotal` and the `StateBranchCount`. But the table is still a single-dimensional table. Sometimes the solution to a problem demands a multidimensional table approach. A multidimensional table is one in which each element of the table is itself a table. This section considers multidimensional tables in the context of a specification change for the YoreCandyShoppe sales report.

Suppose each YoreCandyShoppe branch is asked to provide more granular sales data. Instead of reporting sales for the entire year, each branch must now report sales for each month. To do this, the sales record for each branch must be changed to accommodate a 12-element table of sales data. The new record description is given in Example 11-4.

Example 11-4. New Record Description That Records Candy Sales for Each Month

```

01 BranchSalesRec.
   88 EndOfSalesFile  VALUE HIGH-VALUES.
   02 BranchId        PIC 9(7).
   02 StateNum        PIC 99.
   02 SalesForMonth   PIC 9(5)V99 OCCURS 12 TIMES.

```

The report produced from the sales file must reflect this more granular data and is now required to show the following:

- Total sales for each state
- The count of the number of branches in the state
- Average sales per branch for each state
- Sales per month for each state
- Final country totals showing Total-US-Sales, US-BranchCount, and Average-US-Sales

In the program that implemented the previous specification, the sales for each state and the number of branches in each state were recorded in a 50-element table. In this version, instead of the total sales for the year, you have to record the sales per month. To do that, you need a two-dimensional table as described in Example 11-5.

Example 11-5. Two-dimensional Table to Record Sales per Month and the Number of Branches in the State

```
01 StateSalesTable.
  02 State OCCURS 50 TIMES.
    03 StateBranchCount PIC 9(5).
    03 StateMonthSales PIC 9(5)V99 OCCURS 12 TIMES.
```

COBOL DETAIL

If you wanted to manipulate the table at a further level of granularity, you could describe the table as

```
01 StateSalesTable.
  02 State OCCURS 50 TIMES.
    03 StateBranchCount PIC 9(5).
    03 StateSales.
      04 StateMonthSales PIC 9(5)V99 OCCURS 12 TIMES.
```

The table description in Example 11-5 highlights a difference between COBOL tables and arrays. In other languages, two arrays would be required to record this information: a two-dimensional table to record the state sales per month and a one-dimensional table to record the number of branches per state. You can also record the data using two tables in COBOL, as shown in Example 11-6; but COBOL's hierarchical structuring allows you to combine both tables so that each element of the first dimension consists of the BranchCount and a 12-element table containing the sales for each month.

Example 11-6. A Two-Table Solution

```
01 StateSalesTable.
  02 State OCCURS 50 TIMES.
    03 StateMonthSales PIC 9(5)V99 OCCURS 12 TIMES.

01 StateBranchesTable.
  02 State OCCURS 50 TIMES.
    03 StateBranchCount PIC 9(5).
```

Multidimensional Program

Listing 11-3 is a solution to the changed specification that uses the two-dimensional table described in Example 11-5.

Listing 11-3. Using a Two-dimensional Table to Solve the Problem Posed by the Changed Specification

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing11-3.
AUTHOR. Michael Coughlan
* Program that for each state and for the whole US
* sums the Monthly Sales for each branch of YoreCandyShoppe, counts the number of
* branches and displays the State Sales per month in StateNum order
* Calculates the US sales, the number of branches in the US and the average US sales
* Uses as input the Sequential BranchSalesFile ordered on ascending BranchId
```


ENVIRONMENT DIVISION.

INPUT-OUTPUT SECTION.

FILE-CONTROL.

```
SELECT BranchSalesFile ASSIGN TO "Listing11-3BranchSales.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

DATA DIVISION.

FILE SECTION.

FD BranchSalesFile.

01 BranchSalesRec.

```
88 EndOfSalesFile VALUE HIGH-VALUES.
02 BranchId        PIC 9(7).
02 StateNum        PIC 99.
02 SalesForMonth   PIC 9(5)V99 OCCURS 12 TIMES.
```

WORKING-STORAGE SECTION.

01 StateSalesTable.

```
02 State OCCURS 50 TIMES.
03 StateBranchCount PIC 9(5).
03 StateMonthSales  PIC 9(5)V99 OCCURS 12 TIMES.
```

01 ReportHeading.

```
02 FILLER          PIC X(20) VALUE SPACES.
02 FILLER          PIC X(38) VALUE "YoreCandyShoppe Monthly Sales by State".
```

01 ReportUnderline.

```
02 FILLER          PIC X(20) VALUE SPACES.
02 FILLER          PIC X(38) VALUE ALL "-".
```

01 ReportSubjectHeadings1.

```
02 FILLER          PIC X(12) VALUE "State  NOBs".
02 FILLER          PIC X(63)
   VALUE "      Jan      Feb      Mar      Apr      May      Jun".
```

01 ReportSubjectHeadings2.

```
02 FILLER          PIC X(12) VALUE SPACES.
02 FILLER          PIC X(63)
   VALUE "      Jul      Aug      Sep      Oct      Nov      Dec".
```

01 DetailLine1.

```
02 PrnStateNum     PIC BZ9.
02 PrnBranchCount  PIC BBZZ,ZZ9.
02 PrnMonthSales1  PIC B$$$,$$9.99 OCCURS 6 TIMES.
```

01 DetailLine2.

```
02 FILLER          PIC X(11) VALUE SPACES.
02 PrnMonthSales2  PIC B$$$,$$9.99 OCCURS 6 TIMES.
```

```

01 US-Totals.
  02 US-TotalSales      PIC 9(9)V99.
  02 US-BranchCount    PIC 9(6).
  02 PrnUS-TotalSales  PIC $,,$$,,$$,,$$9.99.
  02 PrnUS-BranchCount PIC B(9)ZZZ,ZZ9.
  02 PrnUS-AverageSales PIC BB$$$$,,$$,,$$9.99.

```

```

01 StateIdx          PIC 99.
01 MonthIdx         PIC 99.

```

PROCEDURE DIVISION.

Begin.

```

  MOVE ZEROS TO StateSalesTable
  OPEN INPUT BranchSalesFile
  READ BranchSalesFile
    AT END SET EndOfSalesFile TO TRUE
  END-READ
  PERFORM UNTIL EndOfSalesFile
    ADD 1 TO StateBranchCount(StateNum), US-BranchCount
    PERFORM VARYING MonthIdx FROM 1 BY 1 UNTIL MonthIdx > 12
      ADD SalesForMonth(MonthIdx) TO
        StateMonthSales(StateNum, MonthIdx), US-TotalSales
    END-PERFORM
  READ BranchSalesFile
    AT END SET EndOfSalesFile TO TRUE
  END-READ
  END-PERFORM
  PERFORM DisplayResults
  CLOSE BranchSalesFile
  STOP RUN.

```

DisplayResults.

```

  DISPLAY ReportHeading
  DISPLAY ReportUnderline
  DISPLAY ReportSubjectHeadings1
  DISPLAY ReportSubjectHeadings2
  PERFORM VARYING StateIdx FROM 1 BY 1
    UNTIL StateIdx GREATER THAN 50
    MOVE StateIdx TO PrnStateNum
    MOVE StateBranchCount(StateIdx) TO PrnBranchCount
    PERFORM VARYING MonthIdx FROM 1 BY 1 UNTIL MonthIdx > 6
      MOVE StateMonthSales(StateIdx, MonthIdx) TO PrnMonthSales1(MonthIdx)
    END-PERFORM
    PERFORM VARYING MonthIdx FROM 7 BY 1 UNTIL MonthIdx > 12
      MOVE StateMonthSales(StateIdx, MonthIdx) TO PrnMonthSales2(MonthIdx - 6)
    END-PERFORM
  DISPLAY DetailLine1
  DISPLAY DetailLine2
  DISPLAY SPACES
  END-PERFORM

```

```

MOVE US-TotalSales TO PrnUS-TotalSales
MOVE US-BranchCount TO PrnUS-BranchCount
COMPUTE PrnUS-AverageSales = US-TotalSales / US-BranchCount
DISPLAY "YoreCandyShoppe branches in the US = " PrnUS-BranchCount
DISPLAY "YoreCandyShoppe sales in the US = " PrnUS-TotalSales
DISPLAY "YoreCandyShoppe average US sales = " PrnUS-AverageSales.

```

Correct Depiction of COBOL Tables

Two-dimensional tables are often depicted using a grid of rows and columns. This is an accurate representation for arrays, but for COBOL tables it has the flaw that it does not accurately reflect the data hierarchy.¹

The table described in Example 11-5 allows you to manipulate the table using statements such as `MOVE ZEROS TO State(1)` and `MOVE 123 TO BranchCount(2)`. In a row-and-column grid depiction, it is not clear how such manipulations are possible.

The diagram in Figure 11-3 uses the correct representation for `StateSalesTable`. This diagram expresses the data hierarchy inherent in the table description where one `OCCURS` clause is subordinate to another. With this representation, you can see how statements such as `MOVE ZEROS TO State(1)` and `MOVE 123 TO StateBranchCount(2)` affect the values in the table.

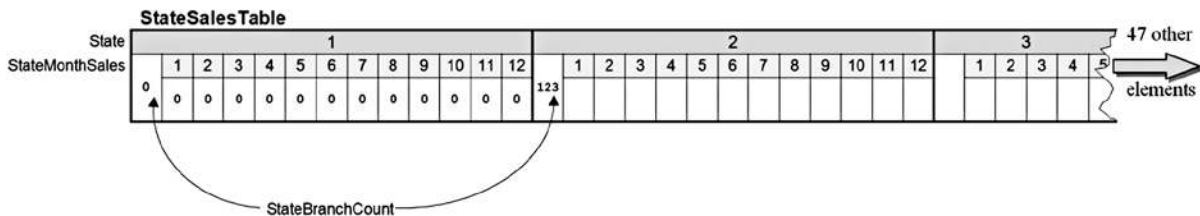


Figure 11-3. Diagram showing the hierarchy in a COBOL table description

Three-Dimensional Tables

In COBOL, multidimensional tables rarely have more than three dimensions. Prior to the ANS 85 version of COBOL, a maximum of three dimensions were permitted; the restriction on `PERFORM. . VARYING` that allows only three counting variables harks back to those days. In the ANS 85 and ISO 2002 COBOL standards, the maximum number of dimensions is seven.

A discussion of how three-dimensional tables are created and processed should help to solidify your understanding of multidimensional tables. This time, however, I present the problem specification and show the declarations necessary to create the three-dimensional table, but I don't write a full program. I leave that as an exercise for you at the end of the chapter.

Keep in mind that this specification is designed with an eye toward what is easy to present diagrammatically rather than toward realism.

Problem Specification

The U.S. Census Bureau has provided you with a subset of census data in a file containing the age category, gender, state number, and car-ownership information of every person in the country. The `CensusFile` is an unordered sequential file, and its records have the following description:

Field	Type	Length	Value
StateNum	9	2	1-50
AgeCategory	9	1	1 = Child 2 = Teen 3 = Adult
GenderCategory	9	1	1 = Female 2 = Male
CarOwner	X	1	Y or N

You are required to write a program to process the `CensusFile` and display the number of males and females in each `AgeCategory` (Child, Teen, and Adult) in each state, as shown in Figure 11-4.

```
Population Details Report
State   Male   Female   Male   Female   Male   Female
Num     Adults Adults   Teens   Teens   Children Children
XX      XXXXXXX XXXXXXX XXXXXXX XXXXXXX XXXXXXX XXXXXXX
XX      XXXXXXX XXXXXXX XXXXXXX XXXXXXX XXXXXXX XXXXXXX
XX      XXXXXXX XXXXXXX XXXXXXX XXXXXXX XXXXXXX XXXXXXX
etc.
```

Figure 11-4. Report template

To accumulate the population totals for each state, you use the three-dimensional table defined in Example 11-7.

Example 11-7. Three-dimensional Table to Hold Population Totals

```
01 US-PopulationTable.
   02 State OCCURS 50 TIMES.
     03 AgeCategory OCCURS 3 TIMES.
       04 GenderCategory OCCURS 2 TIMES.
         05 PopTotal PIC 9(8).
```

For each record that you read from the `CensusFile`, you execute the following statement:

```
ADD 1 TO PopTotal(StateNum, Age, Gender)
```

Depicting a Three-dimensional Table

Figure 11-5 is a depiction of the three-dimensional table defined in the Example 11-7.

US-PopulationTable

State	1						2						48 other elements	
AgeCategory	1		2		3		1		2		3			
GenderCategory	1	2	1	2	1	2	1	2	1	2	1	2	1	2
PopTotal	00000000	00000000	00000000	00000000	00000000	00000000		00000000		156	00000000	00000000		

Figure 11-5. Structure of a three-dimensional table

The data in the table has been changed by executing the following statements:

```
MOVE ZEROS TO State(1)
MOVE ZEROS TO AgeCategory(2,3)
MOVE ZEROS TO GenderCategory (3,1,1)
MOVE ZEROS TO PopTotal(2,1,2)
MOVE 156 TO PopTotal(2,2,2)
```

As you can see from these statements, the data names defined in the table allow you to manipulate the table at various levels of granularity. When you refer to the `State` data item, you must use one subscript because it is a data item whose description contains an `OCCURS` clause. When you refer to `AgeCategory`, you must use two subscripts because `AgeCategory` is subordinate to an item that contains an `OCCURS` clause, and it itself contains an `OCCURS` clause. Finally, when you refer to `GenderCategory` and `PopTotal`, you must use three subscripts: `GenderCategory` is subordinate to two items that contain an `OCCURS` clause, and it contains an `OCCURS` clause itself; and `PopTotal` is subordinate to three items that contain an `OCCURS` clause. `PopTotal` and `GenderCategory` are data names that refer to the same area of storage. The `US-PopulationTable` could have been defined as

```
01 US-PopulationTable.
02 State OCCURS 50 TIMES.
03 AgeCategory OCCURS 3 TIMES.
04 GenderCategory PIC 9(8) OCCURS 2 TIMES.
```

However, the `PopTotal` data item was added for clarity, as documentation.

Prefilled Tables

In all the examples in this chapter, the table used has been filled with data in the course of running the program. Sometimes, however, the table needs to be prefilled with data values. When the program starts, the table must already have been instantiated with the data values.

For instance, in Listing 11-3, when you display the results, you display a state number instead of the name of the state. Obviously it would be better to display the actual state name. A simple way to do this is to set up a prefilled table containing the names of the states and then display the appropriate name using a statement such as `DISPLAY StateName(StateIdx)`.

REDEFINES Clause

To set up a prefilled table in COBOL, you have to use a special data-description clause called the REDEFINES clause. The REDEFINES clause is not limited to creating prefilled tables. It is a powerful data-manipulation language element that is used for a number of purposes. I discuss the REDEFINES clause in detail in Chapter 12, including its full syntax, the semantic rules that apply to it, and the many ways it may be used. In this chapter, I discuss the REDEFINES clause only in the context of creating prefilled tables.

When a file contains different types of records, a record description is created for each record type in the FILE SECTION. However, all these record descriptions map on to the same area of storage. They are, in effect, redefinitions of the area of storage. The REDEFINES clause allows you to achieve the same effect for units smaller than a record and in the other parts of the DATA DIVISION—not just the FILE SECTION.

Creating Prefilled Tables of Values

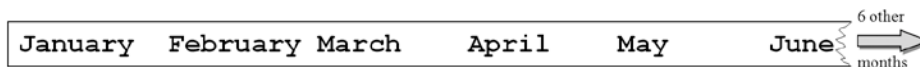
You can use the REDEFINES clause to create a prefilled table by applying the following procedure:

1. Reserve an area of storage, and use the VALUE clause to fill it with the values required in the table.
2. Use the REDEFINES clause to redefine the area of memory as a table.

For instance, to create a table prefilled with the names of the months, the first step is to reserve an area of storage and fill it with the names of the months (see Example 11-8). The diagram in Example 11-8 depicts the undifferentiated area of storage filled with the month names.

Example 11-8. Setting Up an Area of Storage Containing the Month Names

```
01 MonthTable.
  02 MonthValues.
    03 FILLER      PIC X(18) VALUE "January  February".
    03 FILLER      PIC X(18) VALUE "March    April".
    03 FILLER      PIC X(18) VALUE "May      June".
    03 FILLER      PIC X(18) VALUE "July     August".
    03 FILLER      PIC X(18) VALUE "SeptemberOctober".
    03 FILLER      PIC X(18) VALUE "November December".
```



The next step is to redefine the area of storage to impose a table definition on it, as shown in Example 11-9. Now MonthName(3) contains the value "March", and MonthName(6) contains "June".

Example 11-9. Redefining the Area of Storage as a Table

```
01 MonthTable.
  02 MonthValues.
    03 FILLER      PIC X(18) VALUE "January  February".
    03 FILLER      PIC X(18) VALUE "March    April".
    03 FILLER      PIC X(18) VALUE "May      June".
    03 FILLER      PIC X(18) VALUE "July     August".
    03 FILLER      PIC X(18) VALUE "SeptemberOctober".
```

```

03 FILLER          PIC X(18) VALUE "November December".
02 FILLER REDEFINES MonthValues.
03 MonthName OCCURS 12 TIMES PIC X(9).
    
```

1	2	3	4	5	6	6 other elements →
January	February	March	April	May	June	

Creating a Prefilled Two-dimensional Table

To set up a two-dimensional table prefilled with data values, you use the same procedure as for a one-dimensional table. First you create an area of storage that contains the values you want in the table, and then you redefine the area as a table.

Suppose a company pays a bonus depending on ServiceCategory and MaritalStatus, as shown in Table 11-1. You can set up a prefilled table as shown in Example 11-10. In this table, Bonus(4, 1) = 135 and Bonus(2, 2) = 085. The data items MaritalStatus and Bonus refer to the same area of storage. The Bonus data item has been added for purposes of clarity.

Table 11-1. Bonus Table

	Service Category			
	5–10 years	11–20 years	21–30 years	30–50 years
Single	050	085	100	135
Married	075	120	150	175

Example 11-10. Two-dimensional Bonus Table

```

01 BonusTable.
02 BonusValues PIC X(24) VALUE "050075085120100150135175".
03 FILLER REDEFINES BonusValues.
04 ServiceCategory OCCURS 4 TIMES.
05 MaritalStatus OCCURS 2 TIMES.
06 Bonus PIC 9(3).
    
```

ServiceCategory	1		2		3		4	
MaritalStatus	1	2	1	2	1	2	1	2
Bonus	050	075	085	120	100	150	135	175

Prefilled Table Program

The program in Listing 10-1 in Chapter 10 implemented a three-level control break. In the discussion of that program, I noted that in order to reduce the amount of storage occupied by the data file, the normal practice would be to use a state number instead of a state name. I mentioned that in such a program, when it is necessary to print out the state name, the state number is converted to a name by means of a lookup table.

So let's write a program to the same specification as Listing 10-1, except that now the records in the Sales file should use a state number rather than the full state name. The revised program specification follows.

Revised Specification

Electronics2Go has branches in a number of American states. A program is required to produce a report showing the total sales made by each salesperson, the total sales for each branch, the total sales for each state, and a final total showing the total sales for the entire United States. The report must be printed by ascending SalespersonId within ascending BranchId within ascending StateName.

The report is based on the Electronics2Go sales file. This file holds details of sales made in all the branches of the company. It is a sequential file, ordered on ascending SalespersonId within ascending BranchId within ascending StateNum. Each record in the sales file has the following description:

Field	Type	Length	Value
StateNum	9	2	01-50
BranchId	X	5	-
SalespersonId	X	6	99999X (M/F)
ValueOfSale	9	6	0000.00-9999.99

The report format should follow the template shown in Figure 11-6.

```

      Electronics2Go Sales Report
State Name      Branch  SalesId  SalesTotal
XXXXXXXXXXXXXX XXXXX   XXXXXX  XXXXXXXXX
                XXXXXX  XXXXXXXXX
                XXXXXX  XXXXXXXXX
                Branch Total:  XXXXXXXXX

                XXXXX   XXXXXX  XXXXXXXXX
                XXXXXX  XXXXXXXXX
                XXXXXX  XXXXXXXXX
                XXXXXX  XXXXXXXXX
                Branch Total:  XXXXXXXXX
                State Total:  XXXXXXXXX

XXXXXXXXXXXXXX XXXXX   XXXXXX  XXXXXXXXX
                XXXXXX  XXXXXXXXX
                XXXXXX  XXXXXXXXX
                Branch Total:  XXXXXXXXX

XXXXXXXXXXXXXX XXXXXX  XXXXXX  XXXXXXXXX
                XXXXXX  XXXXXXXXX
                XXXXXX  XXXXXXXXX
                Branch Total:  XXXXXXXXX
                State Total:  XXXXXXXXX
                Final Total: XXXXXXXXX

```

Figure 11-6. Template for the Electronics2Go sales report

Final Prefilled Table Program

The program in Listing 11-4 implements the final specification.

Listing 11-4. Report with Three Control Breaks, Using a State Name Table (Changes from Listing 10-1 Shown in Bold)

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing11-4.
AUTHOR. Michael Coughlan.
* A three level Control Break program to process the Electronics2Go
* Sales file and produce a report that shows the value of sales for
* each Salesperson, each Branch, each State, and for the Country.
* The SalesFile is sorted on ascending SalespersonId within BranchId
* within StateNum.
* The report must be printed in SalespersonId within BranchId
* within StateName. There is a correspondence between StateNum order
* and StateName order such that the order of records in
* the file is the same if the file is ordered on ascending StateNum
* as it is when the file is ordered on ascending StateName

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
SELECT SalesFile ASSIGN TO "Listing11-4TestData.Dat"
    ORGANIZATION IS LINE SEQUENTIAL.

SELECT SalesReport ASSIGN TO "Listing11-4.RPT"
    ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD SalesFile.
01 SalesRecord.
    88 EndOfSalesFile VALUE HIGH-VALUES.
    02 StateNum          PIC 99.
    02 BranchId          PIC X(5).
    02 SalesPersonId     PIC X(6).
    02 ValueOfSale       PIC 9(4)V99.

FD SalesReport.
01 PrintLine            PIC X(55).

WORKING-STORAGE SECTION.
01 StateNameTable.
    02 StateNameValues.
        03 FILLER PIC X(14) VALUE "Alabama".
        03 FILLER PIC X(14) VALUE "Alaska".
        03 FILLER PIC X(14) VALUE "Arizona".
        03 FILLER PIC X(14) VALUE "Arkansas".
        03 FILLER PIC X(14) VALUE "California".
        03 FILLER PIC X(14) VALUE "Colorado".
        03 FILLER PIC X(14) VALUE "Connecticut".
```

```

03 FILLER PIC X(14) VALUE "Delaware".
03 FILLER PIC X(14) VALUE "Florida".
03 FILLER PIC X(14) VALUE "Georgia".
03 FILLER PIC X(14) VALUE "Hawaii".
03 FILLER PIC X(14) VALUE "Idaho".
03 FILLER PIC X(14) VALUE "Illinois".
03 FILLER PIC X(14) VALUE "Indiana".
03 FILLER PIC X(14) VALUE "Iowa".
03 FILLER PIC X(14) VALUE "Kansas".
03 FILLER PIC X(14) VALUE "Kentucky".
03 FILLER PIC X(14) VALUE "Louisiana".
03 FILLER PIC X(14) VALUE "Maine".
03 FILLER PIC X(14) VALUE "Maryland".
03 FILLER PIC X(14) VALUE "Massachusetts".
03 FILLER PIC X(14) VALUE "Michigan".
03 FILLER PIC X(14) VALUE "Minnesota".
03 FILLER PIC X(14) VALUE "Mississippi".
03 FILLER PIC X(14) VALUE "Missouri".
03 FILLER PIC X(14) VALUE "Montana".
03 FILLER PIC X(14) VALUE "Nebraska".
03 FILLER PIC X(14) VALUE "Nevada".
03 FILLER PIC X(14) VALUE "New Hampshire".
03 FILLER PIC X(14) VALUE "New Jersey".
03 FILLER PIC X(14) VALUE "New Mexico".
03 FILLER PIC X(14) VALUE "New York".
03 FILLER PIC X(14) VALUE "North Carolina".
03 FILLER PIC X(14) VALUE "North Dakota".
03 FILLER PIC X(14) VALUE "Ohio".
03 FILLER PIC X(14) VALUE "Oklahoma".
03 FILLER PIC X(14) VALUE "Oregon".
03 FILLER PIC X(14) VALUE "Pennsylvania".
03 FILLER PIC X(14) VALUE "Rhode Island".
03 FILLER PIC X(14) VALUE "South Carolina".
03 FILLER PIC X(14) VALUE "South Dakota".
03 FILLER PIC X(14) VALUE "Tennessee".
03 FILLER PIC X(14) VALUE "Texas".
03 FILLER PIC X(14) VALUE "Utah".
03 FILLER PIC X(14) VALUE "Vermont".
03 FILLER PIC X(14) VALUE "Virginia".
03 FILLER PIC X(14) VALUE "Washington".
03 FILLER PIC X(14) VALUE "West Virginia".
03 FILLER PIC X(14) VALUE "Wisconsin".
03 FILLER PIC X(14) VALUE "Wyoming".
02 FILLER REDEFINES StateNameValues.
03 StateName PIC X(14) OCCURS 50 TIMES.

```

```

01 ReportHeading.
   02 FILLER                PIC X(35)
      VALUE "                Electronics2Go Sales Report".

01 SubjectHeading.
   02 FILLER                PIC X(43)
      VALUE "State Name     Branch SalesId SalesTotal".

01 DetailLine.
   02 PrnStateName          PIC X(14).
      88 SuppressStateName VALUE SPACES.
   02 PrnBranchId           PIC BBX(5).
      88 SuppressBranchId  VALUE SPACES.
   02 PrnSalespersonId     PIC BBBBX(6).
   02 PrnSalespersonTotal  PIC BB$$,$$9.99.

01 BranchTotalLine.
   02 FILLER                PIC X(43)
      VALUE "                Branch Total:   ".
   02 PrnBranchTotal       PIC $$$,$$9.99.

01 StateTotalLine.
   02 FILLER                PIC X(40)
      VALUE "                State Total :  ".
   02 PrnStateTotal       PIC $$$,$$,$$9.99.

01 FinalTotalLine.
   02 FILLER                PIC X(39)
      VALUE "                Final Total :".
   02 PrnFinalTotal       PIC $$$,$$$,$$9.99.

01 SalespersonTotal       PIC 9(4)V99.
01 BranchTotal            PIC 9(6)V99.
01 StateTotal             PIC 9(7)V99.
01 FinalTotal             PIC 9(9)V99.

01 PrevStateNum          PIC 99.
01 PrevBranchId           PIC X(5).
01 PrevSalespersonId     PIC X(6).

```

PROCEDURE DIVISION.

```

Begin.
  OPEN INPUT SalesFile
  OPEN OUTPUT SalesReport
  WRITE PrintLine FROM ReportHeading AFTER ADVANCING 1 LINE
  WRITE PrintLine FROM SubjectHeading AFTER ADVANCING 1 LINE

  READ SalesFile
    AT END SET EndOfSalesFile TO TRUE
  END-READ
  PERFORM UNTIL EndOfSalesFile

```

```

MOVE StateNum TO PrevStateNum,
MOVE StateName(StateNum) TO PrnStateName
MOVE ZEROS TO StateTotal
PERFORM SumSalesForState
    UNTIL StateNum NOT = PrevStateNum
        OR EndOfSalesFile
MOVE StateTotal TO PrnStateTotal
WRITE PrintLine FROM StateTotalLine AFTER ADVANCING 1 LINE
END-PERFORM

```

```

MOVE FinalTotal TO PrnFinalTotal
WRITE PrintLine FROM FinalTotalLine AFTER ADVANCING 1 LINE

```

```

CLOSE SalesFile, SalesReport
STOP RUN.

```

SumSalesForState.

```

WRITE PrintLine FROM SPACES AFTER ADVANCING 1 LINE
MOVE BranchId TO PrevBranchId, PrnBranchId
MOVE ZEROS TO BranchTotal
PERFORM SumSalesForBranch
    UNTIL BranchId NOT = PrevBranchId
        OR StateNum NOT = PrevStateNum
        OR EndOfSalesFile
MOVE BranchTotal TO PrnBranchTotal
WRITE PrintLine FROM BranchTotalLine AFTER ADVANCING 1 LINE.

```

SumSalesForBranch.

```

MOVE SalespersonId TO PrevSalespersonId, PrnSalespersonId
MOVE ZEROS TO SalespersonTotal
PERFORM SumSalespersonSales
    UNTIL SalespersonId NOT = PrevSalespersonId
        OR BranchId NOT = PrevBranchId
        OR StateNum NOT = PrevStateNum
        OR EndOfSalesFile
MOVE SalespersonTotal TO PrnSalespersonTotal
WRITE PrintLine FROM DetailLine AFTER ADVANCING 1 LINE
SET SuppressBranchId TO TRUE
SET SuppressStateName TO TRUE.

```

SumSalespersonSales.

```

ADD ValueOfSale TO SalespersonTotal, BranchTotal, StateTotal, FinalTotal
READ SalesFile
    AT END SET EndOfSalesFile TO TRUE
END-READ.

```

ANS 85 Table Changes

The ANS 85 COBOL standard introduced a number of changes to tables. Among these changes is a method that lets you create prefilled tables without using the REDEFINES clause, as long as the number of values is small. For large amounts of data, the REDEFINES clause is still required.

The new method works by assigning the values to a group name defined over a subordinate table. For instance, in Example 11-11, the data item Day actually declares the table, but I have given the table the overall group name DayTable. Assigning the values to this group name fills the area of the table with the values.

Example 11-11. Creating a Prefilled Table Without the REDEFINES Clause

```
01 DayTable VALUE "MonTueWedThrFriSatSun".
   02 Day OCCURS 7 TIMES PIC X(3).
```

Mon	Tue	Wed	Thr	Fri	Sat	Sun
Day(1)	Day(2)	Day(3)	Day(4)	Day(5)	Day(6)	Day(7)

The ANS 85 COBOL standard also introduced some changes to the way tables are initialized. In the previous versions of COBOL, initializing a table was never a problem if the elements of the table were elementary items. All that was required was to move the initializing value to the table's group name. For instance, the statement MOVE ZEROS TO DriverTable initializes the following table to zeros:

```
01 DriverTable.
   02 StateDrivers PIC 9(7) OCCURS 50 TIMES.
```

But initializing a table was much more difficult if each element was a group item that contained different types of data. For instance, in the following table, the StateDrivers part of the element had to be initialized to zeros, and the StateName part had to be initialized to spaces. The only way to do this was to initialize the items, element by element, using iteration:

```
01 DriverTable.
   02 State OCCURS 50 TIMES.
      03 StateDrivers PIC 9(7).
      03 StateName PIC X(14).
```

The ANS 85 standard introduced a new way to initialize table elements that solves this problem. A table cannot be initialized by assigning an initial value to each part of an element using the VALUE clause. The following description initializes the StateDrivers part of the element to zeros and the StateName part to spaces:

```
01 DriverTable.
   02 State OCCURS 50 TIMES.
      03 StateDrivers PIC 9(7) VALUE ZEROS.
      03 StateName PIC X(14) VALUE SPACES.
```

This example shows the ANS 85 changes that allow table elements to be initialized when a program starts; but sometimes data items need to be reinitialized while a program is running. The ANS 85 standard added the INITIALIZE verb for this purpose. The INITIALIZE verb sets data items, including table elements, either to their MOVE fill value (zero for numeric items, spaces for alphabetic or alphanumeric items) or to a specified compatible replacement value. The metalanguage for the INITIALIZE verb is given in Figure 11-7.

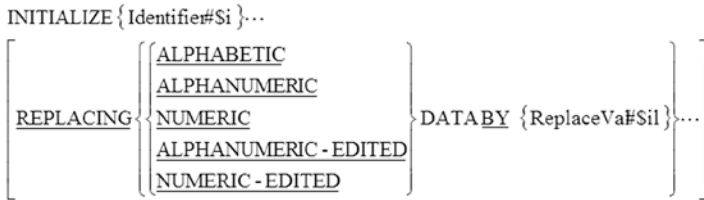


Figure 11-7. Metalanguage for the INITIALIZE verb

A large number of rules govern the operation of the INITIALIZE verb. For full details, please consult your COBOL manual. To get a feel for how INITIALIZE operates, examine output produced by the code in Example 11-12.

Example 11-12. Example Uses of the INITIALIZE Verb

```
01 GroupItem.
  02 Data1 PIC X(7).
  02 Data2 PIC 9(5).
  02 Data3 PIC 99/99/99.
  02 Data4 PIC +99.99.
  02 Data5 PIC $$,$$9.99.
```

```
: : : : : : : : : : :
```

```
PROCEDURE DIVISION.
```

```
Begin.
```

```
MOVE ALL "-" TO GroupItem
```

```
INITIALIZE GroupItem
```

```
DISPLAY "Init1_" Data1 "_" Data2 "_" Data3 "_" Data4 "_" Data5.
```

```
INITIALIZE GroupItem REPLACING ALPHANUMERIC BY "Michael"
NUMERIC BY 54321.
```

```
DISPLAY "Init2_" Data1 "_" Data2 "_" Data3 "_" Data4 "_" Data5.
```

```
STOP RUN.
```

Example 11-12 Output					
Init1_	00000	00/00/00	+00.00		\$0.00
Init2_	Michael	54321	00/00/00	+00.00	\$0.00

Summary

This chapter introduced the concept of tabular data. You learned how to create tables using the OCCURS clause and were introduced to the notion of group items as table elements. I discussed multidimensional tables and showed how to create, use, and graphically depict them. In the final section, you saw how to use the REDEFINES clause to create a table prefilled with table values, and I discussed the table declaration changes that were introduced with the ANS 85 standard.

The next chapter discusses the other uses of the REDEFINES clause and introduces the similar but ill-favored RENAMES clause. You learn about the importance of decimal arithmetic for the business and enterprise programming domains and discover the use and purpose of the USAGE clause.

PROGRAMMING EXERCISE

Earlier in this chapter, I presented a problem specification and suggested an approach to solving the problem that involved using a three-dimensional table. Although the table was defined in Example 11-7, no solution was given. Because you have a problem and no solution, this is an excellent opportunity for you to get some practice using three-dimensional tables.

A subset of the U.S. census data has been made available to you by the U.S. Census Bureau (not really—this is just the specification scenario) in an unordered sequential file called the `CensusFile`. The `CensusFile` contains the age category (adult, teen, child), gender, state number, and car-ownership information of every person in the country. Each record in the file has the following description:

Field	Type	Length	Value
StateNum	9	2	1–50
Age	9	1	1 = Child 2 = Teen 3 = Adult
Gender	9	1	1 = Female 2 = Male
CarOwner	X	1	Y or N

Write a program to process the `CensusFile` and produce a Population Details Report that displays the number of males and females in each `AgeCategory` (Child, Teen, and Adult) in each state. The report format should be as shown in Figure 11-8.

```

                                Population Details Report
State   Male   Female   Male   Female   Male   Female
Num     Adults Adults  Teens  Teens  Children Children
XX      XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
XX      XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
XX      XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
                                etc.

```

Figure 11-8. Template for the Population Details Report

Specification Extension

Change the three-dimensional table so that it can be used to accumulate the number of car owners in each state. Change the program so that the format of the report now conforms to the template in Figure 11-9.

```

                                Population Details Report
State   Car     Male   Female   Male   Female   Male   Female
Name    Owners  Adults Adults  Teens  Teens  Children Children
XX      XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
XX      XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
XX      XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
                                etc.

```

Figure 11-9. Template for the Population Details Report that includes car ownership details

References

1. Fowler GC, Glorfeld LW. COBOL tables: A proposed standard of presentation. SIGCSE Bull. 1983; 15(1): 200-203. <http://doi.acm.org/10.1145/952978.801046>
doi=10.1145/952978.801046



Advanced Data Declaration

In the last chapter, you learned how to create and use a one-dimensional prefilled table. In this chapter, I continue the discussion of the `REDEFINES` clause and demonstrate how you can use it to create a two-dimensional prefilled table.

When I introduced the `REDEFINES` clause in the previous chapter, I did so informally. This chapter formally introduces the `REDEFINES` clause, including the metalanguage syntax and the semantic rules that apply. It also includes several examples of the other ways in which `REDEFINES` may be applied.

Because the `RENAMES` clause is similar to `REDEFINES`, I introduce `RENAMES` in this chapter. You learn about the metalanguage syntax for the clause, explore the semantic rules, and see some examples of how to use `RENAMES`.

The sections discussing the `REDEFINES` and `RENAMES` clauses are followed by an introduction to the `USAGE` clause. I discuss the advantages and disadvantages of `USAGE IS DISPLAY` (the default). I cover the metalanguage syntax and the semantic rules and examine `USAGE IS COMP`, `USAGE IS PACKED-DECIMAL`, and `USAGE IS INDEX` in more detail. Finally, you learn about the purpose and operation of the `SYNCHRONIZED` clause.

The final section discusses the importance of fixed-point decimal arithmetic to COBOL's claim of fitness for creating business or enterprise applications. You learn about the problems with doing financial and commercial calculations using floating-point arithmetic. I discuss the Java `BigDecimal` class and highlight some of the problems with using it, and I contrast COBOL's native support for decimal arithmetic with the bolted-on capability provided by `BigDecimal`.

The Redefines Clause

In the previous chapter, you used the `REDEFINES` clause to create a prefilled table of values. I noted at the time that the `REDEFINES` clause has a number of other uses; this chapter discusses how you can use `REDEFINES` to achieve powerful data-manipulation effects. However, before I discuss the other uses of `REDEFINES`, let's revisit its use in creating prefilled tables. Listing 11-4 used the `REDEFINES` clause to create a table prefilled with the names of the American states. Although it was interesting to see how to create a prefilled table by laying down the values in memory and then using `REDEFINES` to redefine the area of memory as a table, the mapping between the actual values in memory and the table definition was straightforward because only a one-dimensional table was required. In Listing 12-1, later in this section, you see how to create a prefilled two-dimensional table of values.

Specification: Aromamora Base Oil Sales Report

The following specification defines a program that demonstrates how to create and use a prefilled two-dimensional table of values.

Aromamora PLC is a company that sells essential and base (carrier) oils to aromatherapists, health shops, and other mass users of essential oils. Every month, details of the sales of base oils to these customers are gathered together into a sales file (Listing 12-1.Dat in the code download). A program is required that produces a summary report from this file. The report should show the value of the base oils purchased by each customer and should be printed sequenced on ascending `CustomerId`.

The Sales File

The sales file contains details of sales to all Aromamora customers. It is a sequential file ordered on ascending CustomerId. The records in the sales file have the following description:

Field	Type	Length	Value
CustomerId	9	5	0-99999
CustomerName	X	20	-
OilId	X	3	B01-B14
UnitSize	9	1	1/2/3
UnitsSold	9	3	1-999

Report Template

The report format is given in the template shown in Figure 12-1.

Aromamora Base Oils Summary Sales Report

```

Cust Id  Customer Name          ValueOfSales

XXXXX   XXXXXXXXXXXXXXXXXXXXXXXX  XXXXXXXXXXXXX

XXXXX   XXXXXXXXXXXXXXXXXXXXXXXX  XXXXXXXXXXXXX

XXXXX   XXXXXXXXXXXXXXXXXXXXXXXX  XXXXXXXXXXXXX

XXXXX   XXXXXXXXXXXXXXXXXXXXXXXX  XXXXXXXXXXXXX

***** End of Report *****

```

Figure 12-1. Report template for Aromamora Summary Sales Report

Notes

Here are some things to consider:

- The *B* in the OilId indicates that this is a base oil.
- UnitSize represents the size of the oil container purchased. There are only three sizes for base oils: 1 (50ml), 2 (100ml), and 3 (200ml).
- ValueOfSales is the sum of the ValueOfSale calculated for each record.

- ValueOfSale is UnitsSold * UnitCost(OilNum, Unitsize).
- The OilName and UnitCost are obtained from a prefilled table of values (see the program outline for details). The two-dimensional table required to hold these values is shown in Figure 12-2.

		1	2	3	
BaseOil ↑ ↓	1	Almond	\$02.00	\$03.50	\$06.50
	2	Aloe vera	\$04.75	\$08.50	\$16.25
	3	Apricot kernel	\$02.50	\$04.25	\$07.75
	4	Avocado	\$02.75	\$04.75	\$08.75
	5	Coconut	\$02.75	\$04.75	\$08.95
	6	Evening primrose	\$03.75	\$06.55	\$12.25
	7	Grape seed	\$01.85	\$03.25	\$06.00
	8	Peanut	\$02.75	\$04.25	\$07.95
	9	Jojoba	\$07.25	\$13.25	\$25.00
	10	Macadamia	\$03.25	\$05.75	\$10.95
	11	Rosehip	\$05.25	\$09.95	\$18.50
	12	Sesame	\$02.95	\$04.25	\$07.50
	13	Walnut	\$02.75	\$04.55	\$08.25
	14	Wheatgerm	\$04.50	\$07.75	\$14.25
	OilName	←	UnitSize	→	

Figure 12-2. Table of oil names and unit costs

Oil Costs Table

Aromamora sells 14 kinds of base oil. The cost of each type of base oil in each of the three container sizes (50ml, 100ml, and 200ml) is given by the table in Figure 12-2. For instance, almond oil costs \$02.00 for the 50ml size, \$03.50 for 100ml size, and \$06.50 for 200ml size.

Example 12-1 demonstrates how you can translate the information given in Figure 12-1 into a prefilled COBOL table. You start by laying down in memory the information you want in the table. Obviously you have to omit the dollar sign and decimal point because those are text and you need to do calculations on the data in the table. At this point, you have a block of undifferentiated data in memory as follows:

```
Almond      020003500650
Aloe vera   047508501625
Apricot kernel 025004250775
Avocado     027504750875
Coconut     027504750895
Evening primrose037506551225
Grape seed  018503250600
Peanut      027504250795
```

Jojoba	072513252500
Macadamia	032505751095
Rosehip	052509951850
Sesame	029504250750
Walnut	027504550825
Wheatgerm	045007751425

The final step in creating the table is to use the REDEFINES clause to impose a table definition on the area of memory, as shown in Example 12-1. Once the data is redefined, you can access it using the table. For instance, OilName(9) = Jojoba, and UnitCost(9,2) = 1325.

Example 12-1. Table Definition of the Two-Dimensional Table Shown in Figure 12-1

```

01 OilsTable.
  02 OilTableValues.
    03 FILLER PIC X(28) VALUE "Almond      020003500650".
    03 FILLER PIC X(28) VALUE "Aloe vera   047508501625".
    03 FILLER PIC X(28) VALUE "Apricot kernel 025004250775".
    03 FILLER PIC X(28) VALUE "Avocado    027504750875".
    03 FILLER PIC X(28) VALUE "Coconut    027504750895".
    03 FILLER PIC X(28) VALUE "Evening primrose037506551225".
    03 FILLER PIC X(28) VALUE "Grape seed 018503250600".
    03 FILLER PIC X(28) VALUE "Peanut     027504250795".
    03 FILLER PIC X(28) VALUE "Jojoba     072513252500".
    03 FILLER PIC X(28) VALUE "Macadamia  032505751095".
    03 FILLER PIC X(28) VALUE "Rosehip    052509951850".
    03 FILLER PIC X(28) VALUE "Sesame     029504250750".
    03 FILLER PIC X(28) VALUE "Walnut     027504550825".
    03 FILLER PIC X(28) VALUE "Wheatgerm  045007751425".
  02 FILLER REDEFINES OilTableValues.
    03 BaseOil OCCURS 14 TIMES.
      04 OilName PIC X(16).
      04 UnitCost PIC 99V99 OCCURS 3 TIMES.

```

Program

This is a typical one-level control-break program. I have kept the program simple (see Listing 12-1) to allow you to focus on the declaration and use of the two-dimensional table. Note that in a real situation, the oil-cost table would not be static as it is in this program. The cost data is likely to change, so for maintenance reasons the table would probably be instantiated from a file. A portion of the sales file used to test the program and the summary report produced from that file are shown in Figure 12-3 in the next section.

Listing 12-1. Aromamora Base Oils Summary Sales Report

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing12-1.
AUTHOR. Michael Coughlan.
* This program produces a summary report showing the sales of base oils
* to Aromamora customers by processing the OilSalesFile. The OilSalesFile is a
* sequential file ordered on ascending CustomerId. The report is required to be
* printed in ascending CustomerId order.

```

ENVIRONMENT DIVISION.

INPUT-OUTPUT SECTION.

FILE-CONTROL.

 SELECT BaseOilsSalesFile ASSIGN TO "Listing12-1.Dat"
 ORGANIZATION IS LINE SEQUENTIAL.

 SELECT SummaryReport ASSIGN TO "Listing12-1.Rpt"
 ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.

FILE SECTION.

FD BaseOilsSalesFile.

01 SalesRec.

 88 EndOfSalesFile VALUE HIGH-VALUES.
 02 CustomerId PIC X(5).
 02 CustomerName PIC X(20).
 02 OilId.
 03 FILLER PIC X.
 03 OilNum PIC 99.
 02 UnitSize PIC 9.
 02 UnitsSold PIC 999.

FD SummaryReport.

01 PrintLine PIC X(45).

WORKING-STORAGE SECTION.

01 OilsTable.

 02 OilTableValues.

 03 FILLER PIC X(28) VALUE "Almond 020003500650".
 03 FILLER PIC X(28) VALUE "Aloe vera 047508501625".
 03 FILLER PIC X(28) VALUE "Apricot kernel 025004250775".
 03 FILLER PIC X(28) VALUE "Avocado 027504750875".
 03 FILLER PIC X(28) VALUE "Coconut 027504750895".
 03 FILLER PIC X(28) VALUE "Evening primrose037506551225".
 03 FILLER PIC X(28) VALUE "Grape seed 018503250600".
 03 FILLER PIC X(28) VALUE "Peanut 027504250795".
 03 FILLER PIC X(28) VALUE "Jojoba 072513252500".
 03 FILLER PIC X(28) VALUE "Macadamia 032505751095".
 03 FILLER PIC X(28) VALUE "Rosehip 052509951850".
 03 FILLER PIC X(28) VALUE "Sesame 029504250750".
 03 FILLER PIC X(28) VALUE "Walnut 027504550825".
 03 FILLER PIC X(28) VALUE "Wheatgerm 045007751425".

 02 FILLER REDEFINES OilTableValues.

 03 BaseOil OCCURS 14 TIMES.
 04 OilName PIC X(16).
 04 UnitCost PIC 99V99 OCCURS 3 TIMES.

01 ReportHeadingLine PIC X(41)
 VALUE " Aromamora Base Oils Summary Sales Report".

```

01 TopicHeadingLine.
   02 FILLER          PIC X(9) VALUE "Cust Id".
   02 FILLER          PIC X(15) VALUE "Customer Name".
   02 FILLER          PIC X(7) VALUE SPACES.
   02 FILLER          PIC X(12) VALUE "ValueOfSales".

01 ReportFooterLine  PIC X(43)
   VALUE "***** End of Report *****".

01 CustSalesLine.
   02 PrnCustId       PIC B9(5).
   02 PrnCustName     PIC BBBX(20).
   02 PrnCustTotalSales PIC BBB$$$$,$$9.99.

01 CustTotalSales    PIC 9(6)V99.
01 PrevCustId        PIC X(5).
01 ValueOfSale       PIC 9(5)V99.

```

PROCEDURE DIVISION.

Print-Summary-Report.

```

OPEN OUTPUT SummaryReport
OPEN INPUT BaseOilsSalesFile

```

```

WRITE PrintLine FROM ReportHeadingLine AFTER ADVANCING 1 LINE
WRITE PrintLine FROM TopicHeadingLine AFTER ADVANCING 2 LINES

```

```

READ BaseOilsSalesFile
  AT END SET EndOfSalesFile TO TRUE
END-Read

```

```

PERFORM PrintCustomerLines UNTIL EndOfSalesFile

```

```

WRITE PrintLine FROM ReportFooterLine AFTER ADVANCING 3 LINES

```

```

CLOSE SummaryReport, BaseOilsSalesFile
STOP RUN.

```

PrintCustomerLines.

```

MOVE ZEROS TO CustTotalSales
MOVE CustomerId TO PrnCustId, PrevCustId
MOVE CustomerName TO PrnCustName

```

```

PERFORM UNTIL CustomerId NOT = PrevCustId
  COMPUTE ValueOfSale = UnitsSold * UnitCost(OilNum, UnitSize)
  ADD ValueOfSale TO CustTotalSales
  READ BaseOilsSalesFile
    AT END SET EndOfSalesFile TO TRUE
  END-Read
END-PERFORM

```

```

MOVE CustTotalSales TO PrnCustTotalSales
WRITE PrintLine FROM CustSalesLine AFTER ADVANCING 2 LINES.

```

Test Data and Results

Due to space constraints, only a portion of the test data file is shown (see Figure 12-3).

Sales File (Listing12-1.Dat)		Summary Report (Listing12-1.Rpt)		
12332SCENTIMENTS	B122100	Aromamora Base Oils Summary Sales Report		
12332SCENTIMENTS	B112150			
12332SCENTIMENTS	B143050			
12332SCENTIMENTS	B121150	Cust Id	Customer Name	ValueOfSales
12332SCENTIMENTS	B123250	12332	SCENTIMENTS	\$4,947.50
12344AROMANTICS	B112115	12344	AROMANTICS	\$4,035.50
12344AROMANTICS	B132325	12350	EATS OF EDEN	\$760.75
12344AROMANTICS	B082005	12352	OILS FOR ALL	\$3,272.00
12344AROMANTICS	B092105	22342	SCENTS OF SMELL	\$1,937.50
12350EATS OF EDEN	B081025	22346	AROMANIACS	\$500.25
12350EATS OF EDEN	B081050	22354	COMMON SCENTS	\$3,400.00
12350EATS OF EDEN	B031100	32348	HEAVEN SCENT	\$3,552.50
12350EATS OF EDEN	B021022	32350	OILS WELL THAT ENDS	\$25.00
12350EATS OF EDEN	B011100	32358	SCENTS OF DECORUM	\$5,282.50
12352OILS FOR ALL	B031045	42346	OIL IN GOOD TIME	\$105.00
12352OILS FOR ALL	B032055	42348	SCENTS OF FOREBODING	\$122.00
12352OILS FOR ALL	B051035	52332	MAKING SCENTS OF IT	\$77.25
12352OILS FOR ALL	B112025	52336	SCENTSUALITY	\$161.00
12352OILS FOR ALL	B121015	52338	ODOURS OF SANCTITY	\$44.75
12352OILS FOR ALL	B121065	52346	OILS FAYRE IN LOVE	\$1.85
12352OILS FOR ALL	B141005	52348	PERFECT SCENTS	\$3,362.50
12352OILS FOR ALL	B133005	***** End of Report *****		
12352OILS FOR ALL	B132005			
12352OILS FOR ALL	B121105			
12352OILS FOR ALL	B121115			
12352OILS FOR ALL	B112145			
12352OILS FOR ALL	B092005			
12352OILS FOR ALL	B062005			
12352OILS FOR ALL	B042005			
12352OILS FOR ALL	B043005			
22342SCENTS OF SMELL	B032050			
22342SCENTS OF SMELL	B061050			
22342SCENTS OF SMELL	B092050			
22342SCENTS OF SMELL	B082050			
22342SCENTS OF SMELL	B092050			
etc.				

Figure 12-3. Partial test data and results produced

The REDEFINES Clause

So far, I have dealt informally with the REDEFINES clause. You have seen how to use it to create a prefilled table of values, but I have not formally defined what REDEFINES does or explored its other uses.

When a file contains different types of records, you must create a separate record description for each record type in the file's FD entry. You have seen that all these record descriptions map on to the same area of storage. They are, in effect, redefinitions of the area of storage. What the REDEFINES clause allows you to do is to achieve the same effect for units smaller than a record and in parts of the DATA DIVISION other than the FILE SECTION. The REDEFINES clause lets you give different data descriptions to the same area of storage.

REDEFINES Syntax

The syntax metalanguage for the REDEFINES clause is given in Figure 12-4. Identifier1 is the data item that originally defines the area of storage, and Identifier2 is the data item that redefines it.

$$\text{Level} - \text{No} \left\{ \begin{array}{l} \text{Identifier2} \\ \text{FILLER} \end{array} \right\} \text{REDEFINES Identifier1}$$

Figure 12-4. Syntax metalanguage for the REDEFINES clause

REDEFINES Notes

The metalanguage defines the syntax of the REDEFINES clause, but there are also a number of semantic rules that must be obeyed when you use REDEFINES:

- The REDEFINES clause must immediately follow Identifier2 (that is, REDEFINES must come before PIC [see Example 12-2]).
- The level numbers of Identifier1 and Identifier2 must be the same and cannot be 66 or 88.
- The data description of Identifier1 cannot contain an OCCURS clause (that is, you can't redefine a table element).
- If there are multiple redefinitions of the same area of storage, then they must all redefine the data item that originally defined the area (see Example 12-5).
- The redefining entries (Identifier2) cannot contain VALUE clauses except in condition name entries.
- No entry with a level number lower (that is, higher in the hierarchy) than the level number of Identifier1 and Identifier2 can occur between Identifier1 and Identifier2.
- Entries redefining the area must immediately follow those that originally defined it.
- Only entries subordinate to Identifier1 are allowed between Identifier1 and Identifier2.
- The REDEFINES clause must not be used for records (01 level) described in the FILE SECTION because multiple 01 entries for the same file are implicit redefinitions of the first 01 level record.

REDEFINES Examples

The best way to understand how the REDEFINES clause works is to explore some of the ways it may be used through a number of examples.

REDEFINES Example 1

Some COBOL statements, such as UNSTRING, require their receiving fields to be alphanumeric (PIC X) data items. This is inconvenient if the value of the data item is actually numeric, because then a MOVE is required to place the value into a numeric item. If the value contains a decimal point, this creates even more difficulties.

For example, suppose an UNSTRING statement has just extracted the text value “5432195” from a string, and you want to move this value to a numeric item described as PIC 9(5)V99. An ordinary MOVE is not going to work because the computer will not know that you want the item treated as if it were the value 654321.95.

The REDEFINES clause allows you to solve this problem neatly because you can UNSTRING the number into TextValue and then treat TextValue as if it were described as PIC 9(5)V99 (see Example 12-2). If TextValue contains the alphanumeric value “65432195”, then NumericValue, which REDEFINES it, sees the value as 654321.95 (see Figure 12-5).

Example 12-2. Redefining an Alphanumeric Item as a Decimal Data Item

```
01 RedefinesExample1.
  02 TextValue PIC X(8).
  02 NumericValue REDEFINES TextValue PIC 9(6)V99.
```

01 RedefinesExample1.
02 TextValue PIC X(8).
6 5 4 3 2 1 9 5
↑
02 NumericValue PIC 9(6)V99.

01 RedefinesExample1.
02 TextValue PIC X(8).
6 5 4 3 2 1 9 5
↑
02 NumericValue REDEFINES TextValue PIC 9(6)V99.

Figure 12-5. Memory model showing the result of redefinition

REDEFINES Example 2

The first example showed how you can use the REDEFINES clause to treat a set of alphanumeric digits as a decimal number. This example explores a similar problem. When a program ACCEPTs a decimal number from a user, the decimal point is included. This is a problem because this decimal point is a text character. If you move a numeric literal (such as 1234.55) that contains a decimal point into a numeric data item that contains an assumed decimal point (such as PIC 9(5)V99), the actual and assumed decimal points align. This does not happen when you move an item containing the decimal point text character. In fact, if you move an item containing an actual decimal point into a numeric data item and then try to perform an arithmetic calculation on that data item, the program will crash (halt unexpectedly).

A solution to this problem is given in Example 12-3. When a number containing an actual decimal point is accepted from the user, the UNSTRING verb is used to split the input string into the digits before the decimal point and those after the decimal point. Although WorkArea contains only numeric digits, because it is a group item, its type is alphanumeric, and so it can't be used in a calculation. The solution is to redefine WorkArea as WorkNum, which is a numeric data item that can be used in calculations. A model of the redefined data items is given in Figure 12-6.

Example 12-3. Redefining Two Data Items as a Single Numeric Item

WORKING-STORAGE SECTION.

```
01 InputString   PIC X(8).

01 WorkArea.
   02 Fnum       PIC 9(5) VALUE ZEROS.
   02 Snum       PIC 99  VALUE ZEROS.
01 WorkNum REDEFINES WorkArea PIC 99999V99.

01 EditedNum    PIC ZZ,ZZ9.99.
```

PROCEDURE DIVISION.

```
Begin.
  DISPLAY "Enter a decimal number - " WITH NO ADVANCING
  ACCEPT InputString
  UNSTRING InputString DELIMITED BY ".", ALL SPACES
    INTO Fnum, Snum
  MOVE WorkNum TO EditedNum
  DISPLAY "Decimal Number = " EditedNum
  ADD 10 TO WorkNum
  MOVE WorkNum TO EditedNum
  DISPLAY "Decimal Number = " EditedNum
```

Example 12-3 Output

```
Enter a decimal number - 1234.55
Decimal Number = 1,234.55
Decimal Number = 1,244.55
```

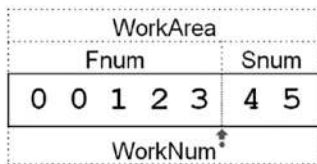


Figure 12-6. Model showing WorkArea, Fnum, and Snum redefined as WorkNum

REDEFINES Example 3

Working with percentages often presents a problem. If the percentage is held as an integer, then calculations are complicated by having to divide by 100. For instance, $\text{COMPUTE PercentOfBase} = \text{BaseAmount} * \text{PercentToApply} / 100$.

On the other hand, if the percentage is held as a decimal fraction, then calculations are made simpler but communication with users is complicated because now they have to input or print the percentage as a decimal fraction rather than a whole number.

The solution is to take in the percentage as an integer value and then use REDEFINES to treat it as a decimal fraction. Example 12-4 is a program fragment that shows how this works.

Example 12-4. Using REDEFINES to Allow Different Views of a Percentage Value

```
DATA DIVISION.
WORKING-STORAGE SECTION.
01 PercentToApply    PIC 9(3).
01 Percentage REDEFINES PercentToApply PIC 9V99.

01 BaseAmount       PIC 9(5) VALUE 10555.
01 PercentOfBase    PIC ZZ,ZZ9.99.
01 PrnPercent       PIC ZZ9.

PROCEDURE DIVISION.
Begin.
  MOVE 23 TO PercentToApply
  COMPUTE PercentOfBase = BaseAmount * Percentage
  DISPLAY "23% of 10555 is = " PercentOfBase
  MOVE PercentToApply to PrnPercent
  DISPLAY "Percentage applied was " PrnPercent "%"
  STOP RUN.
```

Example 12-4 Output

```
23% of 10555 is = 2,427.65
Percentage applied was 23%
```

REDEFINES Example 4

The REDEFINES clause is also useful when you need to treat a numeric item as if it had its decimal point in a different place. For instance, Example 12-5 shows how you can use the REDEFINES clause to provide time conversions between seconds, milliseconds, microseconds, and nanoseconds.

The main purpose of Example 12-5 is to illustrate the rule that if there are multiple redefinitions of an area of storage, they must all refer to the data item that originally defined the area of storage.

Example 12-5. Time Conversion by Multiple Redefinition

```
WORKING-STORAGE SECTION.
01 NanoSecs        PIC 9(10).
01 MicroSecs      REDEFINES NanoSecs PIC 9999999V999.
01 MilliSecs      REDEFINES NanoSecs PIC 9999V999999.
01 Seconds        REDEFINES NanoSecs PIC 9V999999999.

01 EditedNum      PIC Z,ZZZ,ZZZ,ZZ9.99.

PROCEDURE DIVISION.
Begin.
  MOVE 1234567895 TO NanoSecs
  MOVE NanoSecs TO EditedNum
  DISPLAY EditedNum " NanoSecs"
```

```

MOVE MicroSecs TO EditedNum
DISPLAY EditedNum " MicroSecs"

MOVE MilliSecs TO EditedNum
DISPLAY EditedNum " MilliSecs"

MOVE Seconds TO EditedNum
DISPLAY EditedNum " Seconds"
STOP RUN.

```

Example 12-5 Output

```

1,234,567,895.00 NanoSecs
  1,234,567.89 MicroSecs
    1,234.56 MilliSecs
      1.23 Seconds

```

The RENAMEs Clause

As you have seen, the REDEFINES clause allows you to give a new data definition and name to an area of storage. The RENAMEs clause lets you give a new name (or alias) to a data item or a collection of data items. This can be useful when you want to regroup a number of elementary data items in a record so that they can belong to the original as well as to the new group.

The RENAMEs clause is used with the special level number 66. In the same way that condition names are sometimes called level eighty-eights, RENAMEs data items are sometimes called *level sixty-sixes*.

Because of the maintenance problems associated with RENAMEs, it has largely fallen into disuse; and in some programming shops, it is banned. I include it here only for completeness.

RENAMEs Syntax

The syntax metalanguage for the RENAMEs clause is given in Figure 12-7. Identifier2 [THRU Identifier3] is the original area of storage, and Identifier1 is the new name that you can use to manipulate it.

```
66 Identifier1 RENAMEs Identifier2 [ { THRU } Identifier3 ]
```

Figure 12-7. RENAMEs metalanguage

RENAMEs Notes

The syntax diagram in Figure 12-7 is modified by the following semantic rules:

- The level number of Identifier2 and Identifier3 cannot be 77, 88, 01, or 66.
- Identifier2 and Identifier3 must not contain an OCCURS clause or be subordinate to a data item that contains an OCCURS clause.
- No data item between Identifier2 and Identifier3 can contain an OCCURS clause.
- RENAMEs entries must follow the last data-description entry of a record (can't be in the middle of a record description).

RENAMES Examples

Listing 12-2 contains a number of examples that show how to use the RENAME clause.

Listing 12-2. RENAME Examples

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing12-2
AUTHOR. Michael Coughlan.
* RENAME clause examples
DATA DIVISION.
WORKING-STORAGE SECTION.
01 StudentRec.
    02 StudentId          PIC 9(8)  VALUE 12345678.
    02 GPA                PIC 9V99  VALUE 3.25.
    02 ForeName           PIC X(6)  VALUE "Matt".
    02 SurName            PIC X(8)  VALUE "Cullen".
    02 Gender             PIC X      VALUE "M".
    02 PhoneNumber       PIC X(14) VALUE "3536120228233".

66 PersonalInfo RENAME ForeName THRU PhoneNumber.
66 CollegeInfo  RENAME StudentId THRU SurName.
66 StudentName  RENAME ForeName  THRU SurName.

01 ContactInfo.
    02 StudName.
        03 StudForename PIC X(6).
        03 StudSurname  PIC X(8).
    02 StudGender       PIC X.
    02 StudPhone        PIC X(14).

66 MyPhone RENAME StudPhone.

PROCEDURE DIVISION.
Begin.
    DISPLAY "Example 1"
    DISPLAY "All information = " StudentRec
    DISPLAY "College info   = " CollegeInfo
    DISPLAY "Personal Info  = " PersonalInfo

    DISPLAY "Example 2"
    DISPLAY "Combined names = " StudentName

    MOVE PersonalInfo TO ContactInfo

    DISPLAY "Example 3"
    DISPLAY "Name   is " StudName
    DISPLAY "Gender is " StudGender
    DISPLAY "Phone  is " StudPhone

    DISPLAY "Example 4"
    DISPLAY "MyPhone is " MyPhone
    STOP RUN.

```

Listing 12-2 Output

```

Example 1
All information = 12345678325Matt Cullen M3536120228233
College info   = 12345678325Matt Cullen
Personal Info  = Matt Cullen M3536120228233

Example 2
Combined names = Matt Cullen

Example 3
Name   is Matt Cullen
Gender is M
Phone  is 3536120228233

Example 4
MyPhone is 3536120228233

```

Listing Notes

Listing 12-2 contains a number of RENAMEs clause examples. The first example uses the RENAMEs clause to rename sections of the StudentRec to allow the college and personal information parts of the record to be accessed separately. No new data storage is created when this is done, but the existing storage is given new names. This example also shows that multiple, overlapping, RENAMEs may be used.

The second example renames the elementary data items ForeName and SurName as StudentName so they can be treated as a single item (that is, members of a group item). For the purpose of contrast, in the record ContactInfo I made these items subordinate to a group item.

The third example shows that the renamed data can be manipulated using the new name. I moved PersonalInfo to ContactInfo and then displayed the individual fields in ContactInfo.

The final example shows that you can also use RENAMEs to rename a single item.

The USAGE Clause

Computers store their data in the form of binary digits. Apart from cardinal numbers (positive integers), all other data stored in the computer's memory uses some sort of formatting convention.

For instance, text data is stored using an encoding sequence like ASCII or EBCDIC. An encoding system is simply a convention that specifies that a particular set of bits represents a particular character. For instance, Figure 12-8 shows the bit configuration used to represent an uppercase A in the ASCII and EBCDIC encoding sequences.

SYSTEM	CHAR	HEX	DEC	8	4	2	1	8	4	2	1
ASCII	"A"	41	65	0	1	0	0	0	0	0	1
EBCDIC	"A"	C1	193	1	1	0	0	0	0	0	1

Figure 12-8. Uppercase A in the ASCII and EBCDIC encoding sequences

Representation of Numeric Data

COBOL gives you a lot of control over how numeric data is held in memory. In COBOL, numeric data can be held as text digits (ASCII digits), as twos-complement binary numbers, or as decimal numbers (using binary-coded decimal [BCD]).

You use the USAGE clause to specify how a data item is to be stored in the computer's memory. Every data item declared in a COBOL program has a USAGE clause—even when no explicit clause is specified. When there is no explicit USAGE clause, the default USAGE IS DISPLAY is applied. USAGE IS DISPLAY has been used in all the examples so far.

Disadvantage of USAGE DISPLAY

For text items, or for numeric items that will not be used in a computation (phone numbers, account numbers, and so on), the default of USAGE IS DISPLAY presents no problems. But the default usage is not the most efficient way to store data that will be used in a calculation.

When numeric items (PIC 9 items) have a usage of DISPLAY, they are stored as ASCII digits (see the ASCII digits 0-9 in the ASCII table in Figure 12-9).

Char	Dec	Hex	Binary
0	48	30	00110000
1	49	31	00110001
2	50	32	00110010
3	51	33	00110011
4	52	34	00110100
5	53	35	00110101
6	54	36	00110110
7	55	37	00110111
8	56	38	00111000
9	57	39	00111001

Figure 12-9. Table of ASCII digits

Consider the program fragment in Example 12-6. Figure 12-10 shows what would happen if computations were done directly on numbers stored in this format. Because none of the data items have an explicit USAGE clause, they default to USAGE IS DISPLAY. This means the values in the variables Num1, Num2, and Num3 are stored as ASCII digits. This in turn means the digit 4 in Num1 is encoded as 00110100 and the digit 1 in Num2 is encoded as 00110001. When these binary numbers are added together, the result, as shown in Figure 12-10, is the binary value 01100101, which is the ASCII code for the lowercase letter *e*.

Example 12-6. Arithmetic on Items Held as USAGE IS DISPLAY

```

Num1  PIC 9 VALUE 4.
Num2  PIC 9 VALUE 1.
Num3  PIC 9 VALUE ZERO.
: : : : : : : : :
ADD Num1, Num2 GIVING Num3.

```

Num1	PIC 9 VALUE 4.	<table border="1"> <thead> <tr> <th>8</th> <th>4</th> <th>2</th> <th>1</th> <th>8</th> <th>4</th> <th>2</th> <th>1</th> <th>Hex</th> <th>Char</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>1</td> <td>1</td> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>34</td> <td>"4"</td> </tr> </tbody> </table>	8	4	2	1	8	4	2	1	Hex	Char	0	0	1	1	0	1	0	0	34	"4"
8	4	2	1	8	4	2	1	Hex	Char													
0	0	1	1	0	1	0	0	34	"4"													
		+																				
Num2	PIC 9 VALUE 1.	<table border="1"> <tbody> <tr> <td>0</td> <td>0</td> <td>1</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>1</td> <td>31</td> <td>"1"</td> </tr> </tbody> </table>	0	0	1	1	0	0	0	1	31	"1"										
0	0	1	1	0	0	0	1	31	"1"													
Num3	PIC 9 VALUE ZERO.	<table border="1"> <tbody> <tr> <td>0</td> <td>1</td> <td>1</td> <td>0</td> <td>0</td> <td>1</td> <td>0</td> <td>1</td> <td>65</td> <td>"e"</td> </tr> </tbody> </table>	0	1	1	0	0	1	0	1	65	"e"										
0	1	1	0	0	1	0	1	65	"e"													

Figure 12-10. Adding two ASCII digits gives the wrong result

When calculations are done with numeric data items using USAGE IS DISPLAY, the computer has to convert the numeric values to their binary equivalents before the calculation can be done. When the result has been computed, the computer must reconvert it to ASCII digits. Conversion to and from ASCII digits slows down computations.

For this reason, data that is heavily involved in computation is often declared using one of the usages optimized for computation, such as USAGE IS COMPUTATIONAL.

Advantage of USAGE IS DISPLAY

Although it is computationally inefficient, there are a number of advantages to holding numeric data as text digits. One obvious advantage is that `USAGE DISPLAY` items can be output to the computer screen by the `DISPLAY` verb without the need for conversion. Another advantage is portability. Files whose data is encoded as text can be processed without difficulty on different makes of computers or using other programming languages. In contrast, the chosen binary formats of some computers and the Big Endian/Little Endian byte order preference of others means that non-text files produced on one make of computer are often difficult to read on another make of computer or even using another programming language or utility program on the same computer.

STORAGE OF MULTIBYTE NUMBERS

Some computers store numeric binary values using a byte order where the low-order byte of a number is stored at the lowest memory address, and the high-order byte at the highest address. This is known as the *Little Endian* byte order. For instance, a four-byte-long integer value would be stored as

```
Byte0 at BaseAddress+0
Byte1 at BaseAddress+1
Byte2 at BaseAddress+2
Byte3 at BaseAddress+3
```

In contrast, in *Big Endian* computers, the high-order byte of the number is stored at the lowest memory address, and the low-order byte at the highest address. For instance:

```
Byte3 at BaseAddress +0
Byte2 at BaseAddress +1
Byte1 at BaseAddress +2
Byte0 at BaseAddress +3
```

The advantages of the `USAGE IS DISPLAY` format and the speed of modern computers means that the `USAGE` clause is an optimization that is only worth doing if the data item will be used in thousands of computations.

USAGE Clause Syntax

As you have seen, the default representation (`USAGE IS DISPLAY`) used by COBOL for numeric data items can negatively impact the speed of computations. `USAGE` is used for purposes of optimization of both speed and storage. It allows you to control the way data items (normally numeric data items) are stored in memory. One important point to note is that because computers can be quite different under the skin (for instance, register size and Endian order), the COBOL standard leaves the actual implementation of the binary data items to the compiler implementer. This means a `COMP` item on one computer may not be exactly the same as a `COMP` item on another computer.

The metalanguage syntax diagram for the `USAGE` clause is given in Figure 12-11, and some example declarations are shown in Example 12-7.

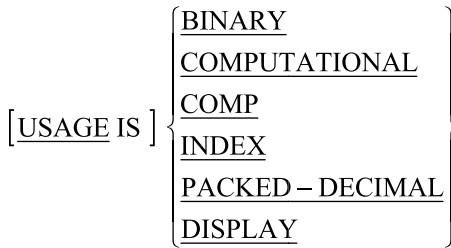


Figure 12-11. The USAGE clause metalanguage

Example 12-7. Example USAGE Clause Declarations

```
01 Num1          PIC 9(5)V99  USAGE IS COMP.
01 Num2          PIC 99      USAGE IS PACKED-DECIMAL.
01 IdxItem       USAGE IS INDEX.

01 FirstGroup    COMP.
  02 Item1       PIC 999.
  02 Item2       PIC 9(4)V99.
  02 Item3       PIC S9(5) COMP SYNC.
```

Notes

Here are some things to note:

- The USAGE clause may be used with any data description entry except those with level numbers of 66 or 88.
- When the USAGE clause is declared for a group item, the usage specified is applied to every item in the group. The group item itself is still treated as an alphanumeric data item (see FirstGroup in Example 12-7).
- The USAGE clause of an elementary item cannot override the USAGE clause of the group to which it is subordinate (for instance, in Example 12-7, the USAGE of Item3 is COMP because that is the USAGE of FirstGroup).
- USAGE IS COMPUTATIONAL and COMP or BINARY are synonyms of one another.
- The USAGE IS INDEX clause is used to provide an optimized table subscript.
- Any item declared with USAGE IS INDEX can only appear in
 - A SEARCH or SET statement
 - A relation condition
 - The USING phrase of the PROCEDURE DIVISION
 - The USING phrase of the CALL statement
- The picture string of a COMP or PACKED-DECIMAL item can contain only the symbols 9, S, V, and/or P.
- The picture clause used for COMP and PACKED-DECIMAL items must be numeric.

■ **Bug Alert** Group items are always treated as alphanumeric, and this can cause problems when there are subordinate `COMP` items. For instance, suppose you defined a group of data items as follows:

```
01 SecondGroup .
   02 NumItem1 PIC 9(3)V99 USAGE IS COMP .
   02 NumItem2 PIC 99V99 USAGE IS COMP .
```

and then applied a statement such as `MOVE ZEROS TO SecondGroup` to it.

On the surface, it appears that the statement is moving the numeric value 0 to `NumItem1` and `NumItem2`; but because `SecondGroup` is an alphanumeric item, what is actually moved into `NumItem1` and `NumItem2` is the ASCII digit “0”. When an attempt is made to use `NumItem1` or `NumItem2` in a calculation, the program will crash because these data items contain non-numeric data.

COMP Explanation

`COMP` items are held in memory as pure binary twos-complement numbers. You don’t have to understand how twos-complement numbers work or how they are stored, but you must understand the storage requirements for fields described as `COMP`. The storage requirements are shown in Table 12-1. For instance, the declaration

```
01 TotalCount PIC 9(7) USAGE IS COMP
```

requires a `LongWord` (4 bytes) of storage.

Table 12-1. Storage Requirements of `COMP` Data Items

Number of Digits	Storage Required
PIC 9(1 to 4)	1 Word (2 bytes)
PIC 9(5 to 9)	1 LongWord (4 bytes)
PIC 9(10 to 18)	1 QuadWord (8 bytes)

PACKED-DECIMAL Explanation

Data items declared as `PACKED-DECIMAL` are held in binary-coded decimal (BCD) form. Instead of representing the value as a single binary number, the binary value of each digit is held in a nibble (half a byte). The sign is held in a separate nibble in the least significant position of the item (see Figure 12-12).

```

01 Num1    PIC S9      VALUE +5    USAGE PACKED-DECIMAL.
           5  +
01 Num2    PIC S9(2)  VALUE -32   USAGE PACKED-DECIMAL.
           0  3  2  -
01 Num3    PIC S9(3)  VALUE +262  USAGE PACKED-DECIMAL.
           2  6  2  +

```

Figure 12-12. Memory representation of BCD numbers

The SYNCHRONIZED Clause

The SYNCHRONIZED clause is sometimes used with USAGE IS COMP or USAGE IS INDEX items. It is used to optimize speed of processing, but it does so at the expense of increased storage requirements.

Many computer memories are organized in such a way that there are natural addressing boundaries, such as word boundaries. If no special action is taken, some data items in memory may straddle these boundaries. This may cause processing overhead because the CPU may need two fetch cycles to retrieve the data from memory. The SYNCHRONIZED clause is used to explicitly align COMP and INDEX items along their natural word boundaries. Without SYNCHRONIZED, data items are aligned on byte boundaries. The metalanguage for SYNCHRONIZED is given in Figure 12-13.

```

{ SYNCHRONIZED } [ LEFT ]
{ SYNC         } [ RIGHT ]

```

Figure 12-13. Metalanguage for the SYNCHRONIZED clause

The effect of the SYNCHRONIZED clause is implementation dependent. You need to read your implementer manual to see how it works on your computer (in some cases it may have no effect). To illustrate how SYNCHRONIZED works in general, assume that a COBOL program is running on a word-oriented computer where the CPU fetches data from memory a word at a time. Suppose the program performs a calculation on the number stored in the variable TwoBytes (as shown in Figure 12-14). Because of the way the data items have been declared, the number stored in TwoBytes straddles a word boundary. In order to use the number, the CPU has to execute two fetch cycles: one to get the first part of the number in Word2 and the second to get the second part of the number in Word3. This double fetch slows down calculations.

```

01 ThreeBytes PIC XXX    VALUE "CAT" .
01 TwoBytes   PIC 9(4)   COMP .

```

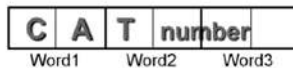


Figure 12-14. With no SYNCHRONIZED clause, numbers may straddle word boundaries

When the SYNCHRONIZED clause is used, as shown in Figure 12-15, TwoBytes is aligned along the word boundary, so the CPU only has to do one fetch cycle to retrieve the number from memory. This speeds up processing, but at the expense of wasting some storage (the second byte of Word2 is no longer used).

```
01 ThreeBytes PIC XXX VALUE "CAT".
01 TwoBytes PIC 9(4) COMP SYNC.
```



Figure 12-15. With the SYNCHRONIZED, clause numbers are aligned along word boundaries

Nonstandard USAGE Extensions

The USAGE clause is one of the areas where many implementers have introduced extensions to the COBOL standard. It is not uncommon to see COMP-1, COMP-2, COMP-3, COMP-4, COMP-5, and POINTER usage items in programs written using these extensions.

Even though COMP-1 and COMP-2 are extensions to the COBOL standard, many implementers seem to use identical representations for these usages. Comp-1 is usually defined as a single-precision, floating-point number, adhering to the IEEE specification for such numbers (Real or float in typed languages). Comp-2 is usually defined as an IEEE double-precision, floating-point number (LongReal or double in typed languages). COMP-3 items are usually defined as BCD numbers. The official introduction of PACKED-DECIMAL in the ANS 85 version of COBOL has made this extension unnecessary.

Decimal Arithmetic

One of COBOL's strengths, and one of its main claims to fitness for writing business and enterprise applications, is its native support for fixed-point decimal arithmetic. Until the problems associated with floating-point arithmetic are pointed out to them, most programmers are not even aware that there is a problem. In the Java community, this is such a problem that even now articles and forum posts are still produced warning of the dangers of using float or double for currency calculations.

The problem with floating-point arithmetic is this: binary floating-point numbers (such as those with a type of real, float, or double) cannot represent common decimal fractions exactly. For instance, common decimal fractions like 0.1 do not have a terminating binary representation. Just as 1/3 is a repeating fraction in decimal, 1/10 is a repeating fraction in binary. As a result, floating-point numbers can't be used safely for financial calculations. In fact, they cannot be used for any calculations where the result produced is required to match those that might be calculated by hand.

In an article on the Java Performance Tuning Guide¹, Mikhail Vorontsov emphasizes this point when he notes that double calculations are not precise even for simple operations such as addition and subtraction. For instance, he notes that the Java statement

```
System.out.println( "362.2 - 362.6 = " + ( 362.2 - 362.6 ) );
```

produces the output

```
362.2 - 362.6 = -0.4000000000000341
```

The advantage of doing computations using fixed-point decimal arithmetic, as COBOL does, is that everyday numbers such as 0.1 can be represented exactly and the results of COBOL calculations do exactly match those that might be produced by hand.

Doing computations using floating-point arithmetic causes tiny inaccuracies that lead to unacceptable errors when taken over millions of computations. For instance, suppose you are required to calculate a tax of 15% on a 70-cent telephone call that is then rounded to the nearest cent². Using the Java compiler at compileonline.com, the calculation `0.70 * 1.15` produces a result of 0.8049999999999999, which rounds down to 0.80 cents. The correct result should

have been 0.805, which would round up to 0.81 cents. This difference of a cent per calculation, when taken over a million calculations of this kind, would result in an undercharge of ten thousand dollars.

If floating-point arithmetic is so problematic, how do languages that do not have native support for fixed-point decimal arithmetic deal with the problem? Nowadays, they implement a class to support decimal arithmetic operations. However, implementing such a class is not a trivial undertaking. Java's original implementation of the `BigDecimal` class was so flawed that IBM raised a Java Specification Request (JSR)² detailing the problems and requesting changes. These changes were implemented and shipped with Java 1.5 in 2004.

So does the revised `BigDecimal` class solve the problems with decimal arithmetic in Java? Only partly; decimal arithmetic in Java is implemented as a class instead of as a native type, and computations using the class are cumbersome, unnatural, and slow. For instance, Vorontsov¹ found that 100 million `BigDecimal` calculations took 8.975 seconds, while the same number of `double` calculations took only 0.047 seconds. `BigDecimal` operations can be called unnatural in the sense that Java floating-point numbers and integers can use the standard assignment operator (`=`) and the standard arithmetic operators (`+` `-` `/` `*`), whereas the `BigDecimal` class has to use its class methods. For instance, to multiply two `BigDecimal` numbers, you might use a statement like

```
calcResult = num1.multiply(num2);
```

instead of

```
calcResult = num1 * num2;
```

Early in Chapter 1, I showed you a Java program that used the `BigDecimal` class and asked you to compare it to the COBOL version for readability. I was confident then that you would be able to appreciate the readability of the COBOL version even though at the time you had not yet been introduced to the elements of the language. However, now that we have a more level playing field, let's look at those programs again (reprinted Listings 1-1 and 1-2).

Listing 1-1. COBOL Version

```
IDENTIFICATION DIVISION.
PROGRAM-ID. SalesTax.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 beforeTax      PIC 999V99  VALUE 123.45.
01 salesTaxRate   PIC V999    VALUE .065.
01 afterTax      PIC 999.99.
PROCEDURE DIVISION.
Begin.
  COMPUTE afterTax ROUNDED = beforeTax + (beforeTax * salesTaxRate)
  DISPLAY "After tax amount is " afterTax.
```

Listing 1-2. Java Version (from http://caliberdt.com/tips/May03_Java_BigDecimal_Class.htm)

```
import java.math.BigDecimal;
public class SalesTaxWithBigDecimal
{
    public static void main(java.lang.String[] args)
    {
        BigDecimal beforeTax = BigDecimal.valueOf(12345, 2);
        BigDecimal salesTaxRate = BigDecimal.valueOf(65, 3);
        BigDecimal ratePlusOne = salesTaxRate.add(BigDecimal.valueOf(1));
```

```

    BigDecimal afterTax = beforeTax.multiply(ratePlusOne);
    afterTax = afterTax.setScale(2, BigDecimal.ROUND_HALF_UP);
    System.out.println( "After tax amount is " + afterTax);
}
}

```

The COBOL version uses native fixed-point decimal arithmetic and is able to use all the standard arithmetic operators. The Java version has to use the `BigDecimal` methods to do even simple calculations. The COBOL program is 10 lines and 335 characters long, whereas the Java program is 13 lines and 484 characters long. Reminded me again. Which one is the verbose language?

Summary

This chapter explored the operation of advanced data-declaration clauses such as the `REDEFINES` clause, the `RENAMES` clause, and the `USAGE` clause. It showed how you can use `REDEFINES` clauses to redefine an area of storage with a new name and new data description. You saw how to use `RENAMES` to group a set of data items under a new name. You also learned how to use the `USAGE` clause to change the default `DISPLAY` data format to one of the binary formats such as `COMPUTATIONAL` or `PACKED-DECIMAL`. The operation of these binary formats was explored in more depth, and the computational efficiency of the binary formats was weighed against the portability of the `DISPLAY` format. You investigated the operation-modifying `SYNCHRONIZED` clause and learned about the `USAGE` clause extensions provided by many COBOL implementers. The chapter ended with a discussion of the problems inherent in using floating-point arithmetic for financial and commercial calculations and the contrast between COBOL's native support for decimal arithmetic and the bolted-on capability provided by Java's `BigDecimal` class.

The next chapter returns to the topic of tabular data to introduce the `SEARCH` and `SEARCH ALL` verbs. Searching tabular data for a particular value is a common operation, but it can be tricky to get the search algorithms right. For this reason, COBOL provides `SEARCH` and `SEARCH ALL`. The `SEARCH ALL` verb allows you to apply a binary search to a table, and `SEARCH` applies a linear search.

LANGUAGE KNOWLEDGE EXERCISES

Sometimes the most instructive lessons arise from the mistakes you make. The debugging exercises that follow are based on some programming errors I made when I was learning to program in COBOL.

Locate your 2B pencil, and provide answers to the problems.

The Problems

The first two programs go into an infinite loop (never halt) and have to be stopped by the user. The third program sometimes crashes with the error message shown in the accompanying runs. The fourth program sometimes goes into an infinite loop.

Examine each program, and use the accompanying runs to discover the bug or bugs responsible for the problem. Identify the problem, and show how you would correct the program to make it work correctly.

Program 2

This program also goes into an infinite loop. Examine the program in Listing 12-4 and the program output, and try to figure out what is going wrong. Identify the problem, and suggest a solution.

Listing 12-4. What Is Wrong with This Program?

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing12-4.
AUTHOR. Michael Coughlan.

DATA DIVISION.
WORKING-STORAGE SECTION.
01  Counters.
    02  Counter1      PIC 99.
    02  Counter2     PIC 9.
    02  Counter3     PIC 9.

PROCEDURE DIVISION.
Begin.
    DISPLAY "Debug2. Why can't I stop?"
    PERFORM EternalLooping VARYING Counter1
        FROM 1 BY 1 UNTIL Counter1 GREATER THAN 25
        AFTER Counter2 FROM 1 BY 1
            UNTIL Counter2 GREATER THAN 9
        AFTER Counter3 FROM 1 BY 1
            UNTIL Counter3 EQUAL TO 5
    STOP RUN.

EternalLooping.
    DISPLAY "Counters 1, 2 and 3 are "
        Counter1 SPACE Counter2 SPACE Counter3.
```

Answer: _____

Listing 12-4 Output

```
Debug2. Why can't I stop?
Counters 1, 2 and 3 are 01 1 1
Counters 1, 2 and 3 are 01 1 2
Counters 1, 2 and 3 are 01 1 3
Counters 1, 2 and 3 are 01 1 4
Counters 1, 2 and 3 are 01 2 1
Counters 1, 2 and 3 are 01 2 2
Counters 1, 2 and 3 are 01 2 3
Counters 1, 2 and 3 are 01 2 4
Counters 1, 2 and 3 are 01 3 1
Counters 1, 2 and 3 are 01 3 2
Counters 1, 2 and 3 are 01 3 3
Counters 1, 2 and 3 are 01 3 4
Counters 1, 2 and 3 are 01 4 1
Counters 1, 2 and 3 are 01 4 2
Counters 1, 2 and 3 are 01 4 3
Counters 1, 2 and 3 are 01 4 4
Counters 1, 2 and 3 are 01 5 1
Counters 1, 2 and 3 are 01 5 2
Counters 1, 2 and 3 are 01 5 3
Counters 1, 2 and 3 are 01 5 4
Counters 1, 2 and 3 are 01 6 1
Counters 1, 2 and 3 are 01 6 2
Counters 1, 2 and 3 are 01 6 3
Counters 1, 2 and 3 are 01 6 4
Counters 1, 2 and 3 are 01 7 1
Counters 1, 2 and 3 are 01 7 2
Counters 1, 2 and 3 are 01 7 3
Counters 1, 2 and 3 are 01 7 4
Counters 1, 2 and 3 are 01 8 1
Counters 1, 2 and 3 are 01 8 2
Counters 1, 2 and 3 are 01 8 3
Counters 1, 2 and 3 are 01 8 4
Counters 1, 2 and 3 are 01 9 1
Counters 1, 2 and 3 are 01 9 2
Counters 1, 2 and 3 are 01 9 3
Counters 1, 2 and 3 are 01 9 4
Counters 1, 2 and 3 are 01 0 1
Counters 1, 2 and 3 are 01 0 2
Counters 1, 2 and 3 are 01 0 3
Counters 1, 2 and 3 are 01 0 4
Counters 1, 2 and 3 are 01 1 1
Counters 1, 2 and 3 are 01 1 2
Counters 1, 2 and 3 are 01 1 3
Counters 1, 2 and 3 are 01 1 4
< Interrupted by user>
```

Program 3

This program sometimes crashes. When it crashes, it produces the error message shown. From the two program outputs shown (one successful and one where the program crashes to produce the error message) and an examination of the program, try to work out why the program crashes. Identify the problem, and suggest a solution.

Listing 12-5. Program Crashes When Numbers Are Even; OK When Odd.

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Debug3.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT PersonFile ASSIGN TO "PERSON.DAT"
        ORGANIZATION IS LINE SEQUENTIAL.
```

```
DATA DIVISION.
FILE SECTION.
FD PersonFile.
01 PersonRec          PIC X(10).
   88 EndOfFile      VALUE HIGH-VALUES.
```

```
WORKING-STORAGE SECTION.
01 Surname            PIC X(10).
   88 EndOfData      VALUE SPACES.
01 Quotient           PIC 9(3).
01 Rem                PIC 9(3).
01 NumberOfPeople    PIC 9(3) VALUE ZERO.
```

```
PROCEDURE DIVISION.
Begin.
    OPEN OUTPUT PersonFile
    DISPLAY "Debug3"
    DISPLAY "Enter list of Surnames."
    DISPLAY "Press RETURN after each name."
    DISPLAY "To finish press return
with no value."
    DISPLAY "This will fill Surname
with spaces"
    DISPLAY "Name -> " WITH NO ADVANCING
    ACCEPT Surname
    PERFORM GetPersons UNTIL EndOfData
    CLOSE PersonFile
```

Listing12-5Output

```
Debug3
Enter list of Surnames.
Press RETURN after each name.
To finish press return with no value.
This will fill Surname with spaces
Name -> Power
Name -> Ryan
Name -> Smith
Name ->
Power
Ryan
Smith
Odd number of people
```

Listing12-5Output

```
Debug3
Enter list of Surnames.
Press RETURN after each name.
To finish press return with no value.
This will fill Surname with spaces
Name -> Power
Name -> Ryan
Name -> Smith
Name -> Roddy
Name ->
Power
Ryan
Smith
Roddy
Even number of people
```

Error Message after program crash

```
148      Wrong open mode or access mode
        for write: PERSON.DAT
```



```

OPEN INPUT PersonFile
READ PersonFile
    AT END SET EndOfFile TO TRUE
END-READ
PERFORM CountPersons UNTIL EndOfFile.
CLOSE PersonFile

DIVIDE NumberOfPeople BY 2
    GIVING Quotient REMAINDER Rem

IF Rem = 0
    DISPLAY "Even number of people"
ELSE
    DISPLAY "Odd number of people"

STOP RUN.

GetPersons.
WRITE PersonRec FROM Surname
DISPLAY "Name -> " WITH NO ADVANCING
ACCEPT Surname.

CountPersons.
DISPLAY PersonRec
ADD 1 TO NumberOfPeople
READ PersonFile
    AT END SET EndOfFile TO TRUE
END-READ.

```

Program 4

Sometimes this program goes into an infinite loop (does not halt). From the two program outputs shown (one where the program halts naturally and one where it has to be halted by the user) and an examination of the program, try to work out why the program sometimes does not halt. Identify the problem, and suggest a solution.

Listing 12-6. Program Sometimes Goes into an Infinite Loop

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Debug4.
AUTHOR. Michael Coughlan.

DATA DIVISION.
WORKING-STORAGE SECTION.
01 Counter1          PIC 99.
01 InNumber          PIC 9.
01 Result            PIC 999.

```

Listing12-6 Output

```

DEBUG4. Sometimes I just don't stop
Enter number 0-9 :--> 4
Counter1 = 01 Result = 004
Counter1 = 02 Result = 008
Counter1 = 03 Result = 012
Counter1 = 04 Result = 016
Counter1 = 05 Result = 020
Counter1 = 06 Result = 024
Counter1 = 07 Result = 028
Counter1 = 08 Result = 032
Counter1 = 09 Result = 036
Counter1 = 10 Result = 040
Back in main paragraph now

```

```

PROCEDURE DIVISION.
Begin.
  DISPLAY "DEBUG4. Sometimes I just don't stop"
  DISPLAY "Enter number 0-9 :--> " WITH NO ADVANCING
  ACCEPT InNumber
  PERFORM EternalLooping
    VARYING Counter1 FROM 1 BY 1
    UNTIL Counter1 GREATER THAN 10

  DISPLAY "Back in main paragraph now"
  STOP RUN.

```

```

EternalLooping.
  COMPUTE Result = InNumber * Counter1
  IF Result > 60
    MOVE 99 TO Counter1
  END-IF
  DISPLAY "Counter1 = " Counter1 " Result = " Result.

```

Listing12-6 Output

```

DEBUG4. Sometimes I just don't stop
Enter number 0-9 :--> 7
Counter1 = 01 Result = 007
Counter1 = 02 Result = 014
Counter1 = 03 Result = 021
Counter1 = 04 Result = 028
Counter1 = 05 Result = 035
Counter1 = 06 Result = 042
Counter1 = 07 Result = 049
Counter1 = 08 Result = 056
Counter1 = 99 Result = 063
Counter1 = 00 Result = 000
Counter1 = 01 Result = 007
Counter1 = 02 Result = 014
Counter1 = 03 Result = 021
Counter1 = 04 Result = 028
Counter1 = 05 Result = 035
Counter1 = 06 Result = 042
Counter1 = 07 Result = 049
Counter1 = 08 Result = 056
Counter1 = 99 Result = 063
Counter1 = 00 Result = 000
Counter1 = 01 Result = 007
Counter1 = 02 Result = 014
Counter1 = 03 Result = 021
Counter1 = 04 Result = 028
      < Interrupted by user>

```

LANGUAGE KNOWLEDGE EXERCISES—ANSWERS

Program 1

Problem Cause

The problem here is that Counter1 and Counter2 go negative but are described as PIC 99—a description that only allows positive values. The problem with Counter1 is masked by the problem with Counter2. You can see the effect of the problem with Counter2 in the program output fragment shown in Figure 12-16. When Counter2 has a value of 03, the next value it should take is -1; but because Counter2 is described as PIC 99, it cannot hold a negative value. This means the sign is lost, and instead of -1, the value of Counter2 is 1. Therefore, Counter2 never reaches its terminating value, and the loop never terminates.

```

PERFORM EternalLooping VARYING Counter1
  FROM 13 BY -5 UNTIL Counter1 LESS THAN 2
  AFTER Counter2 FROM 15 BY -4
  UNTIL Counter2 LESS THAN 1
  AFTER Counter3 FROM 1 BY 1
  UNTIL Counter3 GREATER THAN 5

```

Counters 1, 2 and 3 are -> 13 03 4
Counters 1, 2 and 3 are -> 13 03 5
Counters 1, 2 and 3 are -> 13 01 1
Counters 1, 2 and 3 are -> 13 01 2
Counters 1, 2 and 3 are -> 13 01 3
Counters 1, 2 and 3 are -> 13 01 4
Counters 1, 2 and 3 are -> 13 01 5
Counters 1, 2 and 3 are -> 13 03 1
Counters 1, 2 and 3 are -> 13 03 2
Counters 1, 2 and 3 are -> 13 03 3

Figure 12-16. Fragment of output from Listing 12-3 highlighting the problem area

Problem Solution

The solution to the problem is to describe Counter1 and Counter2 as PIC S99.

Program 2

Problem Cause

The problem here is that Counter2 is described as PIC 9. You can see the problem by examining the flowchart in Figure 12-17.

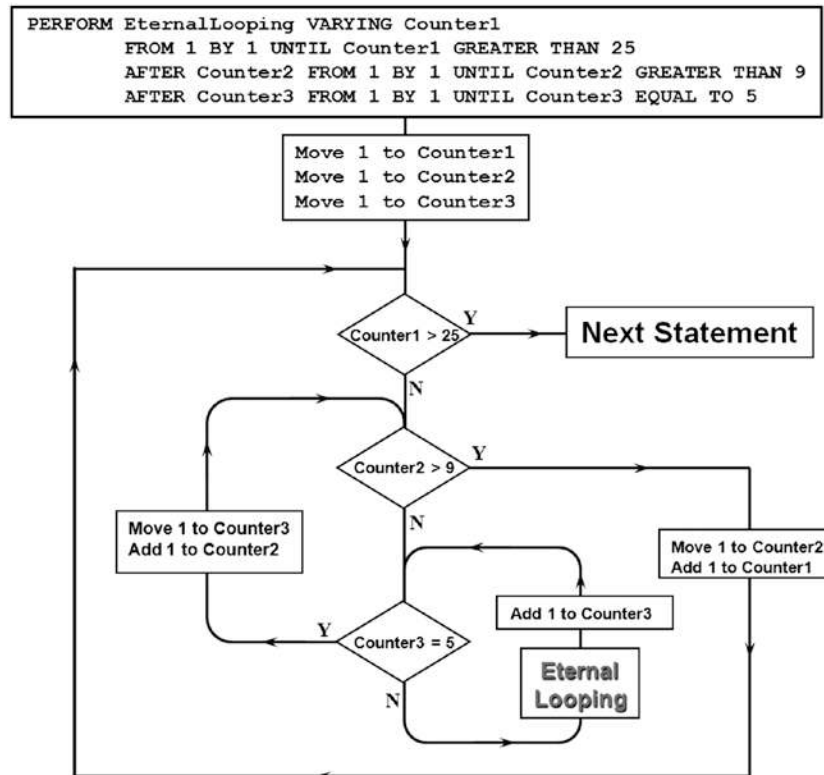


Figure 12-17. Flowchart showing how the three-counter PERFORM...VARYING works

Suppose the program is at the point where Counter2 has a value of 9 and Counter3 has a value of 5. At this point the condition Counter3 = 5 is satisfied, and Counter3 is reset to 1 while Counter2 is incremented, making it equal to 10. Because Counter2 is described as PIC 9, there is only room for one digit, so the 1 is truncated, leaving Counter2 with a value of 0. When the Counter2 > 9 condition is tested, it is not satisfied, and the loop never ends.

Problem Solution

The solution to the problem is to describe Counter2 as PIC 99.

Program 3

Problem Cause

The problem here is that the IF before the STOP RUN does not have an explicit terminator. This means the scope of the IF is terminated by the period that follows the STOP RUN; and this means the scope of the ELSE branch of the IF includes the STOP RUN:

```
DIVIDE NumberOfPeople BY 2
    GIVING Quotient REMAINDER Rem

IF Rem = 0
    DISPLAY "Even number of people"
ELSE
    DISPLAY "Odd number of people"

STOP RUN.
```

```
GetPersons.
WRITE PersonRec FROM Surname
DISPLAY "Name -> " WITH NO ADVANCING
ACCEPT Surname.
```

Failing to specify the scope of the IF with an explicit terminator has the following effect. When there is an odd number of people, the ELSE branch is taken, the STOP RUN is executed, and the program stops normally; but when there is an even number of people, the ELSE branch is not taken, the STOP RUN is not executed, and control falls into the GetPersons paragraph where it tries to write to the closed PersonFile. This write attempt crashes the program and produces the error message.

Problem Solution

Add an explicit scope delimiter to the IF statement:

```
IF Rem = 0
    DISPLAY "Even number of people"
ELSE
    DISPLAY "Odd number of people"
END-IF

STOP RUN.
```

Program 4

Problem Cause

The problem with this program is that the programmer tries to modify the `PERFORM. .VARYING` counter variable `Counter1` in order to force the loop to terminate prematurely. Unfortunately, the programmer has not consulted the flowchart shown in Figure 12-18. That flowchart shows that as control exits, the paragraph `Counter1` is incremented. Because `Counter1` has been given a value of 99 in the paragraph, the increment brings it to 100. But `Counter1` is described as `PIC 99` and only has room for two digits. This means the 1 is truncated, leaving `Counter1` with a value of 00. Because the terminating condition `Counter1 > 10` has not been satisfied, the loop will not terminate.

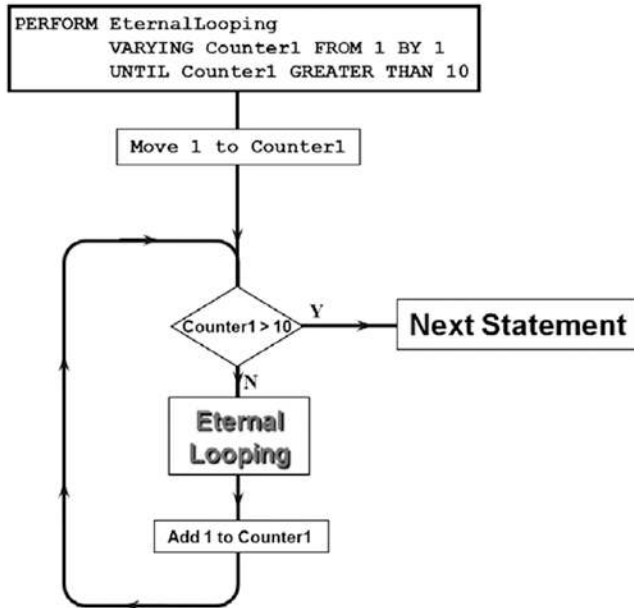


Figure 12-18. Flowchart showing how the single-counter `PERFORM. .VARYING` works

Problem Solution

A simple solution is to change the description of `Counter1` to `PIC 999`. A more complex solution would require you rewrite the program so that it does not require the counting variable to be changed in the loop. When you use a construct such as the `PERFORM. .VARYING`, you make a contract with the reader that construct will operate in the normal way and that the counting variable will take the values specified in the `PERFORM`. If you break that contract, you create uncertainty in the mind of the reader not only for this loop but also for all the loops in the program. Now the reader has to scrutinize each one to make sure they work as expected.

References

1. Vorontsov M. Using double/long vs. BigDecimal for monetary calculations. 2013 Feb. <http://java-performance.info/bigdecimal-vs-double-in-financial-calculations/>
2. IBM. Decimal arithmetic FAQ. 2008. <http://speleotrove.com/decimal/decifaq.html>



Searching Tabular Data

In previous chapters, you saw how to create and use tabular data. This chapter returns to the issue of processing tabular data to examine the operation of the `SEARCH` and `SEARCH ALL` verbs. `SEARCH` is used for linear searches, and `SEARCH ALL` is used for binary searches.

The chapter begins by noting that when you use `SEARCH` or `SEARCH ALL`, the table they are searching must have an associated table index. You learn the metalanguage for the `INDEXED BY` clause used to specify the table index and explore the nature of the index data item. Because index data items can't be manipulated by ordinary COBOL verbs, the chapter introduces the versions of the `SET` verb that are used to assign, increment, and decrement table index values.

With the background material covered, you see how the `SEARCH` verb operates on single-dimension tables and work through an example. The chapter highlights the limitations of the `SEARCH` with regard to searching multidimensional tables and suggests, and demonstrates, a solution.

The `SEARCH` verb searches a table serially. To search a table using a binary search, you must use `SEARCH ALL`. You learn that the `SEARCH ALL` can only work correctly if the table is ordered, and the chapter discusses the extension to the `OCCURS` clause that allows you to identify the data item on which the table is ordered. You see how a binary search works along with an example of the operation of `SEARCH ALL`.

Finally, the chapter introduces the notion of variable-length tables. Although variable-length tables are not truly dynamic, they are still useful, because the variable size limitations are obeyed by COBOL verbs such as the `SEARCH` and `SEARCH ALL`. You see this with an example program.

SEARCHING Tabular Data

The task of searching a table to determine whether it contains a particular value is a common operation. The method used to search a table depends heavily on the way the values are organized in the table. If the values are not ordered, then the only strategy available is a linear search. A linear search starts at the first element and then examines each succeeding element until the item is found or until the end of the table is reached (item not found). If the values are ordered, then you have the option of using either a linear search or a binary search. A binary search works by dividing the table in half and determining whether the item sought is in the top half of the table or the bottom half. This process continues until the item is found or it is determined that the item is not in the table.

COBOL has special verbs that let you search tables using either strategy. The `SEARCH` verb is used for linear searches, and the `SEARCH ALL` verb is used for binary searches.

Searching Using `SEARCH` and `SEARCH ALL`

One advantage of using `SEARCH` or `SEARCH ALL` rather than a handcrafted search is that because these are specialized instructions, their operation can be optimized. Part of that optimization involves creating a special subscript to be used when searching the table. You create this special subscript using an extension to the `OCCURS` clause called the `INDEXED BY` clause.

INDEXED BY Clause

Before you can use `SEARCH` or `SEARCH ALL` to search a table, you must define the table as having an index item associated with it. Using an index makes the searching more efficient. Because the index is linked to a particular table, the compiler—taking into account the size of the table—can choose the most efficient representation possible for the index. This speeds up the search.

The index is specified by the `IndexName` given in an `INDEXED BY` clause attached to the `OCCURS` clause. The extended `OCCURS` clause metalanguage is shown in Figure 13-1.

```
OCCURS TableSize#1 TIMES
[INDEXED BY IndexName...]
```

Figure 13-1. *OCCURS metalanguage, including the INDEXED BY clause*

The following are some things to consider about Figure 13-1:

- The index defined in a table declaration is associated with that table and is the subscript that `SEARCH` or `SEARCH ALL` uses to access the table.
- The only entry that needs to be made for an `IndexName` is to use it in an `INDEXED BY` phrase. It does not require a `PICTURE` clause, because the compiler handles its declaration automatically.
- Because of its special binary representation, the table index cannot be displayed, and its value cannot be manipulated using ordinary COBOL verbs such as `MOVE`, `ADD`, and `SUBTRACT`. Only four COBOL verbs can change the value of a table index: `SEARCH`, `SEARCH ALL`, `PERFORM. . VARYING`, and `SET`.
- Index names must be unique.
- An index is only valid for the table to which it is bound. An index bound to one table cannot be used with another table.

Using SET to Manipulate the Table Index

A table index is a special data item. It has no `PICTURE` clause, it is associated with a particular table, and the compiler defines the index using the most computationally efficient representation possible. Because of its special binary representation, the table index cannot be displayed and can only be assigned a value, or have its value assigned, by the `SET` verb. Similarly, the `SET` verb must be used to increment or decrement the value of an index item.

The metalanguage for the formats of the `SET` verb that are used to manipulate the value of an index item are given in Figure 13-2.

```
SET {IndexName} ... TO {IndexName}
   {Identifier#$}      {DataItem# $il}
```



```
SET {IndexName} ... {UP} {Increment Val# il}
   {DOWN}          {Decrement Val# il}
```

Figure 13-2. *Metalanguage for SET formats used to manipulate index values*

The SEARCH Verb

When the values in a table are not ordered, the only searching strategy available is a linear search. You start at the first element and then search through the table serially, element by element, until either you find the item you seek or you reach the end of the table. You use the SEARCH verb when you want to search a table serially. The metalanguage for the SEARCH verb is given in Figure 13-3.

$$\begin{array}{l} \text{SEARCH } \text{TableName} \left[\text{VARYING} \left\{ \begin{array}{l} \text{Identifier\#i} \\ \text{IndexItem} \end{array} \right\} \right] \\ \quad \left[\text{AT END } \text{StatementBlock} \right] \\ \quad \left\{ \text{WHEN } \text{Condition} \left\{ \begin{array}{l} \text{StatementBlock} \\ \text{NEXT SENTENCE} \end{array} \right\} \right\} \dots \\ \text{END - SEARCH} \end{array}$$

Figure 13-3. Metalanguage for the SEARCH verb

Note the following about Figure 13-3:

- Before you can use SEARCH to search TableName, you must define a table index for the table in an INDEXED BY clause attached to the OCCURS clause that defines the table. The index specified in the INDEXED BY clause of TableName is the controlling index (subscript) of SEARCH. The controlling index controls the submission of the elements, or element items, for examination by the WHEN phrase of SEARCH. A SEARCH can have only one controlling index.
- TableName must identify a data item in the table hierarchy with both OCCURS and INDEXED BY clauses.
- SEARCH searches a table serially, starting at the element pointed to by the table index. This means the table index is under your control.
- Because the table index is under your control, before SEARCH executes you must SET the table index to point to one of the elements in the table (usually the first element).
- When SEARCH executes, the table index cannot have a value less than one or greater than the size of the table, or SEARCH will immediately terminate.
- The VARYING phrase is used for a number of purposes:
 - When more than one index is attached to the table (note the ellipsis after IndexName in Figure 13-1), IndexItem identifies the IndexName that SEARCH uses as the table index.
 - When IndexItem is an index attached to another table or is a data item defined as USAGE IS INDEX, SEARCH increments the IndexItem at the same time and by the same amount as the table index.
 - When a non-index data item is used, SEARCH increments the data item by one each time it increments the table index.
- If AT END is specified and the index is incremented beyond the highest legal occurrence for the table (that is, the item has not been found), then the statement following AT END is executed and SEARCH terminates.
- The WHEN conditions attached to SEARCH are evaluated in turn. As soon as one is true, the statements following the WHEN phrase are executed, SEARCH ends, and the table index remains set at the value it had when the condition was satisfied.

SEARCH Examples

This section contains a number of examples that show how SEARCH is used. The section starts with a simple example by way of introduction and then ratchets up the complexity.

Letter Position Example

The example shown in Listing 13-1 uses SEARCH to discover the alphabet position of a letter entered by the user.

Listing 13-1. Finding the Position of a Letter in the Alphabet

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing13-1.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 LetterTable.
    02 TableValues.
        03 FILLER PIC X(13)
           VALUE "ABCDEFGHIJKLMN".
        03 FILLER PIC X(13)
           VALUE "NOPQRSTUVWXYZ".
    02 FILLER REDEFINES TableValues.
        03 Letter PIC X OCCURS 26 TIMES
           INDEXED BY LetterIdx.

01 IdxValue PIC 99 VALUE ZEROS.

01 LetterIn PIC X.
    88 ValidLetter VALUE "A" THRU "Z".

PROCEDURE DIVISION.
FindAlphabetLetterPosition.
    PERFORM WITH TEST AFTER UNTIL ValidLetter
        DISPLAY "Enter an uppercase letter please - " WITH NO ADVANCING
        ACCEPT LetterIn
    END-PERFORM
    SET LetterIdx TO 1
    SEARCH Letter
        WHEN Letter(LetterIdx) = LetterIn
            SET IdxValue TO LetterIdx
            DISPLAY LetterIn, " is in position ", IdxValue
    END-SEARCH
STOP RUN.
```

Listing13-1 Output

```
Enter an uppercase letter please - Q
Q is in position 17
```

I use a loop to get a valid uppercase letter from the user. Because the loop will exit only when a valid letter has been entered, the AT END clause is not used in SEARCH because the letter is always found in the table.

LetterIdx is the table index. It is automatically incremented by SEARCH. Note how it is associated with the table by means of the INDEXED BY clause.

Before SEARCH executes, the SET verb is used to set the table index (LetterIdx) to the position in the table where I want SEARCH to start.

Finally, because LetterIdx is a special binary index item, you can't display its value directly. So IdxValue, a numeric data item whose value can be displayed, is set to value of LetterIdx, and then IdxValue is displayed.

American States Example

The program in Listing 13-2 uses SEARCH to interrogate a table of American states, their ISO two-letter codes, and their capitals. The user is asked to choose the state code, state name, or state capital as their search term. Whichever is chosen, the program displays the other two. For instance, if the user chooses to search on the state code, then the program displays the state name and the state capital. If the state name is chosen, then the program displays the state code and state capital.

Listing 13-2. Given One of StateCode, StateName, or StateCapital, Display the Other Two

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing13-2.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 StatesTable.
   02 StateValues.
      03 FILLER PIC X(60)
         VALUE "ALAlabama      Montgomery AKAlaska      Juneau".
      03 FILLER PIC X(60)
         VALUE "AZArizona      Phoenix     ARArkansas    Little Rock".
      03 FILLER PIC X(60)
         VALUE "CACalifornia  Sacramento COColorado  Denver".
      03 FILLER PIC X(60)
         VALUE "CTConnecticut  Hartford   DEDelaware    Dover".
      03 FILLER PIC X(60)
         VALUE "FLFlorida      Tallahassee GAGeorgia     Atlanta".
      03 FILLER PIC X(60)
         VALUE "HIHawaii       Honolulu   IDIdaho       Boise".
      03 FILLER PIC X(60)
         VALUE "ILIllinois     Springfield INIndiana     Indianapolis".
      03 FILLER PIC X(60)
         VALUE "IAIowa         Des Moines KSKansas      Topeka".
      03 FILLER PIC X(60)
         VALUE "KYKentucky     Frankfort  LALouisiana   Baton Rouge".
      03 FILLER PIC X(60)
         VALUE "MEMaine        Augusta    MDMaryland    Annapolis".
      03 FILLER PIC X(60)
         VALUE "MAMassachusetts Boston     MIMichigan    Lansing".
      03 FILLER PIC X(60)
         VALUE "MNMMinnesota  Saint Paul MSMississippi Jackson".
      03 FILLER PIC X(60)
         VALUE "MOMissouri     Jefferson CityMTMontana  Helena".
```

```

03 FILLER PIC X(60)
  VALUE "NEbraska Lincoln NVNevada Carson City".
03 FILLER PIC X(60)
  VALUE "NHNew Hampshire Concord NJNew Jersey Trenton".
03 FILLER PIC X(60)
  VALUE "NMNew Mexico Santa Fe NYNew York Albany".
03 FILLER PIC X(60)
  VALUE "NCSouth CarolinaRaleigh NDSouth Dakota Bismarck".
03 FILLER PIC X(60)
  VALUE "OHOhio Columbus OKOklahoma Oklahoma City".
03 FILLER PIC X(60)
  VALUE "OROregon Salem PAPennsylvania Harrisburg".
03 FILLER PIC X(60)
  VALUE "RIRhode Island Providence SCSouth CarolinaColumbia".
03 FILLER PIC X(60)
  VALUE "SDSouth Dakota Pierre TNTennessee Nashville".
03 FILLER PIC X(60)
  VALUE "TXTexas Austin UTUtah Salt Lake City".
03 FILLER PIC X(60)
  VALUE "VTVermont Montpelier VAVirginia Richmond".
03 FILLER PIC X(60)
  VALUE "WAWashington Olympia WWest Virginia Charleston".
03 FILLER PIC X(60)
  VALUE "WIWisconsin Madison WYWyoming Cheyenne".
02 FILLER REDEFINES StateValues.
  03 State OCCURS 50 TIMES
    INDEXED BY StateIdx.
    04 StateCode PIC XX.
    04 StateName PIC X(14).
    04 StateCapital PIC X(14).

01 StateNameIn PIC X(14).

01 StateCapitalIn PIC X(14).

01 StateCodeIn PIC XX.

01 SearchChoice PIC 9 VALUE ZERO.
  88 ValidSearchChoice VALUES 1, 2, 3, 4.
  88 EndOfInput VALUE 4.

```

PROCEDURE DIVISION.

Begin.

```

  PERFORM WITH TEST AFTER UNTIL EndOfInput
  PERFORM WITH TEST AFTER UNTIL ValidSearchChoice
  DISPLAY SPACES
  DISPLAY "Search by StateCode (1), StateName (2), StateCapital (3), STOP (4) - "
  WITH NO ADVANCING
  ACCEPT SearchChoice
  END-PERFORM

```

```

SET StateIdx TO 1
EVALUATE SearchChoice
  WHEN 1 PERFORM GetNameAndCapital
  WHEN 2 PERFORM GetCodeAndCapital
  WHEN 3 PERFORM GetCodeAndName
END-EVALUATE
END-PERFORM
STOP RUN.

```

GetNameAndCapital.

```

DISPLAY "Enter the two letter State Code - " WITH NO ADVANCING
ACCEPT StateCodeIn
MOVE FUNCTION UPPER-CASE(StateCodeIn) TO StateCodeIn
SEARCH State
  AT END DISPLAY "State code " StateCodeIn " does not exist"
  WHEN StateCode(StateIdx) = StateCodeIn
    DISPLAY "State Name = " StateName(StateIdx)
    DISPLAY "State Capital = " StateCapital(StateIdx)
END-SEARCH.

```

GetCodeAndCapital.

```

DISPLAY "Enter the State Name - " WITH NO ADVANCING
ACCEPT StateNameIn
SEARCH State
  AT END DISPLAY "State Name " StateNameIn " does not exist"
  WHEN FUNCTION UPPER-CASE(StateName(StateIdx)) = FUNCTION UPPER-CASE(StateNameIn)
    DISPLAY "State Code = " StateCode(StateIdx)
    DISPLAY "State Capital = " StateCapital(StateIdx)
END-SEARCH.

```

GetCodeAndName.

```

DISPLAY "Enter the State Capital - " WITH NO ADVANCING
ACCEPT StateCapitalIn
SEARCH State
  AT END DISPLAY "State capital " StateCapitalIn " does not exist"
  WHEN FUNCTION UPPER-CASE(StateCapital(StateIdx)) = FUNCTION UPPER-CASE(StateCapitalIn)
    DISPLAY "State Code = " StateCode(StateIdx)
    DISPLAY "State Name = " StateName(StateIdx)
END-SEARCH.

```

Listing13-2 Output

```

Search by StateCode (1), StateName (2), StateCapital (3), STOP (4) - 3
Enter the State Capital - deS mOines
State Code = IA
State Name = Iowa

Search by StateCode (1), StateName (2), StateCapital (3), STOP (4) - 2
Enter the State Name - iowA
State Code   = IA
State Capital = Des Moines

Search by StateCode (1), StateName (2), StateCapital (3), STOP (4) - 1
Enter the two letter State Code - ia
State Name   = Iowa
State Capital = Des Moines

Search by StateCode (1), StateName (2), StateCapital (3), STOP (4) - 3
Enter the State Capital - saint paul
State Code = MN
State Name = Minnesota

Search by StateCode (1), StateName (2), StateCapital (3), STOP (4) - 4

```

The program contains a table prefilled with the state codes, state names, and state capitals of the American states. The user provides any one of the three (state code, state name, or state capital), and SEARCH returns the other two from the table.

Most of the program is straightforward and doesn't require any explanation. However, each of the three paragraphs `GetNameAndCapital`, `GetCodeAndCapital`, and `GetCodeAndName` makes use of *intrinsic functions*. You have not encountered intrinsic functions yet. You won't examine them formally until chapter 15, but I have introduced them here by way of a preview.

A *function* is a closed subroutine (block of code) that substitutes a returned value for its invocation. In Java, a method with a non-void return value type is a function. COBOL does not have user-defined functions, but it does have a number of built-in system functions called intrinsic functions.

The problem with using user input for comparison purposes is that you have to compare like with like. *Alaska* is not the same as *alaska* or *ALASKA* or *aLaska*. In `GetCodeAndCapital` and `GetCodeAndName`, the intrinsic function `UPPER-CASE` is used to convert the table data item and the data entered by the user to uppercase to ensure that the program is comparing like with like. In the comparison, the intrinsic function invocation is replaced by the returned function result, and then the comparison is done. For instance, an IF statement such as

```
IF FUNCTION UPPER-CASE("rEdMond") = FUNCTION UPPER-CASE("REDmond")
```

becomes

```
IF "REDMOND" = "REDMOND"
```

In `GetNameAndCapital`, I could have used the intrinsic function the same way as in `GetCodeAndCapital` and `GetCodeAndName`; but because the state code is already in uppercase, I took the opportunity to show another way of using intrinsic functions. In this paragraph, I use the intrinsic function to convert the user input to uppercase by moving the converted input data back into the input data item `StateCodeIn`.

Searching Multidimensional Tables

In the notes on SEARCH, I observed that SEARCH can have only one controlling index (the IndexName specified in the INDEXED BY phrase attached to the table being searched). Because SEARCH can have only one controlling index, SEARCH can only be used to search a single dimension of a table at a time. If the table to be searched is multidimensional, then *you* must control the indexes of the other dimensions.

Listing 13-3 is a small program that demonstrates how to use SEARCH to search a two-dimensional table. The program sets Appointment(3, 2) and Location(3, 2) to “Peter’s Wedding” and “Saint John’s Church”. SEARCH is then used to search the appointments timetable for the appointment details of “Peter’s Wedding”. When found, these details are displayed.

Listing 13-3. Program Demonstrating How to Search a Two-Dimensional Table

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing13-3.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 MyTimeTable.
    02 DayOfApp OCCURS 5 TIMES INDEXED BY DayIdx.
    03 HourOfApp OCCURS 9 TIMES INDEXED BY HourIdx.
    04 Appointment PIC X(15).
    04 Location PIC X(20).

01 AppointmentType PIC X(15).

01 DaySub PIC 9.
01 HourSub PIC 9.

01 FILLER PIC 9 VALUE ZERO.
    88 AppointmentNotFound VALUE ZERO.
    88 AppointmentFound VALUE 1.

01 DayValues VALUE "MonTueWedThuFri".
    02 DayName PIC XXX OCCURS 5 TIMES.

01 TimeValues VALUE " 9:0010:0011:0012:0013:0014:0015:0016:0017:00".
    02 TimeValue PIC X(5) OCCURS 9 TIMES.

PROCEDURE DIVISION.
Begin.
    MOVE "Peter's Wedding" TO AppointmentType, Appointment(2, 3)
    MOVE "Saint John's Church" TO Location(2, 3)
    SET DayIdx TO 1.
    PERFORM UNTIL AppointmentFound OR DayIdx > 5
        SET HourIdx TO 1
        SEARCH HourOfApp
            AT END SET DayIdx UP BY 1
            WHEN AppointmentType = Appointment(DayIdx, HourIdx)
                SET AppointmentFound TO TRUE
                SET HourSub TO HourIdx
                SET DaySub TO DayIdx
```

Listing13-3 Output

```
Peter's Wedding is on Tue
at 11:00 in Saint John's Church
```

```

        DISPLAY AppointmentType " is on " DayName(DaySub)
        DISPLAY "at " TimeValue(HourSub) " in " Location(DayIdx, HourIdx)
    END-SEARCH
END-PERFORM
IF AppointmentNotFound
    DISPLAY "Appointment " AppointmentType " was not in the timetable"
END-IF
STOP RUN.

```

The table used to hold the appointment timetable is described in Example 13-1 and is graphically depicted in Figure 13-4.

Example 13-1. Declarations for the Table Used to Record Appointments

```

01 MyTimeTable.
  02 DayOfApp OCCURS 5 TIMES INDEXED BY DayIdx.
    03 HourOfApp OCCURS 9 TIMES INDEXED BY HourIdx.
      04 Appointment PIC X(15) VALUE SPACES.
      04 Location PIC X(20) VALUE SPACES.

```

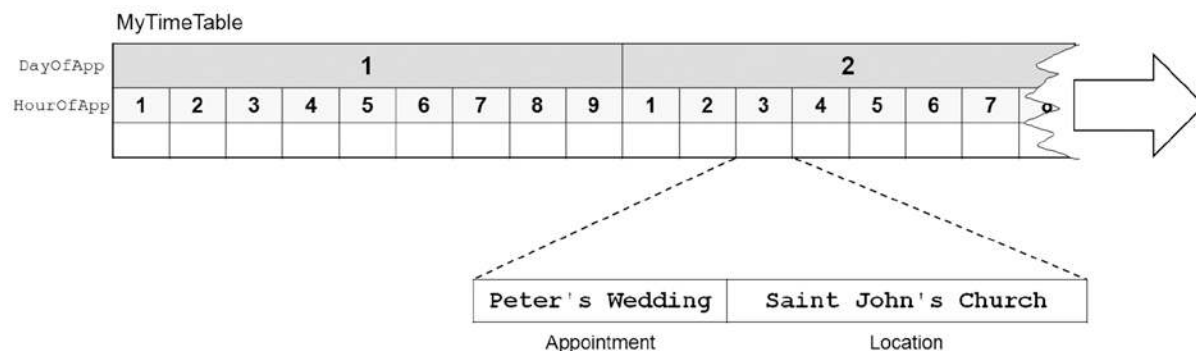


Figure 13-4. Graphical depiction of the two-dimensional table *MyTimeTable*

As you can see by examining Figure 13-4, in this two-dimensional table each day element consists of a table of hour elements. The table of hour elements is the SEARCH target. In most searches of a multidimensional table, the SEARCH target is the lowest data item in the hierarchy that contains both a OCCURS and an INDEXED BY clause. In this case, HourOfApp is the SEARCH target. In SEARCH, the controlling index is the item attached to the target table by an INDEXED BY clause. In this case, it is HourIdx.

Because SEARCH can have only one controlling index, you have to control the other. In this program, the SET verb is used to control the value in DayIdx, and HourIdx is under the control of SEARCH.

When SEARCH executes, it searches whichever of the HourOfApp tables is pointed to by DayIdx. If the appointment is not found, AT END activates, DayIdx is incremented, and SEARCH is executed again, this time examining the HourOfApp table in the next DayOfApp element. If the appointment is found, WHEN activates, and the HourIdx and DayIdx values are used to display the time (24-hour format) and day of the appointment. DayName and TimeValue are set up using the facility introduced in the ANS 85 version of COBOL that allows you to create prefilled tables without using the REDEFINES clause.

Searching the First Dimension of a Two-Dimensional Table

Listing 13-3 uses SEARCH to search the second dimension of the two-dimensional table. It does not normally make sense to search the first dimension of a two-dimensional table, because as you can see from Figure 13-4, each element at that level contains a table, not a discrete value. Sometimes, though, you need to perform such a search.

Suppose you have a two-dimensional table that records the number of jeans sold in three different colors in 150 shops. Suppose for each group of jeans sales totals, you also record the shop name. The table to record this information is described in Example 13-2 and is graphically depicted in Figure 13-5.

Example 13-2. Description of JeansSalesTable

```
01 JeansSalesTable.
  02 Shop OCCURS 150 TIMES INDEXED BY ShopIdx.
    03 ShopName          PIC X(15).
    03 JeansColor OCCURS 3 TIMES INDEXED BY ColorIdx.
      04 TotalSold       PIC 9(5).
```

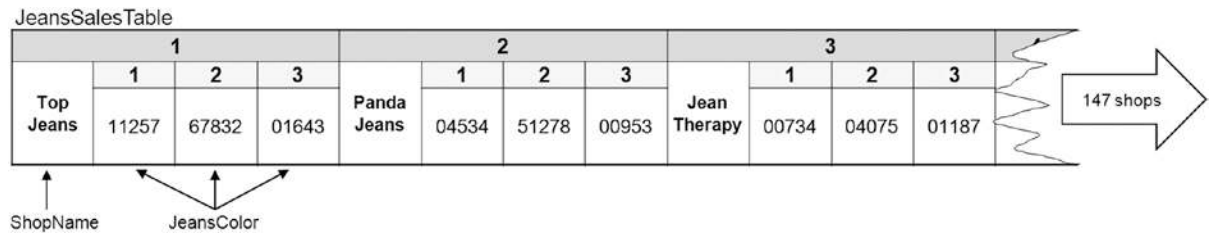


Figure 13-5. Graphical depiction of JeansSalesTable

Listing 13-4 is a simple program that shows how to use SEARCH to search the first dimension of a two-dimensional table. To keep the program simple, I haven't filled the table with all the values shown in Figure 13-5; only the element Shop(3) is filled with data values.

Listing 13-4. Searching the First Dimension of a Two-Dimensional Table

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing13-4.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 JeansSalesTable.
  02 Shop OCCURS 150 TIMES INDEXED BY ShopIdx.
    03 ShopName          PIC X(15) VALUE SPACES.
    03 JeansColor OCCURS 3 TIMES.
      04 TotalSold       PIC 9(5) VALUE ZEROS.

01 ShopQuery           PIC X(15).

01 PrnWhiteJeans.
  02 PrnWhiteTotal     PIC ZZ,ZZ9.
  02 FILLER            PIC X(12) VALUE " white jeans".
```



```

01 PrnBlueJeans.
  02 PrnBlueTotal      PIC ZZ,ZZ9.
  02 FILLER            PIC X(12) VALUE " blue jeans".

01 PrnBlackJeans.
  02 PrnBlackTotal    PIC ZZ,ZZ9.
  02 FILLER           PIC X(12) VALUE " black jeans".

```

PROCEDURE DIVISION.

Begin.

```

MOVE "Jean Therapy" TO ShopName(3), ShopQuery
MOVE 00734 TO TotalSold(3, 1)
MOVE 04075 TO TotalSold(3, 2)
MOVE 01187 TO TotalSold(3, 3)

SET ShopIdx TO 1
SEARCH Shop
  AT END Display "Shop not found"
  WHEN ShopName(ShopIdx) = ShopQuery
    MOVE TotalSold(ShopIdx, 1) TO PrnWhiteTotal
    MOVE TotalSold(ShopIdx, 2) TO PrnBlueTotal
    MOVE TotalSold(ShopIdx, 3) TO PrnBlackTotal
    DISPLAY "Sold by " ShopQuery
    DISPLAY PrnWhiteJeans
    DISPLAY PrnBlueJeans
    DISPLAY PrnBlackJeans
  END-SEARCH
STOP RUN.

```

Listing13-4 Output

```

Sold by Jean Therapy
  734 white jeans
 4,075 blue jeans
 1,187 black jeans

```

The SEARCH ALL Verb

As I noted earlier in this chapter, the method used to search a table depends heavily on the way the values are organized in the table. If the values are not ordered, then the only strategy available is a linear search. If the values are ordered, then you have the option of using either a linear search or a binary search. This section introduces SEARCH ALL, the COBOL verb used for binary searches.

Because SEARCH ALL implements a binary search, it only works on an ordered table. The table must be ordered on the values in the element or, where the element is a group item, on a data item within the element. The item on which the table is ordered is known as the *key field* and is identified using the KEY IS phrase in the table declaration.

KEY IS Clause

The KEY IS clause is used to identify the data item on which the table to be searched is ordered. If you want to search a table using SEARCH ALL, the table declaration must contain a KEY IS phrase. The OCCURS metalanguage that includes the KEY IS clause is given in Figure 13-6.

```

OCCURS TableSize#1 TIMES
[ { ASCENDING }
  { DESCENDING } KEY IS TableItem$#i... ]...
[ INDEXED BY IndexName... ]

```

Figure 13-6. OCCURS metalanguage including the KEY IS clause

How a Binary Search Works

I have mentioned that SEARCH ALL implements a binary search. Before discussing SEARCH ALL itself, let's take the time to refresh your memory about how a binary search works.

A binary search works by repeatedly dividing the search area into a top half and a bottom half, deciding which half contains the required item, and making that half the new search area. The search continues halving the search area like this until the required item is found or the search discovers that the item is not in the table.

The algorithm for a binary search is given in Example 13-3.

Example 13-3. Binary Search Algorithm

```

PERFORM UNTIL ItemFound OR ItemNotInTable
  COMPUTE Middle = (Lower + Upper) / 2
  EVALUATE TRUE
    WHEN Lower > Upper THEN SET ItemNotInTable TO TRUE
    WHEN KeyField(Middle) < SearchItem THEN Lower = Middle + 1
    WHEN KeyField(Middle) > SearchItem THEN Upper = Middle -1
    WHEN KeyField(Middle) = SearchItem THEN SET ItemFound TO TRUE
  END-EVALUATE
END-PERFORM

```

To illustrate how this algorithm works, let's consider it in the context of a table containing the letters of the alphabet. The table holding the letters is described in Example 13-4, and its representation in memory is illustrated pictorially in Figure 13-7.

Example 13-4. Table Prefilled with the Letters of the Alphabet

```

01 LetterTable.
02 LetterValues.
03 FILLER PIC X(13)
   VALUE "ABCDEFGHIJKLM".
03 FILLER PIC X(13)
   VALUE "NOPQRSTUVWXYZ".
02 FILLER REDEFINES LetterValues.
03 Letter PIC X OCCURS 26 TIMES
   ASCENDING KEY IS Letter
   INDEXED BY LetterIdx.

```

LetterTable

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Figure 13-7. Table containing the letters of the alphabet

Suppose you want to search LetterTable to find the position of the letter R. The general binary search algorithm introduced in Example 13-3 can be made more specific to the problem, as shown in Example 13-5. Figure 13-8 shows a succession of diagrams illustrating the application of this algorithm.

Example 13-5. Binary Search to Find the Letter R

```
PERFORM UNTIL ItemFound OR ItemNotInTable
  COMPUTE Middle = (Lower + Upper) / 2
  EVALUATE TRUE
    WHEN Lower > Upper THEN SET ItemNotInTable TO TRUE
    WHEN Letter(Middle) < "R" THEN Lower = Middle + 1
    WHEN Letter(Middle) > "R" THEN Upper = Middle - 1
    WHEN Letter(Middle) = "R" THEN SET ItemFound TO TRUE
  END-EVALUATE
END-PERFORM
```

LetterTable

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

```
COMPUTE Middle = (1 + 26) / 2
             13
```

```
WHEN Letter(Middle) < "R" THEN Lower = Middle + 1
                               14
```

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

```
COMPUTE Middle = (14 + 26) / 2
             20
```

```
WHEN Letter(Middle) > "R" THEN Upper = Middle - 1
                               19
```

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

```
COMPUTE Middle = (14 + 19) / 2
             16
```

```
WHEN Letter(Middle) < "R" THEN Lower = Middle + 1
                               17
```

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

```
COMPUTE Middle = (17 + 19) / 2
             18
```

```
WHEN Letter(Middle) = "R" THEN SET ItemFound TO TRUE
```

Figure 13-8. Finding the letter R using a binary search

SEARCH ALL

The metalanguage for SEARCH ALL is given in Figure 13-9.

$$\begin{array}{l}
 \underline{\text{SEARCH}} \ \underline{\text{ALL}} \ \text{TableName} \quad [\text{AT} \ \underline{\text{END}} \ \text{StatementBlock}] \\
 \\
 \underline{\text{WHEN}} \left\{ \begin{array}{l} \text{ElementIdentifier} \left\{ \begin{array}{l} \underline{\text{IS EQUAL TO}} \\ \text{IS} \ = \end{array} \right\} \left\{ \begin{array}{l} \text{Identifier} \\ \text{Literal} \\ \text{ArithExpression} \end{array} \right\} \\ \text{ConditionName} \end{array} \right\} \\
 \\
 \left[\underline{\text{AND}} \left\{ \begin{array}{l} \text{ElementIdentifier} \left\{ \begin{array}{l} \underline{\text{IS EQUAL TO}} \\ \text{IS} \ = \end{array} \right\} \left\{ \begin{array}{l} \text{Identifier} \\ \text{Literal} \\ \text{ArithExpression} \end{array} \right\} \\ \text{ConditionName} \end{array} \right\} \right] \\
 \\
 \left\{ \begin{array}{l} \text{StatementBlock} \\ \underline{\text{NEXT SENTENCE}} \end{array} \right\}
 \end{array}$$

END – SEARCH

Figure 13-9. Metalanguage for SEARCH ALL

Consider the following:

- The OCCURS clause of the table to be searched must have a KEY IS clause in addition to an INDEXED BY clause. The KEY IS clause identifies the data item on which the table is ordered.
- When you use SEARCH ALL, you do not need to set the table index to a starting value because SEARCH ALL controls it automatically.
- ElementIdentifier must be the item referenced by the table's KEY IS clause.
- ConditionName may have only one value, and it must be associated with a data item referenced by the table's KEY IS clause.

■ **Bug Alert** SEARCH ALL presents no problems when the table is fully loaded (all the elements have been assigned data values); but if the table is not fully loaded, then SEARCH ALL may not function correctly because the values in the unloaded part of the table will not be in key order. To rectify this problem, before you load the table you should fill it with HIGH-VALUES if the key is ascending or LOW-VALUES if the key is descending. See Listing 13-5 for an example.

Listing 13-5 is a simple program that displays the country name when the user enters a two-letter Internet code. Unlike the other example programs in this chapter, the table data in Listing 13-5 is obtained from a file that is loaded into the table at runtime. This is a much more realistic scenario for any sort of volatile data. Countries come and go and change their names with sufficient frequency that loading the table from a file makes good sense from a maintenance perspective. The table can hold up to 250 countries, but the country-code file contains only 243 entries at present.

Listing 13-5. Displaying the Corresponding Country Name When the User Enters a Country Code

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing13-5.
AUTHOR. Michael Coughlan.

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.

```
SELECT CountryCodeFile ASSIGN TO "Listing13-5.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

DATA DIVISION.
FILE SECTION.
FD CountryCodeFile.
01 CountryCodeRec.
88 EndOfCountryCodeFile VALUE HIGH-VALUES.
02 CountryCodeCF PIC XX.
02 CountryNameCF PIC X(25).

WORKING-STORAGE SECTION.
01 CountryCodeTable.
02 Country OCCURS 300 TIMES
ASCENDING KEY IS CountryCode
INDEXED BY Cidx.
03 CountryCode PIC XX.
03 CountryName PIC X(25).

01 CountryCodeIn PIC XX.
88 EndOfInput VALUE SPACES.

01 FILLER PIC 9 VALUE ZERO.
88 ValidCountryCode VALUE 1.

PROCEDURE DIVISION.

```
Begin.
  PERFORM LoadCountryCodeTable
  PERFORM WITH TEST AFTER UNTIL EndOfInput
  PERFORM WITH TEST AFTER UNTIL ValidCountryCode OR EndOfInput
  DISPLAY "Enter a country code (space to stop) :- "
  WITH NO ADVANCING
  ACCEPT CountryCodeIn
  SEARCH ALL Country
  AT END IF NOT EndOfInput
  DISPLAY "Country code " CountryCodeIn " is not valid"
  END-IF
  WHEN CountryCode(Cidx) = FUNCTION UPPER-CASE(CountryCodeIn)
  DISPLAY CountryCodeIn " is " CountryName(Cidx)
  END-SEARCH
  DISPLAY SPACES
  END-PERFORM
END-PERFORM
STOP RUN.
```

Listing 13-5 Output

```
Enter a country code (space to stop) :- ie
ie is Ireland

Enter a country code (space to stop) :- AZ
AZ is Azerbaijan

Enter a country code (space to stop) :- za
za is South Africa

Enter a country code (space to stop) :- us
us is United States

Enter a country code (space to stop) :- tt
tt is Trinidad and Tobago

Enter a country code (space to stop) :- qq
Country code qq is not valid

Enter a country code (space to stop) :- zw
zw is Zimbabwe

Enter a country code (space to stop) :-
```

LoadCountryCodeTable.

```
* Loads table with HIGH-VALUES so the SEARCH ALL works when the table is partially loaded
  MOVE HIGH-VALUES TO CountryCodeTable
  OPEN INPUT CountryCodeFile
  READ CountryCodeFile
    AT END SET EndOfCountryCodeFile TO TRUE
  END-READ

  PERFORM VARYING Cidx FROM 1 BY 1 UNTIL EndOfCountryCodeFile
    MOVE CountryCodeRec TO Country(Cidx)
    READ CountryCodeFile
      AT END SET EndOfCountryCodeFile TO TRUE
    END-READ
  END-PERFORM
CLOSE CountryCodeFile.
```

Variable-Length Tables

All the examples you have seen so far have used fixed-length tables. You may have wondered if COBOL supports variable-length tables. The answer is that it does support variable-length tables—of a sort.

You can declare variable-length tables using extensions to the OCCURS clause, as shown in Figure 13-10. Although you can dynamically alter the number of *element occurrences* in a variable-length table, the amount of storage allocated is fixed. It is defined by the value of `LargestSize#i` and is assigned at compile time. Standard COBOL has no mechanism for dynamically changing the amount of storage allocated to a table.

```
OCCURS SmallestSize#1 TO LargestSize#1 TIMES DEPENDING ON TableSize# i
{ { ASCENDING }
  { DESCENDING } } KEY IS TableItem$#i ... ] ...
[INDEXED BY IndexName ...]
```

Figure 13-10. Full OCCURS metalanguage, including the entries required for variable-length tables and the SEARCH and SEARCH ALL verbs

Note that this format of the OCCURS clause may only be used to vary the number of elements in the first dimension of a table.

An example declaration is shown in Example 13-6.

Example 13-6. Example Variable-Length Table Declaration

```
01 BooksReservedTable.
  02 BookId      PIC 9(7) OCCURS 1 TO 10
                 DEPENDING ON NumOfReservations.
```

The program in Listing 13-5 fills the table with HIGH-VALUES in order to get SEARCH ALL to work correctly, because the table was only partially populated (250 elements in size but only 243 countries). You could achieve the same effect by declaring the table as a variable-length table.

Although variable-length tables are not dynamic (the storage allocated is defined by the table's maximum size), they are treated by COBOL verbs as if they were dynamic. For instance, when you use SEARCH or SEARCH ALL with the table, only the elements between `SmallestSize#i` and `TableSize#i` are interrogated.

Listing 13-6 revisits the program from Listing 13-5 to emphasize these points.

Listing 13-6. SEARCH ALL Used with a Variable-Length Table

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing13-6.
AUTHOR. Michael Coughlan.

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.

```
SELECT CountryCodeFile ASSIGN TO "Listing13-6.dat"
      ORGANIZATION IS LINE SEQUENTIAL.
```

DATA DIVISION.

FILE SECTION.

FD CountryCodeFile.

01 CountryCodeRec.

```
88 EndOfCountryCodeFile VALUE HIGH-VALUES.
02 CountryCodeCF PIC XX.
02 CountryNameCF PIC X(25).
```

WORKING-STORAGE SECTION.

01 CountryCodeTable.

```
02 Country OCCURS 1 TO 300 TIMES
      DEPENDING ON NumberOfCountries
      ASCENDING KEY IS CountryCode
      INDEXED BY Cidx.
03 CountryCode PIC XX.
03 CountryName PIC X(25).
```

```
01 CountryCodeIn PIC XX.
88 EndOfInput VALUE SPACES.
```

```
01 FILLER PIC 9 VALUE ZERO.
88 ValidCountryCode VALUE 1.
```

```
01 NumberOfCountries PIC 999.
```

PROCEDURE DIVISION.

Begin.

```
PERFORM LoadCountryCodeTable
PERFORM WITH TEST AFTER UNTIL EndOfInput
      PERFORM WITH TEST AFTER UNTIL ValidCountryCode OR EndOfInput
      DISPLAY "Enter a country code (space to stop) :- "
      WITH NO ADVANCING
      ACCEPT CountryCodeIn
      PERFORM SearchCountryCodeTable
      DISPLAY SPACES
      END-PERFORM
      END-PERFORM
```

Listing 13-6 Output

```
Enter a country code (space to stop) :- us
us is United States

Enter a country code (space to stop) :- az
az is Azerbaijan

Enter a country code (space to stop) :- za
za is South Africa

Enter a country code (space to stop) :- zz
Country code zz is not valid

Enter a country code (space to stop) :- ie
ie is Ireland

Enter a country code (space to stop) :-
ZZ is **** FOUND ****
```

```

MOVE 244 TO NumberOfCountries
MOVE "ZZ" TO CountryCodeIn
PERFORM SearchCountryCodeTable
STOP RUN.

```

SearchCountryCodeTable.

```

SEARCH ALL Country
  AT END IF NOT EndOfInput
    DISPLAY "Country code " CountryCodeIn " is not valid"
  END-IF
  WHEN CountryCode(Cidx) = FUNCTION UPPER-CASE(CountryCodeIn)
    DISPLAY CountryCodeIn " is " CountryName(Cidx)
END-SEARCH.

```

LoadCountryCodeTable.

```

OPEN INPUT CountryCodeFile
READ CountryCodeFile
AT END SET EndOfCountryCodeFile TO TRUE
END-READ

PERFORM VARYING NumberOfCountries FROM 1 BY 1 UNTIL EndOfCountryCodeFile
  MOVE CountryCodeRec TO Country(NumberOfCountries)
  READ CountryCodeFile
  AT END SET EndOfCountryCodeFile TO TRUE
  END-READ
END-PERFORM
MOVE "ZZ **** FOUND ****" TO Country(244)
CLOSE CountryCodeFile.

```

The program in Listing 13-6 is the same as Listing 13-5, with the following changes:

- Variable-length tables are used. When the country data is loaded into the table from the file, the table increases in size as each record is read (see `VARYING NumberOfCountries`).
- Once the table has been loaded from the file, the value `"ZZ **** FOUND ****"` is loaded into element 244. The purpose of this is to prove that `SEARCH ALL` recognizes the table size specified in `NumberOfCountries`.
- In this program, I moved `SEARCH ALL` to its own paragraph because I need to use it in two different parts of the program and I don't want to repeat the code.
- When the program runs, the user enters a number of country codes, and the country names are returned. Note that this all works correctly even though the table has not had `HIGH-VALUES` moved to it.
- Then user enters `ZZ`. This is the country code of the entry I placed beyond the end of the table (as identified by `NumberOfCountries`). `SEARCH ALL` reports that it can't find this country code.
- When the loop exits, the program increases `NumberOfCountries` to 244, and the search is attempted again. This time `SEARCH ALL` does find the `ZZ` country code, because this time the code is the table.

Summary

This chapter examined `SEARCH` and `SEARCH ALL`, the COBOL verbs that allow you to search tabular data. The chapter introduced the `INDEXED BY` and `KEY IS` extensions to the `OCCURS` clause. These extensions are required when you want to use `SEARCH` and `SEARCH ALL` to search a table. You saw how to use `SEARCH` for linear searches of single-dimension tables and how, by controlling one of the indexes yourself, you can even use `SEARCH` to search a multidimensional table. The chapter showed how a binary search works and demonstrated how to use `SEARCH ALL` to search a table. Finally, you were introduced to the topic of variable-length tables and learned to declare and use them.

The next chapter introduces the `SORT` and `MERGE` verbs. `SORT` is generally used to sort files, but it may also be used to sort a table. As I noted when discussing sequential files in Chapter 7, many operations on sequential files are not possible unless the files are ordered. For this reason, many programs begin by sorting the file into the required order.

PROGRAMMING EXERCISE 1

Prepare your 2B pencil; it's exercise time again. In this program, you will use your knowledge of variable-length tables and the `SEARCH` verb.

A program is required that will report the frequency of all the words in a document. To make the problem easier, the document has been split into individual words, one word per record. The program should be able to report on a maximum of 1,000 words.

The document words are held in an unordered sequential file called `DocWords.dat`. Each record has the following description:

Field	Type	Length	Value
Word	X	20	-

Write a program to read a file of document words and produce a report that shows the top ten words in descending order of frequency. The report template is as follows:

```

Top Ten Words In Document
Pos   Occurs   Document Word
1.    XXX     XXXXXXXXXXXXXXXXXXXX
2.    XXX     XXXXXXXXXXXXXXXXXXXX
3.    XXX     XXXXXXXXXXXXXXXXXXXX
4.    XXX     XXXXXXXXXXXXXXXXXXXX
5.    XXX     XXXXXXXXXXXXXXXXXXXX
6.    XXX     XXXXXXXXXXXXXXXXXXXX
7.    XXX     XXXXXXXXXXXXXXXXXXXX
8.    XXX     XXXXXXXXXXXXXXXXXXXX
9.    XXX     XXXXXXXXXXXXXXXXXXXX
10.   XXX     XXXXXXXXXXXXXXXXXXXX

```

PROGRAMMING EXERCISE 2

The task in this exercise is to write a program that accepts ten numbers from the user, places them in a table, and then detects and reports on the following states:

- No zeros found in the table
- Only one zero found in the table
- Two zeros found, but no numbers between the two zeros
- Two zeros, and between them an even number of non-zeros
- Two zeros, and between them an odd number of non-zeros

PROGRAMMING EXERCISE 1: ANSWER

Listing 13-7. Program to Find the Top Ten Words in a Document

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing13-7.
AUTHOR. Michael Coughlan.

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT DocWordsFile ASSIGN TO "Listing13-7.DAT"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD DocWordsFile.
01 WordIn                PIC X(20).
   88 EndOfDocWordsFile VALUE HIGH-VALUES.

WORKING-STORAGE SECTION.
01 WordFreqTable.
   02 Word OCCURS 0 TO 2000 TIMES
       DEPENDING ON NumberOfWords
       INDEXED BY Widx.
   03 WordFound          PIC X(20).
   03 WordFreq           PIC 9(3).

01 TopTenTable.
   02 WordTT OCCURS 11 TIMES
       INDEXED BY TTidx.
   03 WordFoundTT       PIC X(20) VALUE SPACES.
   03 WordFreqTT        PIC 9(3) VALUE ZEROS.

01 NumberOfWords        PIC 9(4) VALUE ZERO.
```

```

01 ReportHeader      PIC X(27) VALUE " Top Ten Words In Document".
01 SubjectHeader     PIC X(29) VALUE "Pos   Occurs   Document Word".

01 DetailLine.
  02 PrnPos          PIC Z9.
  02 FILLER          PIC X VALUE ".".
  02 PrnFreq        PIC BBBBZZ9.
  02 PrnWord        PIC BBBBXX(20).

01 Pos              PIC 99.

```

PROCEDURE DIVISION.

Begin.

```

  OPEN INPUT DocWordsFile
  READ DocWordsFile
  AT END SET EndOfDocWordsFile TO TRUE
  END-READ
  PERFORM LoadWordFreqTable UNTIL EndOfDocWordsFile
  PERFORM FindTopTenWords
  VARYING Widx FROM 1 BY 1 UNTIL Widx > NumberOfWords
  PERFORM DisplayTopTenWords
  CLOSE DocWordsFile
  STOP RUN.

```

LoadWordFreqTable.

* The AT END triggers when Widx is one greater than the current size of the
 * table so all we have to do is extend the table and write into the new table
 * element

```

  SET Widx TO 1
  SEARCH Word
  AT END ADD 1 TO NumberOfWords
  MOVE 1 TO WordFreq(Widx)
  MOVE FUNCTION LOWER-CASE(WordIn) TO WordFound(Widx)
  WHEN FUNCTION LOWER-CASE(WordIn) = WordFound(Widx)
  ADD 1 TO WordFreq(Widx)
  END-SEARCH
  READ DocWordsFile
  AT END SET EndOfDocWordsFile TO TRUE
  END-READ.

```

FindTopTenWords.

```

  PERFORM VARYING TTidx FROM 10 BY -1 UNTIL TTidx < 1
  IF WordFreq(Widx) > WordFreqTT(TTidx)
  MOVE WordTT(TTidx) TO WordTT(TTidx + 1)
  MOVE Word(Widx) TO WordTT(TTidx)
  END-IF
  END-PERFORM.

```

DisplayTopTenWords.

Listing13-7 Output

Top Ten Words In Document		
Pos	Occurs	Document Word
1.	69	and
2.	42	will
3.	30	remote
4.	29	web
5.	24	procedures
6.	21	services
7.	20	other
8.	18	with
9.	17	them
10.	16	from

```

DISPLAY ReportHeader
DISPLAY SubjectHeader
PERFORM VARYING TTidx FROM 1 BY 1 UNTIL TTidx > 10
    SET Pos TO TTidx
    MOVE Pos TO PrnPos
    MOVE WordFoundTT(TTidx) TO PrnWord
    MOVE WordFreqTT(TTidx) TO PrnFreq
    DISPLAY DetailLine
END-PERFORM

```

PROGRAMMING EXERCISE 2: ANSWER

Listing 13-8. Program to Find the Number of Zeros in a List of Ten Numbers

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing13-8.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 NumberArray.
    02 Num PIC 99 OCCURS 10 TIMES
        INDEXED BY Nidx.

01 FirstZeroPos          PIC 99 VALUE ZERO.
   88 NoZeros            VALUE 0.

01 SecondZeroPos        PIC 99 VALUE ZERO.
   88 OneZero           VALUE 0.

01 ValuesBetweenZeros   PIC 9 VALUE ZERO.
   88 NoneBetweenZeros VALUE 0.

PROCEDURE DIVISION.
Begin.
    DISPLAY "Enter 10 two digit numbers "
    PERFORM VARYING Nidx FROM 1 BY 1 UNTIL Nidx > 10
        DISPLAY "Enter number - " SPACE WITH NO ADVANCING
        ACCEPT Num(Nidx)
    END-PERFORM

    SET Nidx TO 1
    SEARCH Num
        AT END SET NoZeros TO TRUE
        WHEN Num(Nidx) = ZERO
            SET FirstZeroPos TO Nidx
            SET Nidx UP BY 1
        SEARCH Num
            AT END SET OneZero TO TRUE
            WHEN Num(Nidx) = ZERO

```

```
        SET SecondZeroPos TO Nidx
        COMPUTE ValuesBetweenZeros = (SecondZeroPos - 1) - FirstZeroPos
    END-SEARCH
END-SEARCH

EVALUATE TRUE
    WHEN NoZeros      DISPLAY "No zeros found"
    WHEN OneZero     DISPLAY "Only one zero found"
    WHEN NoneBetweenZeros DISPLAY "No numbers between the two zeros"
    WHEN FUNCTION REM(ValuesBetweenZeros, 2)= ZERO
        DISPLAY "Even number of non-zeros between zeros"
    WHEN OTHER       DISPLAY "Odd number of non-zeros between zeros"
END-EVALUATE
STOP RUN.
```



Sorting and Merging

If there is one thing you should have learned from the chapters on sequential files, it is that your processing options are very limited if a sequential file is not ordered. Solutions based on control breaks, and the file-update problem, are impossible unless the file is ordered on some key field. In previous chapters, I mentioned the very useful program design technique called *beneficial wishful thinking* in which, when you are confronted by a difficult programming problem, you imagine a set of circumstances under which the difficulty would be greatly reduced and then try to bring about that set of circumstances. In the context of sequential files, you will often find yourself confronted with problems that would be much easier to solve if the file was ordered. A solution based on the beneficial wishful thinking approach first puts the file into the required order.

In this chapter, you discover how to use the SORT verb to sort a sequential file in ascending or descending order. You learn how to use an INPUT PROCEDURE to filter or modify the records presented for sorting and how to use an OUTPUT PROCEDURE to process the sorted records instead of sending them directly to an output file. In addition, you see how to use the MERGE verb to merge the records in two or more ordered files to create a combined file with the records in the correct order.

SORTING

I noted in previous chapters that it is possible to apply processing to an ordered sequential file that is difficult, or impossible, when the file is unordered. In cases where you need to apply ordered processing to an unordered sequential file, part of the solution must be to sort the file. COBOL provides the SORT verb for this purpose.

The SORT verb is usually used to sort sequential files. Some programmers claim that the SORT verb is unnecessary, preferring to use an implementer-provided or “off-the-shelf” sort. However, one major advantage of using the SORT verb is that it enhances the portability of COBOL programs. Because the SORT verb is available in every COBOL compiler, when a program that uses SORT has to be moved to a different computer system, it can make the transition without requiring any changes to the SORT. This is rarely the case when programs rely on an implementer-supplied or bought-in sort.

Simple Sorting

The syntax for the simple SORT is given in Figure 14-1. This version of SORT takes the records in the InFileName file, sorts them on the WorkSortKey#*i* key or keys, and writes the sorted records to the OutFileName file.

```

SORT SDWorkFileName { ON { ASCENDING } KEY { WorkSortKey#i } ... } ...
    [ WITH DuplicatesInOrder ]
    [ COLLATING SEQUENCE IS AlphabetName ]
    { USING { InFileName } ... }
    { GIVING { OutFileName } ... }

```

Figure 14-1. Metalanguage for the simple version of SORT

Some example SORT statements are given in Example 14-1.

Example 14-1. Example SORT Statements

```

SORT WorkFile
  ON ASCENDING BookId-WF
    AuthorName-WF
  USING BookSalesFileUS, BookSalesFileEU
  GIVING SortedBookSales

SORT WorkFile
  ON DESCENDING NCAP-Result-WF
    ASCENDING ManfName-WF, VehicleName-WF
  USING NCAP-TestResultsFile
  GIVING Sorted-NCAP-TestResultsFile

```

Simple Sorting Notes

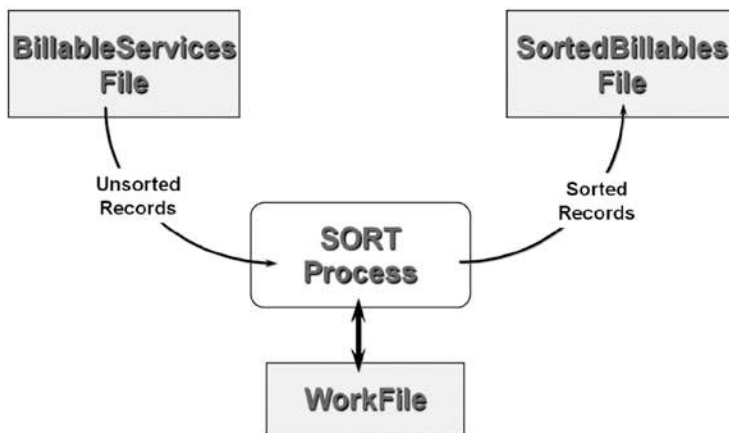
Consider the following:

- SDWorkFileName identifies a temporary work file that the sort process uses as a kind of scratch pad for sorting. The file is defined in the FILE SECTION using a sort description (SD) rather than a file description (FD) entry. Even though the work file is a temporary file, it must still have associated SELECT and ASSIGN clauses in the ENVIRONMENT DIVISION. You can give this file any name you like; I usually call it WorkFile as I did in Example 14-1.
- SDWorkFileName file is a sequential file with an organization of RECORD SEQUENTIAL. Because this is the default organization, it is usually omitted (see Listing 14-1).
- Each WorkSortKey#i identifies a field in the record of the work file. The sorted file will be ordered on this key field(s).
- When more than one WorkSortKey#i is specified, the keys decrease in significance from left to right (the leftmost key is the most significant, and the rightmost is the least significant).
- InFileName and OutFileName are the names of the input and output files, respectively.
- If more than one InFileName is specified, the files are combined (OutFileSize = InFile1Size + InFile2Size) and then sorted.
- If more than one OutFileName is specified, then each file receives a copy of the sorted records.

- If the `DUPLICATES` clause is used, then when the file has been sorted, the final order of records with duplicate keys (keys with the same value) is the same as that in the unsorted file. If no `DUPLICATES` clause is used, the order of records with duplicate keys is undefined.
- `AlphabetName` is an alphabet name defined in the `SPECIAL-NAMES` paragraph of the `ENVIRONMENT DIVISION`. This clause is used to select the character set the `SORT` verb uses for collating the records in the file. The character set may be `STANDARD-1` (ASCII), `STANDARD-2` (ISO 646), `NATIVE` (may be defined by the system to be ASCII or EBCDIC; see your implementer manual), or user defined.
- `SORT` can be used anywhere in the `PROCEDURE DIVISION` except in an `INPUT PROCEDURE (SORT)` or `OUTPUT PROCEDURE (SORT or MERGE)` or in the `DECLARATIVES SECTION`. The purpose of the `INPUT PROCEDURE` and `OUTPUT PROCEDURE` is explained later in this chapter, but an explanation of the `DECLARATIVES SECTION` has to wait until Chapter 18.
- The records described for the input file (`USING`) must be able to fit into the records described for `SDWorkFileName`.
- The records described for `SDWorkFileName` must be able to fit into the records described for the output file (`GIVING`).
- The description of `WorkSortKey#$i` cannot contain an `OCCURS` clause (it cannot be a table), nor can it be subordinate to an entry that contains one.
- The `InFileName` and `OutFileName` files are automatically opened by the `SORT`. When the `SORT` executes, they *must not already be open*.

How the Simple SORT Works

Figure 14-2 shows how the simple version of `SORT` works. In this case, the diagram uses the example in Listing 14-1 to illustrate the point. The sort process takes records from the unsorted `BillableServicesFile`, sorts them using `WorkFile` (the temporary work area), and, when the records have been sorted, sends them to `SortedBillablesFile`. After sorting, the records in the `SortedBillablesFile` will be ordered on ascending `SubscriberId`.



```

SORT WorkFile ON ASCENDING KEY SubscriberId-WF
USING BillableServicesFile
GIVING SortedBillablesFile.
  
```

Figure 14-2. Diagram showing how the simple `SORT` works

Simple Sorting Program

Universal Telecoms has subscribers all over the United States. Each month, the billable activities of these subscribers are gathered into a file. `BillableServicesFile` is an unordered sequential file. Each record has the following description:

Field	Type	Length	Value
<code>SubscriberId</code>	9	10	-
<code>ServiceType</code>	9	1	1(text)/2(voice)
<code>ServiceCost</code>	9	6	0.10-9999.99

A program is required to produce a report that shows the value of the billable services for each subscriber (see Listing 14-1). In the report, `BillableValue` is the sum of the `ServiceCost` fields for each subscriber. The report must be printed on ascending `SubscriberId` and have the following format:

```
Universal Telecoms Monthly Report
SubscriberId      BillableValue
XXXXXXXXXX       XXXXXXXXXXXX
XXXXXXXXXX       XXXXXXXXXXXX
XXXXXXXXXX       XXXXXXXXXXXX
```

Listing 14-1. A simple SORT applied to the `BillableServicesFile`

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing14-1.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT WorkFile ASSIGN TO "WORK.TMP".

    SELECT BillableServicesFile ASSIGN TO "Listing14-1.dat"
        ORGANIZATION LINE SEQUENTIAL.

    SELECT SortedBillablesFile ASSIGN TO "Listing14-1.Srt"
        ORGANIZATION LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.

FD BillableServicesFile.
01 SubscriberRec-BSF PIC X(17).

SD WorkFile.
01 WorkRec.
   02 SubscriberId-WF PIC 9(10).
   02 FILLER PIC X(7).

FD SortedBillablesFile.
01 SubscriberRec.
   88 EndOfBillablesFile VALUE HIGH-VALUES.
   02 SubscriberId PIC 9(10).
```

```

    02 ServiceType      PIC 9.
    02 ServiceCost     PIC 9(4)V99.

WORKING-STORAGE SECTION.
01 SubscriberTotal    PIC 9(5)V99.

01 ReportHeader      PIC X(33) VALUE "Universal Telecoms Monthly Report".

01 SubjectHeader     PIC X(31) VALUE "SubscriberId      BillableValue".

01 SubscriberLine.
    02 PrnSubscriberId PIC 9(10).
    02 FILLER          PIC X(8) VALUE SPACES.
    02 PrnSubscriberTotal PIC $$$,$$9.99.

01 PrevSubscriberId  PIC 9(10).

PROCEDURE DIVISION.
Begin.
    SORT WorkFile ON ASCENDING KEY SubscriberId-WF
        USING BillableServicesFile
        GIVING SortedBillablesFile
    DISPLAY ReportHeader
    DISPLAY SubjectHeader
    OPEN INPUT SortedBillablesFile
    READ SortedBillablesFile
        AT END SET EndOfBillablesFile TO TRUE
    END-READ
    PERFORM UNTIL EndOfBillablesFile
        MOVE SubscriberId TO PrevSubscriberId, PrnSubscriberId
        MOVE ZEROS TO SubscriberTotal
        PERFORM UNTIL SubscriberId NOT EQUAL TO PrevSubscriberId
            ADD ServiceCost TO SubscriberTotal
            READ SortedBillablesFile
                AT END SET EndOfBillablesFile TO TRUE
            END-READ
        END-PERFORM
        MOVE SubscriberTotal TO PrnSubscriberTotal
        DISPLAY SubscriberLine
    END-PERFORM
    CLOSE SortedBillablesFile
    STOP RUN.

```

Program Notes

I have kept this program simple for reasons of clarity and space, and because you will meet a more fully worked version of the program when I explore advanced versions of the SORT. Because the SORT uses a disk-based `WorkFile`, it is slower than purely RAM-bound operations. You should be aware of this whenever you are considering using SORT. You should probably use SORT only when no practical RAM-based solution is available; and even then, you should ensure that only the data items required in the sorted file are sorted. This may involve leaving out some of the records or changing the record size.

In this instance, sorting the file does seem to be the only viable option. There are millions of telephone subscribers, and, in the course of a month, they make many calls and send hundreds of texts. So `BillableServicesFile` contains tens of millions, or hundreds of millions, of records. In COBOL, the only possible RAM-based solution (you can't create dynamic structures like trees or linked lists pre-ISO 2002) would be to use a table (one element per subscriber) to sum the subscribers' `ServiceCost` fields. That solution has many problems. The array would have to contain millions of elements, you would have to ensure that the elements were in `SubscriberId` order, and, because new subscribers are constantly joining, the table would have to be redimensioned every time the program ran.

You may wonder why the example uses different record descriptions for the three files when the records are identical. The reason is that although the records are identical, they are used in different ways in the program, and the granular data descriptions reflect way the records are used.

The input file is used only by the SORT, so while you have to define how much storage a record will occupy you never need to refer to the individual fields. You could fully define the record as follows:

```
01 UnsortedSubscriberRec.
   02 SubscriberId      PIC 9(10).
   02 ServiceType      PIC 9.
   02 ServiceCost      PIC 9(4)V99
```

But then you would either have to use slightly different field names for the sorted file or qualify them using references such as `SubscriberId OF SubscriberRec`.

In `WorkFile`, only the data items on which the file is to be sorted (mentioned in the KEY phrase) need to be explicitly defined. In this case, the only item that must be explicitly identified is `SubscriberId-WF`.

The sorted file is normally the file that the program uses to do whatever work is required. This generally means that all, or nearly all, of the data items are mentioned by name in the program; and, hence, they have to be declared. Normally, the record description for this file fully defines the record.

Using Multiple Keys

If you examine the SORT metalanguage in Figure 14-1, you will realize not only that a file can be sorted on a number of keys but also that one key can be ascending while another is descending. This is illustrated in Table 14-1 and Example 14-2. The table contains student results that have been sorted into descending `StudentId` order within ascending GPA order. Notice that GPA is the major key and that `StudentId` is only in descending sequence within GPA. This is because the first key named in a SORT statement is the major key, and keys become less significant with each successive declaration.

Example 14-2. SORT with One Key Descending and Another Ascending

```
SORT WorkFile ON DESCENDING GPA
              ASCENDING StudentId
              USING StudentResultsFile
              GIVING SortedStudentsResultsFile
```

Table 14-1. *Ascending StudentId within Descending GPA*

SortedStudentsResultsFile

GPA	StudentId	Record remainder
4	11234598	Et cetera
4	22334567	Et cetera
4	33435678	Et cetera
4	44245666	Et cetera
3.50	11103456	Et cetera
3.50	22234567	Et cetera
3.50	33315432	Et cetera
3.25	11114321	Et cetera
3.25	22228676	Et cetera
3.25	33339758	Et cetera
3.25	44449878	Et cetera
3.25	55559990	Et cetera
3.25	66669990	Et cetera
3.15	11111345	Et cetera
3.15	22222567	Et cetera
3.00	11111123	Et cetera
3.00	22222254	Et cetera
3.00	33333356	Et cetera
3.00	44444487	Et cetera
2.75	11111117	Et cetera
2.75	33333336	Et cetera
etc.	etc.	etc.

SORT with Procedures

The simple version of SORT takes the records from `InFileName`, sorts them, and then outputs them to `OutFileName`. Sometimes, however, not all the records in the unsorted file are required in the sorted file, or not all the data items in the unsorted file record are required in the record of the sorted file. For instance, suppose the specification for the Universal Telecoms Monthly Report changes so that you are only required to show the value of the *voice calls* made by subscribers. In that situation, the text records (`ServiceType = 1`) are not required in the sorted file. Similarly, if the specification changes so that the *number* of texts and phone calls is required rather than their *value*, you do not need the `ServiceCost` data item in sorted file records. In both cases, processing must be applied, to eliminate unwanted records or alter their format, before the records are submitted to the sort process. This processing is achieved by specifying `INPUT PROCEDURE` with SORT.

Sometimes, to reduce the number of files that have to be declared, you may find it useful to process the records directly from the sort process instead of creating a sorted file and then processing that. For instance, you could create the Universal Telecoms Monthly Report directly instead of creating a sorted file and then processing the sorted file to create the report. Such processing is accomplished by using `OUTPUT PROCEDURE` with SORT.

An `INPUT PROCEDURE` is a block of code that consists of one or more sections or paragraphs that execute, having been passed control by SORT. When the block of code has finished, control reverts to SORT. An `OUTPUT PROCEDURE` works in a similar way.

Figure 14-3 gives the metalanguage for the full SORT including the INPUT PROCEDURE and the OUTPUT PROCEDURE.

$$\text{SORT } \text{SDWorkFileName} \left\{ \text{ON } \left\{ \begin{array}{l} \text{ASCENDING} \\ \text{DESCENDING} \end{array} \right\} \text{ KEY } \{ \text{WorkSortKey\#Si} \} \dots \right\} \dots$$

$$\left[\text{WITH } \underline{\text{DUPLICATES IN ORDER}} \right]$$

$$\left[\text{COLLATING SEQUENCE IS } \text{AlphabetName} \right]$$

$$\left\{ \begin{array}{l} \text{INPUT PROCEDURE IS } \text{ProcedureName} \left\{ \begin{array}{l} \text{THRU} \\ \text{THROUGH} \end{array} \right\} \text{ProcedureName} \\ \text{USING } \{ \text{InFileName} \} \dots \end{array} \right\}$$

$$\left\{ \begin{array}{l} \text{OUTPUT PROCEDURE IS } \text{ProcedureName} \left\{ \begin{array}{l} \text{THRU} \\ \text{THROUGH} \end{array} \right\} \text{ProcedureName} \\ \text{GIVING } \{ \text{OutFileName} \} \dots \end{array} \right\}$$

Figure 14-3. Metalanguage for the full version of the SORT verb

INPUT PROCEDURE Notes

You should consider the following when using an INPUT PROCEDURE:

- The block of code specified by the INPUT PROCEDURE allows you to select which records, and what format of records, are submitted to the sort process. Because an INPUT PROCEDURE executes before the SORT sorts the records, only the data that is actually required in the sorted file is sorted.
- When you use an INPUT PROCEDURE, it replaces the USING phrase. The ProcedureName in the INPUT PROCEDURE phrase identifies a block of code that uses the RELEASE verb to supply records to the sort process. The INPUT PROCEDURE must contain at least one RELEASE statement to transfer the records to the work file (identified by SDWorkFileName).
- The INPUT PROCEDURE finishes before the sort process sorts the records supplied to it by the procedure. That's why the records are RELEASEd to the work file. They are stored there until the INPUT PROCEDURE finishes, and then they are sorted.
- Neither an INPUT PROCEDURE nor an OUTPUT PROCEDURE can contain a SORT or MERGE statement.
- The pre-ANS 85 COBOL rules for the SORT verb stated that the INPUT PROCEDURE and OUTPUT PROCEDURE had to be self-contained sections of code and could not be entered from elsewhere in the program.
- In the ANS 85 version of COBOL, the INPUT PROCEDURE and OUTPUT PROCEDURE can be any contiguous group of paragraphs or sections. The only restriction is that the range of paragraphs or sections used must not overlap.

OUTPUT PROCEDURE Notes

You should consider the following when using an OUTPUT PROCEDURE:

- An OUTPUT PROCEDURE retrieves sorted records from the work file using the RETURN verb. An OUTPUT PROCEDURE must contain at least one RETURN statement to get the records from the work file.
- An OUTPUT PROCEDURE only executes after the file has been sorted.
- If you use an OUTPUT PROCEDURE, the SORT . . GIVING phrase cannot be used.

How an INPUT PROCEDURE Works

A simple SORT works by taking records from the USING file, sorting them, and then writing them to the GIVING file. When an INPUT PROCEDURE is used, there is no USING file, so the sort process has to get its records from the INPUT PROCEDURE. The INPUT PROCEDURE uses the RELEASE verb to supply the records to the work file of the SORT, one at a time.

Although an INPUT PROCEDURE usually gets the records it supplies to the sort process from an input file, the records can originate from anywhere. For instance, if you wanted to sort the elements of a table, you could use INPUT PROCEDURE to send the elements, one at a time, to the sort process (see Listing 14-7, in the section “Sorting Tables Program”). Or, if you wanted to sort the records as they were entered by the user, you could use INPUT PROCEDURE to get the records from the user and supply them to the sort process (see Listing 14-3, later in this section). When an INPUT PROCEDURE gets its records from an input file, it can select which records to send to the sort process and can even alter the structure of the records before they are sent.

Creating an INPUT PROCEDURE

When you use an INPUT PROCEDURE, a RELEASE verb must be used to send records to the work file associated with SORT. The work file is declared in an SD entry in the FILE SECTION. RELEASE is a special verb used only in INPUT PROCEDURES to send records to the work file. It is the equivalent of a WRITE command and works in a similar way. The metalanguage for the RELEASE verb is given in Figure 14-4.

```
RELEASE SDWorkRecordName [FROM Identifier]
```

Figure 14-4. Metalanguage for the RELEASE verb

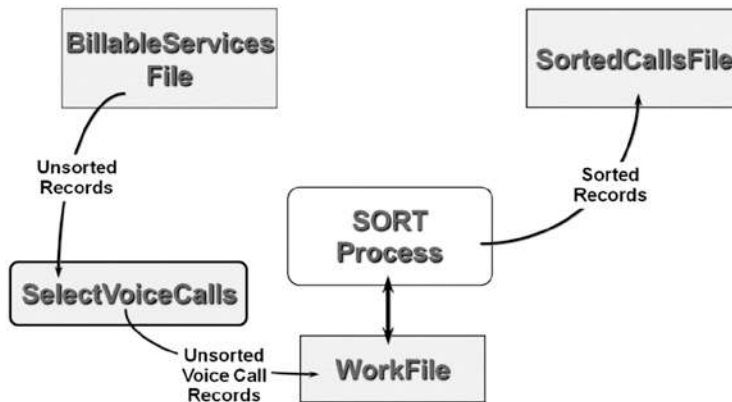
A template for an INPUT PROCEDURE that gets records from an input file and releases them to the SORT work file is given in Example 14-3. Notice that the work file is not opened in the OUTPUT PROCEDURE. The work file is automatically opened by the SORT.

Example 14-3. INPUT PROCEDURE File-Processing Template

```
OPEN INPUT InFileName
READ InFileName RECORD
PERFORM UNTIL TerminatingCondition
    RELEASE SDWorkRec
    READ InFileName RECORD
END-PERFORM
CLOSE InFileName
```

Using an INPUT PROCEDURE to Select Records

Suppose that the specification for the Universal Telecoms Monthly Report is changed so that only the value of the *voice calls* made by subscribers is required. Figure 14-5 shows how you can use an INPUT PROCEDURE between the input file and the sort process to filter out the unwanted text (*ServiceType = 1*) records. Listing 14-2 implements the specification change and also produces a more fully worked version. In this program, the report is written to a print file rather than just displayed on the computer screen.



```

SORT WorkFile ON ASCENDING KEY SubscriberId-WF
INPUT PROCEDURE IS SelectVoiceCalls
GIVING SortedCallsFile
  
```

Figure 14-5. INPUT PROCEDURE used to select the voice call records

Listing 14-2. Using an INPUT PROCEDURE to Select Only Voice Calls Records

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing14-2.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT WorkFile ASSIGN TO "WORK.TMP".

    SELECT BillableServicesFile ASSIGN TO "Listing14-2.dat"
        ORGANIZATION LINE SEQUENTIAL.

    SELECT SortedCallsFile ASSIGN TO "Listing14-2.Srt"
        ORGANIZATION LINE SEQUENTIAL.

    SELECT PrintFile ASSIGN TO "Listing14-2.prn"
        ORGANIZATION LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD BillableServicesFile.
01 SubscriberRec-BSF.
  
```

```

88 EndOfBillableServicesFile VALUE HIGH-VALUES.
02 FILLER          PIC X(10).
02 FILLER          PIC 9.
   88 VoiceCall    VALUE 2.
02 FILLER          PIC X(6).

SD WorkFile.
01 WorkRec.
   02 SubscriberId-WF  PIC 9(10).
   02 FILLER          PIC X(7).

FD SortedCallsFile.
01 SubscriberRec.
   88 EndOfCallsFile VALUE HIGH-VALUES.
   02 SubscriberId    PIC 9(10).
   02 ServiceType     PIC 9.
   02 ServiceCost     PIC 9(4)V99.

FD PrintFile.
01 PrintRec          PIC X(40).

WORKING-STORAGE SECTION.
01 SubscriberTotal   PIC 9(5)V99.

01 ReportHeader     PIC X(33) VALUE "Universal Telecoms Monthly Report".

01 SubjectHeader    PIC X(31) VALUE "SubscriberId      BillableValue".

01 SubscriberLine.
   02 PrnSubscriberId PIC 9(10).
   02 FILLER          PIC X(8) VALUE SPACES.
   02 PrnSubscriberTotal PIC $$$,$$9.99.

01 PrevSubscriberId PIC 9(10).

PROCEDURE DIVISION.
Begin.
   SORT WorkFile ON ASCENDING KEY SubscriberId-WF
     INPUT PROCEDURE IS SelectVoiceCalls
     GIVING SortedCallsFile
   OPEN OUTPUT PrintFile
   OPEN INPUT SortedCallsFile
   WRITE PrintRec FROM ReportHeader AFTER ADVANCING PAGE
   WRITE PrintRec FROM SubjectHeader AFTER ADVANCING 1 LINE

   READ SortedCallsFile
   AT END SET EndOfCallsFile TO TRUE
   END-READ
   PERFORM UNTIL EndOfCallsFile
     MOVE SubscriberId TO PrevSubscriberId, PrnSubscriberId
     MOVE ZEROS TO SubscriberTotal
     PERFORM UNTIL SubscriberId NOT EQUAL TO PrevSubscriberId

```



```

        ADD ServiceCost TO SubscriberTotal
        READ SortedCallsFile
            AT END SET EndOfCallsFile TO TRUE
        END-READ
    END-PERFORM
    MOVE SubscriberTotal TO PrnSubscriberTotal
    WRITE PrintRec FROM SubscriberLine AFTER ADVANCING 1 LINE
END-PERFORM
CLOSE SortedCallsFile, PrintFile
STOP RUN.

```

SelectVoiceCalls.

```

OPEN INPUT BillableServicesFile
READ BillableServicesFile
    AT END SET EndOfBillableServicesFile TO TRUE
END-READ
PERFORM UNTIL EndOfBillableServicesFile
    IF VoiceCall
        RELEASE WorkRec FROM SubscriberRec-BSF
    END-IF
    READ BillableServicesFile
        AT END SET EndOfBillableServicesFile TO TRUE
    END-READ
END-PERFORM
CLOSE BillableServicesFile.

```

The file declarations are once more of interest. Because only the voice call records are released to the work file, you need to be able to detect which records are voice call records. To do this, you cannot declare `SubscriberRec-BSF` as an undifferentiated group of 17 characters, as in Listing 14-1. Instead, you isolate the `ServiceType` character position so that you can monitor it with the condition name `VoiceCall`. Because you never refer to `ServiceType` in the `PROCEDURE DIVISION`, you do not explicitly name it but instead give it the generic name `FILLER`.

Using an INPUT PROCEDURE to Modify Records

In addition to selecting which records to send to be sorted, you can also use an `INPUT PROCEDURE` to modify the records before releasing them to the sort process. Suppose the specification for the Universal Telecoms Monthly Report is changed again. Now you are now required to count the *number of calls made* and the *number of texts sent* by each subscriber. Because sorting is a slow, disk-based process, every effort should be made to reduce the amount of data that has to be sorted. The `ServiceCost` data item is not required to produce the report, so you do not need to include it in the records sent to the work file. You can use an `INPUT PROCEDURE` to modify the input record so that only the required data items are submitted to the `SORT`.

Listing 14-3 implements the specification change, and Figure 14-6 shows how the `INPUT PROCEDURE` sits between the input file and the sort process to modify the records before they are released to the work file.

Listing 14-3. Using an `INPUT PROCEDURE` to Modify the Record Structure

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing14-3.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.

```

```
SELECT WorkFile ASSIGN TO "WORK.TMP".
```

```
SELECT BillableServicesFile ASSIGN TO "Listing14-3.dat"
      ORGANIZATION LINE SEQUENTIAL.
```

```
SELECT SortedSubscriberFile ASSIGN TO "Listing14-3.Srt"
      ORGANIZATION LINE SEQUENTIAL.
```

```
SELECT PrintFile ASSIGN TO "Listing14-3.prn"
      ORGANIZATION LINE SEQUENTIAL.
```

```
DATA DIVISION.
```

```
FILE SECTION.
```

```
FD BillableServicesFile.
```

```
01 SubscriberRec-BSF.
```

```
88 EndOfBillableServicesFile VALUE HIGH-VALUES.
```

```
02 SubscriberId-BSF PIC 9(10).
```

```
02 ServiceType-BSF PIC 9.
```

```
02 FILLER PIC X(6).
```

```
SD WorkFile.
```

```
01 WorkRec.
```

```
02 SubscriberId-WF PIC 9(10).
```

```
02 ServiceType-WF PIC 9.
```

```
FD SortedSubscriberFile.
```

```
01 SubscriberRec.
```

```
88 EndOfCallsFile VALUE HIGH-VALUES.
```

```
02 SubscriberId PIC 9(10).
```

```
02 ServiceType PIC 9.
```

```
88 VoiceCall VALUE 2.
```

```
FD PrintFile.
```

```
01 PrintRec PIC X(40).
```

```
WORKING-STORAGE SECTION.
```

```
01 CallsTotal PIC 9(4).
```

```
01 TextsTotal PIC 9(5).
```

```
01 ReportHeader PIC X(33) VALUE "Universal Telecoms Monthly Report".
```

```
01 SubjectHeader PIC X(31) VALUE "SubscriberId Calls Texts".
```

```
01 SubscriberLine.
```

```
02 PrnSubscriberId PIC 9(10).
```

```
02 FILLER PIC X(6) VALUE SPACES.
```

```
02 PrnCallsTotal PIC Z,ZZ9.
```

```
02 FILLER PIC X(4) VALUE SPACES.
```

```
02 PrnTextsTotal PIC ZZ,ZZ9.
```

```
01 PrevSubscriberId      PIC 9(10).
```

```
PROCEDURE DIVISION.
```

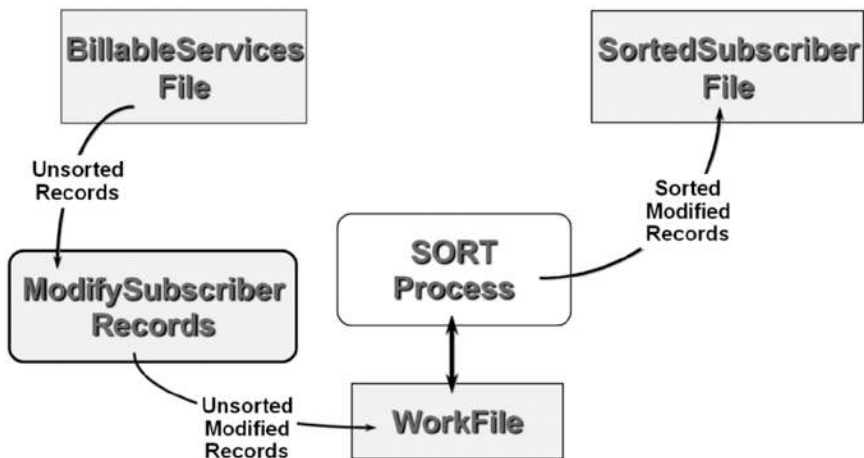
```
Begin.
```

```
  SORT WorkFile ON ASCENDING KEY SubscriberId-WF
    INPUT PROCEDURE IS ModifySubscriberRecords
      GIVING SortedSubscriberFile
  OPEN OUTPUT PrintFile
  OPEN INPUT SortedSubscriberFile
  WRITE PrintRec FROM ReportHeader AFTER ADVANCING PAGE
  WRITE PrintRec FROM SubjectHeader AFTER ADVANCING 1 LINE

  READ SortedSubscriberFile
    AT END SET EndOfCallsFile TO TRUE
  END-READ
  PERFORM UNTIL EndOfCallsFile
    MOVE SubscriberId TO PrevSubscriberId, PrnSubscriberId
    MOVE ZEROS TO CallsTotal, TextsTotal
    PERFORM UNTIL SubscriberId NOT EQUAL TO PrevSubscriberId
      IF VoiceCall ADD 1 TO CallsTotal
      ELSE ADD 1 TO TextsTotal
    END-IF
    READ SortedSubscriberFile
      AT END SET EndOfCallsFile TO TRUE
    END-READ
  END-PERFORM
  MOVE CallsTotal TO PrnCallsTotal
  MOVE TextsTotal TO PrnTextsTotal
  WRITE PrintRec FROM SubscriberLine AFTER ADVANCING 1 LINE
  END-PERFORM
  CLOSE SortedSubscriberFile, PrintFile
  STOP RUN.
```

```
ModifySubscriberRecords.
```

```
  OPEN INPUT BillableServicesFile
  READ BillableServicesFile
    AT END SET EndOfBillableServicesFile TO TRUE
  END-READ
  PERFORM UNTIL EndOfBillableServicesFile
    MOVE SubscriberId-BSF TO SubscriberId-WF
    MOVE ServiceType-BSF TO ServiceType-WF
    RELEASE WorkRec
    READ BillableServicesFile
      AT END SET EndOfBillableServicesFile TO TRUE
    END-READ
  END-PERFORM
  CLOSE BillableServicesFile.
```



```

SORT WorkFile ON ASCENDING KEY SubscriberId-WF
INPUT PROCEDURE IS ModifySubscriberRecords
GIVING SortedSubscriberFile
  
```

Figure 14-6. Using an INPUT PROCEDURE to modify the subscriber records

As before, the record declarations are of some interest. For reasons of clarity, I chose to explicitly identify the data items in `SubscriberRec-BSF` that are being preserved in `WorkRec`. You may, on consideration of the character positions, wonder if you could simply move `SubscriberRec-BSF` to `WorkRec` and let `MOVE` truncation eliminate the unwanted data. If those are your thoughts, then you are correct. You could save yourself some typing by doing that.

Feeding SORT from the Keyboard

As I mentioned earlier, and as you can see from Figure 14-5 and Figure 14-6, when an INPUT PROCEDURE is used, it is responsible for supplying records to the sort process. The records supplied can come from anywhere. They can come from a file, a table, or (as in this example) directly from the user.

The program in Listing 14-4 gets records directly from the user, sorts them on ascending `StudentId`, and then outputs them to `SortedStudentFile`. The diagram in Figure 14-7 represents the process. Note that the sort process only sorts the file when the INPUT PROCEDURE has finished.

Listing 14-4. Feeding SORT from the Keyboard

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Lsiting14-4.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT StudentFile ASSIGN TO "Listing14-4.DAT"
        ORGANIZATION IS LINE SEQUENTIAL.

    SELECT WorkFile ASSIGN TO "WORK.TMP".
  
```

DATA DIVISION.

FILE SECTION.

FD StudentFile.

01 StudentDetails PIC X(32).

* The StudentDetails record has the description shown below.

* But in this program I don't actually need to refer to any

* of the items in the record and so have described it as PIC X(32)

* 01 StudentDetails

* 02 StudentId PIC 9(8).

* 02 StudentName.

* 03 Surname PIC X(8).

* 03 Initials PIC XX.

* 02 DateOfBirth.

* 03 YOBirth PIC 9(4).

* 03 MOBirth PIC 9(2).

* 03 DOBirth PIC 9(2).

* 02 CourseCode PIC X(5).

* 02 Gender PIC X.

SD WorkFile.

01 WorkRec.

88 EndOfInput VALUE SPACES.

02 FILLER PIC X(8).

02 SurnameWF PIC X(8).

02 FILLER PIC X(16).

PROCEDURE DIVISION.

Begin.

SORT WorkFile ON ASCENDING KEY SurnameWF

INPUT PROCEDURE IS GetStudentDetails

GIVING StudentFile

STOP RUN.

GetStudentDetails.

DISPLAY "Use the template below"

DISPLAY "to enter your details."

DISPLAY "Enter spaces to end."

DISPLAY "NNNNNNNNSSSSSSSIYYYYMMDDCCCCCG".

ACCEPT WorkRec.

PERFORM UNTIL EndOfInput

RELEASE WorkRec

ACCEPT WorkRec

END-PERFORM.

Listing 14-4 Input

Use the template below
to enter your details.
Enter spaces to end.

```
NNNNNNNNSSSSSSSIYYYYMMDDCCCCCG
12345678Molloy DJ19940107LM051M
13456789Ryan TT19951213LM051F
12986378Smith AJ19910221LM069M
12764523Luskin WA19951111LM051M
113498720'Brien RR19941010LM110F
13246454Sheridan
```

SortedStudentFile

```
13456723Andrews DD19941212LM110M
12111234Cullen MM19920314LM114M
12764523Luskin WA19951111LM051M
12345678Molloy DJ19940107LM051M
113498720'Brien RR19941010LM110F
13456789Ryan TT19951213LM051F
13246454SheridanVV19920918LM069F
12986378Smith AJ19910221LM069M
12987786WilliamsRR19920817LM051M
```

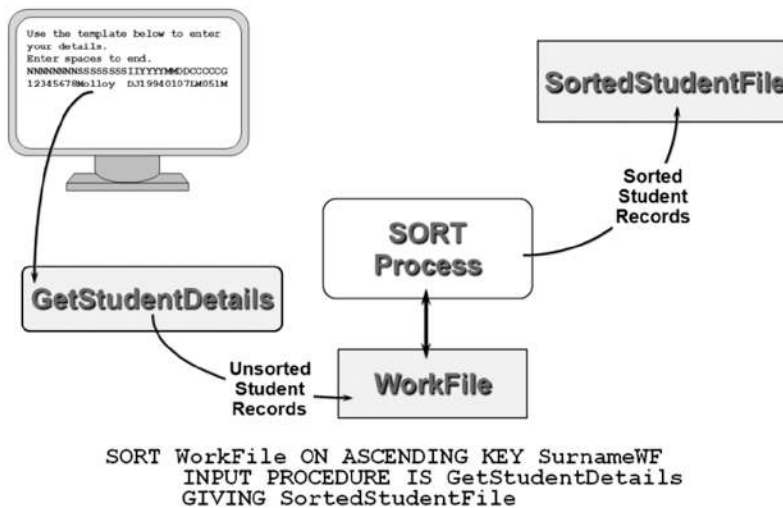


Figure 14-7. Supplying SORT records directly from the user

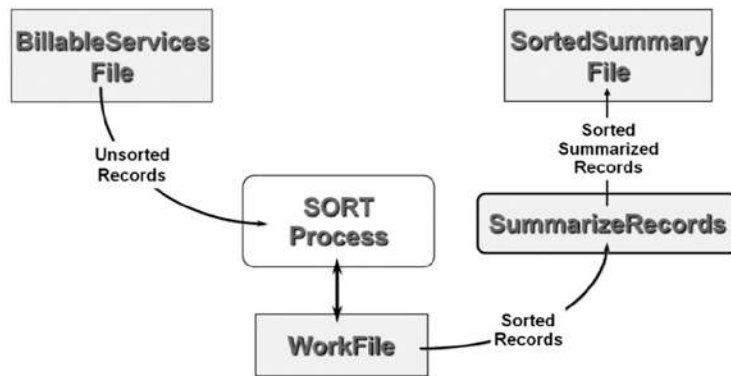
OUTPUT PROCEDURE

An INPUT PROCEDURE allows you to filter, or alter, records before they are supplied to the sort process. This can substantially reduce the amount of data that has to be sorted. An OUTPUT PROCEDURE has no such advantage. An OUTPUT PROCEDURE only executes when the sort process has already sorted the file.

Nevertheless, an OUTPUT PROCEDURE is useful when you don't need to preserve the sorted file. For instance, if you are sorting records to produce a one-off report, you can use an OUTPUT PROCEDURE to create the report directly, without first having to create a file containing the sorted records. This saves you the effort of having to define an unnecessary file. An OUTPUT PROCEDURE is also useful when you want to alter the structure of the records written to the sorted file. For instance, if you were required to produce a summary file from the sorted records, you could use an OUTPUT PROCEDURE to summarize the sorted records and then write each of the summary records to summary file. The resulting file would contain summary records, rather than the detail records contained in the unsorted file.

How the OUTPUT PROCEDURE Works

A simple SORT takes the records from the unsorted input file, sorts them, and then outputs them to the sorted output file. As Figure 14-8 shows, the OUTPUT PROCEDURE breaks the connection between the SORT and the output file. The OUTPUT PROCEDURE uses the RETURN verb to retrieve sorted records from the work file. It may then send the retrieved records to the output file, but it doesn't have to. Once the OUTPUT PROCEDURE has retrieved the sorted records from the work file, it can do whatever it likes with them. For instance, it can summarize them, alter them, put them into a table, display them on the screen, or send them to the output file. When the OUTPUT PROCEDURE does send the sorted records to an output file, it can control which records, and what type of records, appear in the file.



```

SORT WorkFile ON ASCENDING KEY SubscriberId-WF
INPUT PROCEDURE IS SummarizeRecords
GIVING SortedSummaryFile
  
```

Figure 14-8. Using an OUTPUT PROCEDURE TO summarize records

Creating an OUTPUT PROCEDURE

When you use an OUTPUT PROCEDURE, you must use the RETURN verb to retrieve records from the work file associated with the SORT. RETURN is a special verb used only in OUTPUT PROCEDURES. It is the equivalent of the READ verb and works in a similar way. The metalanguage for the RETURN verb is given in Figure 14-9.

```

RETURN SDFilename RECORD [INTO Identifier]
    AT END StatementBlock
END - RETURN
  
```

Figure 14-9. Metalanguage for the RETURN verb

Example 4-4 shows an operational template for an OUTPUT PROCEDURE that gets records from the work file and writes them to an output file. Notice that the work file is not opened in the OUTPUT PROCEDURE; the work file is automatically opened by the SORT.

Example 14-4. OUTPUT PROCEDURE File-Processing Template

```

OPEN OUTPUT OutFile
RETURN SDWorkFile RECORD
PERFORM UNTIL TerminatingCondition
    Setup OutRec
    WRITE OutRec
    RETURN SDWorkFile RECORD
END-PERFORM
CLOSE OutFile
  
```

Using an OUTPUT PROCEDURE to Produce a Summary File

The example in Listing 14-5 returns to the specification for the Universal Telecoms Monthly Report. However, the specification has been changed again. This time, instead of producing a report, you are required to produce a summary file. The summary file is a sequential file, ordered on ascending SubscriberId. Each subscriber record in the summary file summarizes all the records in BillableServicesFile for that subscriber. Each record in the file has the following description:

Field	Type	Length	Value
SubscriberId	9	10	-
CostOfTexts	9	6	0.10-9999.99
CostOfCalls	9	8	0.10-999999.99

Listing 14-5. Using an OUTPUT PROCEDURE to Create a Summary File

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing14-5.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT WorkFile ASSIGN TO "WORK.TMP".

    SELECT BillableServicesFile ASSIGN TO "Listing14-5.dat"
        ORGANIZATION LINE SEQUENTIAL.

    SELECT SortedSummaryFile ASSIGN TO "Listing14-5.Srt"
        ORGANIZATION LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD BillableServicesFile.
01 SubscriberRec-BSF      PIC X(17).

SD WorkFile.
01 WorkRec.
    88 EndOfWorkFile      VALUE HIGH-VALUES.
    02 SubscriberId-WF    PIC 9(10).
    02 FILLER              PIC 9.
        88 TextCall       VALUE 1.
        88 VoiceCall      VALUE 2.
    02 ServiceCost-WF     PIC 9(4)V99.

FD SortedSummaryFile.
01 SummaryRec.
    02 SubscriberId       PIC 9(10).
    02 CostOfTexts        PIC 9(4)V99.
    02 CostOfCalls        PIC 9(6)V99.
```


PROCEDURE DIVISION.

Begin.

```

    SORT WorkFile ON ASCENDING KEY SubscriberId-WF
      USING BillableServicesFile
      OUTPUT PROCEDURE IS CreateSummaryFile
    STOP RUN.

```

CreateSummaryFile.

```

    OPEN OUTPUT SortedSummaryFile
    RETURN WorkFile
    AT END SET EndOfWorkFile TO TRUE
    END-RETURN
    PERFORM UNTIL EndOfWorkFile
      MOVE ZEROS TO CostOfTexts, CostOfCalls
      MOVE SubscriberId-WF TO SubscriberId
      PERFORM UNTIL SubscriberId-WF NOT EQUAL TO SubscriberId
        IF VoiceCall
          ADD ServiceCost-WF TO CostOfCalls
        ELSE
          ADD ServiceCost-WF TO CostOfTexts
        END-IF
      RETURN WorkFile
      AT END SET EndOfWorkFile TO TRUE
    END-RETURN
    END-PERFORM
    WRITE SummaryRec
  END-PERFORM
  CLOSE SortedSummaryFile.

```

Figure 14-8 illustrates the process of producing the summary file. The SORT takes records from `BillableServicesFile` and sorts them, and then the `OUTPUT PROCEDURE` summarizes them and writes the summary records to `SortedSummaryFile`.

The data items in `BillableServicesFile` are not referred to in the program and so are not explicitly defined, although the storage they require is reserved (`PIC X(17)`). For reasons of brevity, and because it would obscure the core logic, the program does not check the data for validity.

Some Interesting Programs

You have seen how you can use an `INPUT PROCEDURE` to process records before they are sent to a SORT and how you can use an `OUTPUT PROCEDURE` to process the sorted records. But each was used in isolation. You can achieve some interesting results by using them in concert.

Sorting Student Records into Date-of-Entry Order

Suppose there exists an unordered sequential file of student records, and each record in the file has the following description:

Field	Type	Length	Value
StudentId	9	7	YYxxxxx
CourseCode	9	5	LMxxxx

StudentId is a number that consists of two digits representing the year of entry followed by six other digits. Write a program to sort StudentFile on the “real” ascending StudentId.

This specification presents an interesting issue. It says that the file should be ordered on the “real” ascending StudentId. This means the IDs of students who entered the university after the year 2000 should appear after those of students who entered the university before 2000. This is a problem because you can't just sort the records in ascending StudentId order, as is demonstrated in Figure 14-10.

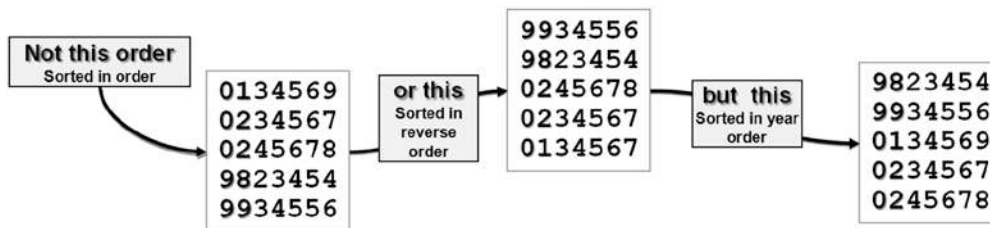


Figure 14-10. Showing the real StudentId sort order

How can this be done? Listing 14-6 solves the problem by using an INPUT PROCEDURE to alter StudentId to add the millennium to the date-of-entry part. Then the altered records are sorted, and the OUTPUT PROCEDURE strips off the millennium digits.

Listing 14-6. Using INPUT PROCEDURE and OUTPUT PROCEDURE in Concert

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing14-6.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT UnsortedStudentsFile ASSIGN TO "Listing14-6.DAT"
        ORGANIZATION IS LINE SEQUENTIAL.

    SELECT WorkFile ASSIGN TO "Workfile.tmp".

    SELECT SortedStudentsFile ASSIGN TO "Listing14-6.srt"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD UnsortedStudentsFile.
```

```

01 StudentRecUF.
   88 EndOfUnsortedFile VALUE HIGH-VALUES.
   02 StudentIdUF.
       03 MillenniumUF PIC 99.
       03 FILLER PIC 9(5).
   02 RecBodyUF PIC X(14).

```

```
SD WorkFile.
```

```

01 StudentRecWF.
   88 EndOfWorkFile VALUE HIGH-VALUES.
   02 FullStudentIdWF.
       03 MillenniumWF PIC 99.
       03 StudentIdWF PIC 9(7).
   02 RecBodyWF PIC X(14).

```

```
FD SortedStudentsFile.
```

```

01 StudentRecSF.
   02 StudentIdSF PIC 9(7).
   02 RecBodySF PIC X(14).

```

```
PROCEDURE DIVISION.
```

```
Begin.
```

```

    SORT WorkFile ON ASCENDING KEY FullStudentIdWF
        INPUT PROCEDURE IS AddInMillennium
        OUTPUT PROCEDURE IS RemoveMillennium
    STOP RUN.

```

```
AddInMillennium.
```

```

OPEN INPUT UnsortedStudentsFile
READ UnsortedStudentsFile
    AT END SET EndOfUnsortedFile TO TRUE
END-READ
PERFORM UNTIL EndOfUnsortedFile
    MOVE RecBodyUF TO RecBodyWF
    MOVE StudentIDUF TO StudentIdWF
    IF MillenniumUF < 70
        MOVE 20 TO MillenniumWF
    ELSE
        MOVE 19 TO MillenniumWF
    END-IF
RELEASE StudentRecWF
READ UnsortedStudentsFile
    AT END SET EndOfUnsortedFile TO TRUE
END-READ
END-PERFORM
CLOSE UnsortedStudentsFile.

```

```
RemoveMillennium.
```

```

OPEN OUTPUT SortedStudentsFile
RETURN WorkFile
    AT END SET EndOfWorkFile TO TRUE

```

```

END-RETURN
PERFORM UNTIL EndOfWorkFile
  MOVE RecBodyWF TO RecBodySF
  MOVE StudentIdWF TO StudentIdSF
  WRITE StudentRecSF
  RETURN WorkFile
  AT END SET EndOfWorkFile TO TRUE
END-RETURN
END-PERFORM
CLOSE SortedStudentsFile.

```

Sorting Tables

Versions of COBOL before ISO 2002 did not allow you to apply a SORT to a table. But it was possible to work around this restriction by using an INPUT PROCEDURE to release table elements to the work file and an OUTPUT PROCEDURE to get the sorted element-records from the work file and put them back into the table. The process is illustrated in Figure 14-11; see Listing 14-7.

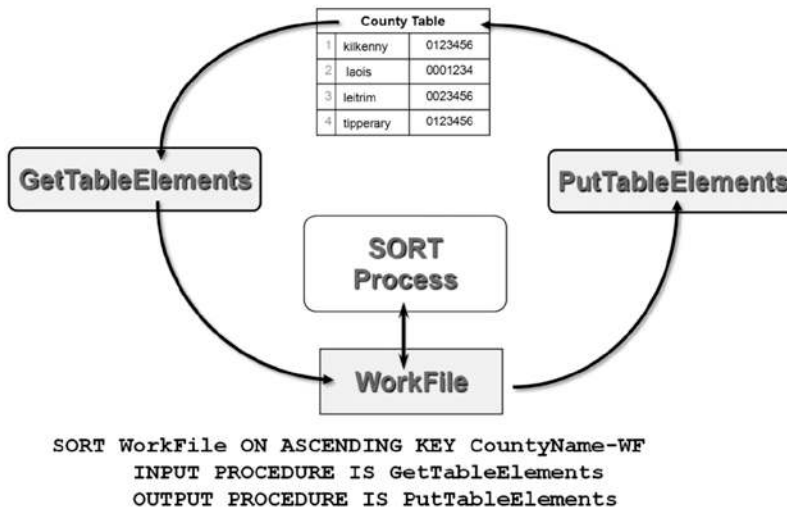


Figure 14-11. Using INPUT PROCEDURE and OUTPUT PROCEDURE to sort a table

Listing 14-7. Sorting a Table Using INPUT PROCEDURE and OUTPUT PROCEDURE

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing14-7.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 CountyTable.
  02 TableValues.
    03 FILLER PIC X(16) VALUE "kilkenny 0080421".
    03 FILLER PIC X(16) VALUE "laois 0058732".
    03 FILLER PIC X(16) VALUE "leitrim 0025815".
    03 FILLER PIC X(16) VALUE "tipperary0140281".
    03 FILLER PIC X(16) VALUE "waterford0101518".

```

```

03 FILLER PIC X(16) VALUE "westmeath0072027".
03 FILLER PIC X(16) VALUE "carlow 0045845".
03 FILLER PIC X(16) VALUE "wicklow 0114719".
03 FILLER PIC X(16) VALUE "cavan 0056416".
03 FILLER PIC X(16) VALUE "clare 0103333".
03 FILLER PIC X(16) VALUE "meath 0133936".
03 FILLER PIC X(16) VALUE "monaghan 0052772".
03 FILLER PIC X(16) VALUE "offaly 0063702".
03 FILLER PIC X(16) VALUE "roscommon0053803".
03 FILLER PIC X(16) VALUE "sligo 0058178".
03 FILLER PIC X(16) VALUE "cork 0448181".
03 FILLER PIC X(16) VALUE "donegal 0137383".
03 FILLER PIC X(16) VALUE "dublin 1122600".
03 FILLER PIC X(16) VALUE "galway 0208826".
03 FILLER PIC X(16) VALUE "wexford 0116543".
03 FILLER PIC X(16) VALUE "kerry 0132424".
03 FILLER PIC X(16) VALUE "kildare 0163995".
03 FILLER PIC X(16) VALUE "limerick 0175529".
03 FILLER PIC X(16) VALUE "longford 0031127".
03 FILLER PIC X(16) VALUE "louth 0101802".
03 FILLER PIC X(16) VALUE "mayo 0117428".
02 FILLER REDEFINES TableValues.
03 CountyDetails OCCURS 26 TIMES
   INDEXED BY Cidx.
   04 CountyName PIC X(9).
   04 CountyPop PIC 9(7).

```

```
01 PrnCountyPop PIC Z,ZZZ,ZZ9.
```

```
PROCEDURE DIVISION.
```

```
Begin.
```

```

DISPLAY "County name order"
SORT CountyDetails ON ASCENDING KEY CountyName
PERFORM DisplayCountyTotals
   VARYING Cidx FROM 1 BY 1 UNTIL Cidx GREATER

```

```
THAN 26.
```

```

DISPLAY SPACES
DISPLAY "County population order"
SORT CountyDetails ON DESCENDING KEY CountyPop
PERFORM DisplayCountyTotals
   VARYING Cidx FROM 1 BY 1 UNTIL Cidx GREATER

```

```
THAN 26.
```

```
STOP RUN.
```

```
DisplayCountyTotals.
```

```

MOVE CountyPop(Cidx) TO PrnCountyPop
DISPLAY CountyName(Cidx) " is " PrnCountyPop

```

LISTING 14-7 Output

County name	order
carlow	is 45,845
cavan	is 56,416
clare	is 103,333
cork	is 448,181
donegal	is 137,383
dublin	is 1,122,600
galway	is 208,826
kerry	is 132,424
kildare	is 163,995
kilkenny	is 80,421
laois	is 58,732
leitrim	is 25,815
limerick	is 175,529
longford	is 31,127
louth	is 101,802
mayo	is 117,428
meath	is 133,936
monaghan	is 52,772
offaly	is 63,702
roscommon	is 53,803
sligo	is 58,178
tipperary	is 140,281
waterford	is 101,518
westmeath	is 72,027
wexford	is 116,543
wicklow	is 114,719

County population	order
dublin	is 1,122,600
cork	is 448,181
galway	is 208,826
limerick	is 175,529
kildare	is 163,995
tipperary	is 140,281
donegal	is 137,383
meath	is 133,936
kerry	is 132,424
mayo	is 117,428
wexford	is 116,543
wicklow	is 114,719
clare	is 103,333
louth	is 101,802
waterford	is 101,518
kilkenny	is 80,421
westmeath	is 72,027
offaly	is 63,702
laois	is 58,732
sligo	is 58,178
cavan	is 56,416
roscommon	is 53,803
monaghan	is 52,772
carlow	is 45,845
longford	is 31,127
leitrim	is 25,815

Sorting Tables: ISO 2002 Changes

Listing 14-7 shows how to sort a table using an INPUT PROCEDURE and an OUTPUT PROCEDURE. The problem with this solution is the work file. The sort operation, being bound to a file on backing storage, is comparatively slow. Sorting the table would be faster if it could be done wholly in memory.

Sorting a table directly in memory is exactly what the ISO 2002 version of COBOL now allows. The metalanguage for this SORT format is given in Figure 14-12, and Listing 14-8 shows how you can use this format to sort the County table from Listing 14-7.

$$\text{SORT } \text{TableName} \left\{ \text{ON } \left\{ \begin{array}{l} \text{ASCENDING} \\ \text{DESCENDING} \end{array} \right\} \text{ KEY } \{ \text{TableElement} \} \dots \right\} \dots$$

[WITH DUPLICATES IN ORDER]

$$\left[\text{COLLATING SEQUENCE } \left\{ \begin{array}{l} \text{IS AlphabetName1 [AlphabetName2]} \\ \text{FOR ALPHANUMERIC IS AlphabetName1} \\ \text{FOR NATIONAL IS AlphabetName2} \end{array} \right\} \right]$$

Figure 14-12. Metalanguage for the ISO 2002 version of SORT

Listing 14-8. Applying SORT Directly to a Table

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing14-8.
*> ISO 2002 Applying the SORT to a table
DATA DIVISION.
WORKING-STORAGE SECTION.
01 CountyTable.
   02 TableValues.
      03 FILLER PIC X(16) VALUE "kilkenny 0080421".
      03 FILLER PIC X(16) VALUE "laois 0058732".
      03 FILLER PIC X(16) VALUE "leitrim 0025815".
      03 FILLER PIC X(16) VALUE "tipperary0140281".
      03 FILLER PIC X(16) VALUE "waterford0101518".
      03 FILLER PIC X(16) VALUE "westmeath0072027".
      03 FILLER PIC X(16) VALUE "carlow 0045845".
      03 FILLER PIC X(16) VALUE "wicklow 0114719".
      03 FILLER PIC X(16) VALUE "cavan 0056416".
      03 FILLER PIC X(16) VALUE "clare 0103333".
      03 FILLER PIC X(16) VALUE "meath 0133936".
      03 FILLER PIC X(16) VALUE "monaghan 0052772".
      03 FILLER PIC X(16) VALUE "offaly 0063702".
      03 FILLER PIC X(16) VALUE "roscommon0053803".
      03 FILLER PIC X(16) VALUE "sligo 0058178".
      03 FILLER PIC X(16) VALUE "cork 0448181".
      03 FILLER PIC X(16) VALUE "donegal 0137383".
      03 FILLER PIC X(16) VALUE "dublin 1122600".
      03 FILLER PIC X(16) VALUE "galway 0208826".
      03 FILLER PIC X(16) VALUE "wexford 0116543".
      03 FILLER PIC X(16) VALUE "kerry 0132424".
      03 FILLER PIC X(16) VALUE "kildare 0163995".
      03 FILLER PIC X(16) VALUE "limerick 0175529".
```

```

    03 FILLER PIC X(16) VALUE "longford 0031127".
    03 FILLER PIC X(16) VALUE "louth 0101802".
    03 FILLER PIC X(16) VALUE "mayo 0117428".
02 FILLER REDEFINES TableValues.
    03 CountyDetails OCCURS 26 TIMES
      INDEXED BY Cidx.
      04 CountyName PIC X(9).
      04 CountyPop PIC 9(7).

01 PrnCountyPop PIC Z,ZZZ,ZZ9.

PROCEDURE DIVISION.
Begin.
  DISPLAY "County name order"
  SORT CountyDetails ON ASCENDING KEY CountyName
  PERFORM DisplayCountyTotals
    VARYING Cidx FROM 1 BY 1 UNTIL Cidx GREATER THAN 26.

  DISPLAY SPACES
  DISPLAY "County population order"
  SORT CountyDetails ON ASCENDING KEY CountyPop
  PERFORM DisplayCountyTotals
    VARYING Cidx FROM 1 BY 1 UNTIL Cidx GREATER THAN 26.

  STOP RUN.

DisplayCountyTotals.
  MOVE CountyPop(Cidx) TO PrnCountyPop
  DISPLAY CountyName(Cidx) " is " PrnCountyPop.

```

■ **Note** For full details, read your implementer manual.

Merging Files

It is often useful to combine two or more files into a single large file. If the files are unordered, this is easy to accomplish because you can simply append the records in one file to the end of the other. But if the files are ordered, the task is somewhat more complicated—especially if there are more than two files—because you must preserve the ordering in the combined file.

In COBOL, instead of having to write special code every time you want to merge files, you can use the MERGE verb. MERGE takes a number of files, all ordered on the same key values, and combines them based on those key values. The combined file is then sent to an output file or an OUTPUT PROCEDURE.

MERGE Verb

The metalanguage for the MERGE verb is given in Figure 14-13. It should be obvious from the metalanguage that MERGE shares many of same declarations required for SORT. Just like SORT, MERGE uses a temporary work file that must be defined using an SD entry in the FILE SECTION. Also just as with SORT, the KEY field (on which the files are merged) must be a data item declared in the work file. And just as with SORT, you can use an OUTPUT PROCEDURE to get records from the work file before sending them to their ultimate destination. Unlike with SORT, however, no INPUT PROCEDURE is permitted.

$$\begin{array}{l} \text{MERGE } \underline{\text{SDWorkFileName}} \left\{ \text{ON } \left\{ \begin{array}{l} \underline{\text{ASCENDING}} \\ \underline{\text{DESCENDING}} \end{array} \right\} \text{KEY } \{ \text{MergeKeyIdentifier} \} \dots \right\} \dots \\ \left[\underline{\text{COLLATINGSEQUENCEIS}} \text{ AlphabetName} \right] \\ \underline{\text{USING}} \text{ InFileName1 } \{ \text{InFileName2} \} \dots \\ \left\{ \begin{array}{l} \underline{\text{OUTPUTPROCEDUREIS}} \text{ ProcedureName } \left\{ \begin{array}{l} \underline{\text{THRU}} \\ \underline{\text{THROUGH}} \end{array} \right\} \text{ ProcedureName} \\ \underline{\text{GIVING}} \{ \text{MergedFileName} \} \dots \end{array} \right\} \end{array}$$

Figure 14-13. Metalanguage for the MERGE verb

MERGE Notes

You should consider the following when using MERGE:

- The results of the MERGE verb are predictable only when the records in the USING files are ordered as described in the KEY clause associated with the MERGE. For instance, if the MERGE statement has an ON DESCENDING KEY StudentId clause, then all the USING files must be ordered on descending StudentId.
- As with SORT, SDWorkFileName is the name of a temporary file, with an SD entry in the FILE SECTION, SELECT and ASSIGN entries in the INPUT-OUTPUT SECTION, and an organization of RECORD SEQUENTIAL.
- Each MergeKeyIdentifier identifies a field in the record of the work file. The merged files are ordered on this key field(s).
- When more than one MergeKeyIdentifier is specified, the keys decrease in significance from left to right (the leftmost key is most significant, and the rightmost is least significant).
- InFileName and MergedFileName are the names of the input file to be merged and the resulting combined file produced by the MERGE, respectively. These files are automatically opened by the MERGE. When the MERGE executes, they must not be already open.
- AlphabetName is an alphabet name defined in the SPECIAL-NAMES paragraph of the ENVIRONMENT DIVISION. This clause is used to select the character set the SORT verb uses for collating the records in the file. The character set may be STANDARD-1 (ASCII), STANDARD-2 (ISO 646), NATIVE (may be defined by the system to be ASCII or EBCDIC; see your implementer manual), or user defined.
- MERGE can use an OUTPUT PROCEDURE and the RETURN verb to get merged records from SDWorkFileName.
- The OUTPUT PROCEDURE executes only after the files have been merged and must contain at least one RETURN statement to get the records from SortFile.

Merging Province Sales Files

Listing 14-9 is an example program that uses MERGE to combine four sequential files, each ordered on ascending ProductCode. The program is based on the following specification.

Listing 14-9. Merging ProvinceSales Files and Producing a Sales Summary File

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing14-9.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT UlsterSales    ASSIGN TO "Listing14-9ulster.dat"
        ORGANIZATION IS LINE SEQUENTIAL.

    SELECT ConnachtSales  ASSIGN TO "Listing14-9connacht.dat"
        ORGANIZATION IS LINE SEQUENTIAL.

    SELECT MunsterSales   ASSIGN TO "Listing14-9munster.dat"
        ORGANIZATION IS LINE SEQUENTIAL.

    SELECT LeinsterSales  ASSIGN TO "Listing14-9leinster.dat"
        ORGANIZATION IS LINE SEQUENTIAL.

    SELECT SummaryFile    ASSIGN TO "Listing14-9.sum"
        ORGANIZATION IS LINE SEQUENTIAL.

    SELECT WorkFile       ASSIGN TO "WORK.TMP".

DATA DIVISION.
FILE SECTION.
FD UlsterSales.
01 FILLER                PIC X(12).

FD ConnachtSales.
01 FILLER                PIC X(12).

FD MunsterSales.
01 FILLER                PIC X(12).

FD LeinsterSales.
01 FILLER                PIC X(12).

FD SummaryFile.
01 SummaryRec.
02 ProductCode-SF       PIC X(6).
02 TotalSalesValue     PIC 9(6)V99.
```

```

SD WorkFile.
01 WorkRec.
   88 EndOfWorkfile      VALUE HIGH-VALUES.
   02 ProductCode-WF     PIC X(6).
   02 ValueOfSale-WF     PIC 9999V99.

PROCEDURE DIVISION.
Begin.
  MERGE WorkFile ON ASCENDING KEY ProductCode-WF
    USING UlsterSales, ConnachtSales, MunsterSales, LeinsterSales
    OUTPUT PROCEDURE IS SummarizeProductSales

  STOP RUN.

SummarizeProductSales.
  OPEN OUTPUT SummaryFile
  RETURN WorkFile
    AT END SET EndOfWorkfile TO TRUE
  END-RETURN

  PERFORM UNTIL EndOfWorkFile
    MOVE ZEROS TO TotalSalesValue
    MOVE ProductCode-WF TO ProductCode-SF
    PERFORM UNTIL ProductCode-WF NOT EQUAL TO ProductCode-SF
      ADD ValueOfSale-WF TO TotalSalesValue
    RETURN WorkFile
      AT END SET EndOfWorkfile TO TRUE
    END-RETURN
  END-PERFORM
  WRITE SummaryRec
  END-PERFORM
  CLOSE SummaryFile.

```

Every month, the TrueValue head office receives a file from its branch in each of the four provinces of Ireland. Each file records the sales made in that province. A program is required that will combine these four files and, from them, produce a summary file that records the total value of the sales of each product sold by the company. The summary file must be ordered on ascending ProductCode. The record description for each of the four files is as follows:

Field	Type	Length	Value
ProductCode	X	6	-
ValueOfSale	9	6	0-9999.99

The record description for the summary file is shown next:

Field	Type	Length	Value
ProductCode	X	6	-
TotalValueOfSale	9	8	0-999999.99

PROGRAMMING EXERCISE 1: ANSWER

Because only foreign visitors are of interest, there is no point in sorting the entire file. An INPUT PROCEDURE is used to select only the records of visitors from foreign (non-Irish) countries. An OUTPUT PROCEDURE is used to create the report.

When you examine the fields of a GuestBookFile record, notice that, for the purposes of this report, GuestName and GuestComment are irrelevant. The only field you need for the report is the CountryName field. So in addition to selecting only foreign guests, the INPUT PROCEDURE alters the structure of the records supplied to the sort process. Because the new records are only 20 characters in size, rather than 80 characters, the amount of data that has to be sorted is substantially reduced.

Listing 14-10. Using an INPUT PROCEDURE to Modify and Filter the Records in the Input File

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing14-10.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT GuestBookFile
        ASSIGN TO "Listing14-10.Dat"
        ORGANIZATION IS LINE SEQUENTIAL.

    SELECT WorkFile
        ASSIGN TO "Work.Tmp".

    SELECT ForeignGuestReport
        ASSIGN TO "Listing14-10.rpt"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD GuestBookFile.
01 GuestRec.
    88 EndOfFile VALUE HIGH-VALUES.
    02 GuestNameGF PIC X(20).
    02 CountryNameGF PIC X(20).
    88 CountryIsIreland VALUE "IRELAND".
    02 GuestCommentGF PIC X(40).

SD WorkFile.
01 WorkRec.
    88 EndOfWorkFile VALUE HIGH-VALUES.
    02 CountryNameWF PIC X(20).

FD ForeignGuestReport.
01 PrintLine PIC X(38).
```

WORKING-STORAGE SECTION.

```

01 Heading1          PIC X(25)
   VALUE "          Foreign Guests Report".

01 Heading2.
  02 FILLER          PIC X(22) VALUE "Country".
  02 FILLER          PIC X(8)  VALUE "Visitors".

01 CountryLine.
  02 PrnCountryName  PIC X(20).
  02 PrnVisitorCount PIC BBBZZ,ZZ9.

01 ReportFooting    PIC X(27)
   VALUE "          ***** End of report *****".

01 VisitorCount     PIC 9(5).

```

PROCEDURE DIVISION.

```

Begin.
  SORT WorkFile ON ASCENDING CountryNameWF
    INPUT PROCEDURE IS SelectForeignGuests
    OUTPUT PROCEDURE IS PrintGuestsReport.

```

```

  STOP RUN.

```

PrintGuestsReport.

```

  OPEN OUTPUT ForeignGuestReport
  WRITE PrintLine FROM Heading1
    AFTER ADVANCING PAGE
  WRITE PrintLine FROM Heading2
    AFTER ADVANCING 1 LINES

  RETURN WorkFile
    AT END SET EndOfWorkfile TO TRUE
  END-RETURN
  PERFORM PrintReportBody UNTIL EndOfWorkfile

  WRITE PrintLine FROM ReportFooting
    AFTER ADVANCING 2 LINES
  CLOSE ForeignGuestReport.

```

PrintReportBody.

```

  MOVE CountryNameWF TO PrnCountryName
  MOVE ZEROS TO VisitorCount
  PERFORM UNTIL CountryNameWF NOT EQUAL TO PrnCountryName
    ADD 1 TO VisitorCount
  RETURN WorkFile
    AT END SET EndOfWorkfile TO TRUE
  END-RETURN
  END-PERFORM

```

```
MOVE VisitorCount TO PrnVisitorCount
WRITE PrintLine FROM CountryLine
  AFTER ADVANCING 1 LINE.
```

```
SelectForeignGuests.
OPEN INPUT GuestBookFile.
READ GuestBookFile
  AT END SET EndOfFile TO TRUE
END-READ
PERFORM UNTIL EndOfFile
  IF NOT CountryIsIreland
    MOVE CountryNameGF TO CountryNameWF
    RELEASE WorkRec
  END-IF
  READ GuestBookFile
  AT END SET EndOfFile TO TRUE
END-READ
END-PERFORM
CLOSE GuestBookFile.
```



String Manipulation

In many languages, string manipulation is achieved by using a library of string functions or, as in Java, the methods of a `String` class. COBOL also uses a library of string-manipulation functions, but most string manipulation is done using reference modification and the three string-handling verbs: `STRING`, `UNSTRING`, and `INSPECT`.

This chapter starts by examining the string-handling verbs. These verbs allow you to count and replace characters, and concatenate and split strings. You are then introduced to reference modification, which lets you treat any string as an array of characters. Finally, you learn about the intrinsic functions used for string and date manipulation.

The `INSPECT` Verb

The `INSPECT` verb has four formats;

- The first format is used for counting characters in a string.
- The second replaces a group of characters in a string with another group of characters.
- The third combines both operations in one statement.
- The fourth format converts each character in a set of characters to its corresponding character in another set of characters.

Before starting a formal examination of the `INSPECT` formats, let's get a feel for how the verb operates by looking at a short program (see Listing 15-1). The program accepts a line of text from the user and then counts and displays how many times each letter of the alphabet occurs in the text.

Listing 15-1. Finding the Number of Times Each Letter Occurs in a Line of Text

```
IDENTIFICATION DIVISION.  
PROGRAM-ID. Listing15-1.  
AUTHOR. Michael Coughlan.  
DATA DIVISION.  
WORKING-STORAGE SECTION.  
01 TextLine          PIC X(80).  
  
01 LowerCase        PIC X(26) VALUE "abcdefghijklmnopqrstuvwxy".  
  
01 UpperCase        VALUE "ABCDEFGHIJKLMNOPQRSTUVWXYZ".  
   02 Letter         PIC X OCCURS 26 TIMES.
```

```

01 idx          PIC 99.
01 LetterCount  PIC 99
01 PrnLetterCount PIC Z9.

```

```
PROCEDURE DIVISION.
```

```
Begin.
```

```

    DISPLAY "Enter text : " WITH NO ADVANCING
    ACCEPT TextLine
    INSPECT TextLine
        CONVERTING LowerCase TO UpperCase

```

```

    PERFORM VARYING idx FROM 1 BY 1 UNTIL idx > 26
        MOVE ZEROS TO LetterCount
        INSPECT TextLine TALLYING LetterCount FOR ALL Letter(idx)
        IF LetterCount > ZERO
            MOVE LetterCount TO PrnLetterCount
            DISPLAY "Letter " Letter(idx) " occurs " PrnLetterCount " times"
        END-IF
    END-PERFORM
STOP RUN.

```

Listing 15-1 output	
Enter text :	That time of year thou mayst in me behold
Letter A occurs	3 times
Letter B occurs	1 times
Letter D occurs	1 times
Letter E occurs	4 times
Letter F occurs	1 times
Letter H occurs	3 times
Letter I occurs	2 times
Letter L occurs	1 times
Letter M occurs	3 times
Letter N occurs	1 times
Letter O occurs	3 times
Letter R occurs	1 times
Letter S occurs	1 times
Letter T occurs	5 times
Letter U occurs	1 times
Letter Y occurs	2 times

The program gets a line of text from the user. It then uses `INSPECT . . CONVERTING` to convert all the characters to their uppercase equivalents.

The `UpperCase` data item in this program does double duty. It is used in `INSPECT CONVERTING` as an ordinary alphanumeric data item, but it is also defined as a 26-element prefilled table of letters. Using this table, the `PERFORM` loop supplies the letters one at a time to `INSPECT . . TALLYING`, which counts the number of times each letter occurs in `TextLine`. It stores the count in `LetterCount`. If the letter occurred in `TextLine`, then the count is displayed.

There are some interesting things to note about this program. First, since intrinsic functions were introduced in the ANS 85 version of COBOL, is it no longer necessary to use `INSPECT . . CONVERTING` to convert characters to uppercase. Nowadays you can use the `UPPER-CASE` function. This function has the added benefit that it can do the conversion without changing the original text. Second, you don't actually need to hold the letters of the alphabet as a table. Reference modification allows you to treat any alphanumeric data item as a table of characters. Listing 15-2 shows a version of the program that incorporates these modernizations.

Listing 15-2. Modernized Version of the Program in Listing 15-1

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing15-2.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 TextLine          PIC X(80).

01 Letters           PIC X(26) VALUE "ABCDEFGHIJKLMNOPQRSTUVWXYZ".

01 LetterPos         PIC 99.

01 LetterCount       PIC 99.

01 PrnLetterCount    PIC Z9.

```


PROCEDURE DIVISION.

Begin.

```

DISPLAY "Enter text : " WITH NO ADVANCING
ACCEPT TextLine
PERFORM VARYING LetterPos FROM 1 BY 1 UNTIL LetterPos > 26
  MOVE ZEROS TO LetterCount
  INSPECT FUNCTION UPPER-CASE(TextLine)
    TALLYING LetterCount FOR ALL Letters(LetterPos:1)
  IF LetterCount > ZERO
    MOVE LetterCount TO PrnLetterCount
    DISPLAY "Letter " Letters(LetterPos:1) " occurs " PrnLetterCount " times"
  END-IF
END-PERFORM
STOP RUN.

```

INSPECT .. TALLYING: Format 1

INSPECT .. TALLYING counts the number of occurrences of a character in a string. The metalanguage for this version of INSPECT is given in Figure 15-1.

INSPECT SourceStr*i* TALLYING

$$\left\{ \text{Counter\#}i \text{ FOR } \left\{ \begin{array}{l} \text{CHARACTERS} \left[\left\{ \begin{array}{l} \text{BEFORE} \\ \text{AFTER} \end{array} \right\} \text{INITIAL Delim}\$il \right] \dots \\ \left\{ \begin{array}{l} \text{ALL} \\ \text{LEADING} \end{array} \right\} \left\{ \text{Compare}\$il \left[\left\{ \begin{array}{l} \text{BEFORE} \\ \text{AFTER} \end{array} \right\} \text{INITIAL Delim}\$il \right] \dots \right\} \dots \end{array} \right. \right\} \dots \dots$$

Figure 15-1. Metalanguage for INSPECT .. TALLYING

This version of INSPECT works by scanning the source string SourceStr*i* from left to right, counting the occurrences of all characters or just a specified character:

- The behavior of INSPECT is modified by the LEADING, ALL, BEFORE, and AFTER phrases. An ALL, LEADING, or CHARACTERS phrase may only be followed by one BEFORE and one AFTER phrase.
- As indicated by the ellipsis after the final bracket, you can use a number of counters—each with its own modifying phrases—with an INSPECT .. TALLYING statement.
- If Compare*il* or Delim*il* is a figurative constant, it is one character in size.

Modifying Phrases

The operation of INSPECT is governed by the modifying phrases used. The meaning of these phrases is as follows:

BEFORE: Designates the characters to the left of the associated delimiter (Delim*il*) as valid. If the delimiter is not present in SourceStr*i*, then using the BEFORE phrase implies that all the characters are valid.

AFTER: Designates the characters to the right of the associated delimiter (Delim*il*) as valid. If the delimiter is not present in the SourceStr*i*, then using the AFTER phrase implies that there are no valid characters in the string.

ALL: Counts all Compare\$il characters from the first matching valid character to the first invalid one.

LEADING: Counts leading Compare\$il characters from the first matching valid character encountered to the first nonmatching or invalid character.

INSPECT ..TALLYING Examples

Example 15-1 shows some example INSPECT statements, and Listing 15-3 presents a small program. The program's task is to count the number of vowels and the number of consonants in a line of text entered by the user.

Example 15-1. Some INSPECT..TALLYING Example Statements

```
INSPECT TextLine TALLYING UnstrPtr FOR LEADING SPACES.
```

```
INSPECT TextLine TALLYING
    eCount FOR ALL "e" AFTER INITIAL "start"
        BEFORE INITIAL "end".
```

```
INSPECT TextLine TALLYING
    aCount FOR ALL "a"
    eCount FOR ALL "e"
    oCount FOR ALL "o"
```

```
INSPECT FUNCTION REVERSE(TextLine) TALLYING
    TrailingSpaces FOR LEADING SPACES
COMPUTE StrLength = FUNCTION LENGTH(TextLine) - TrailingSpaces
```

Listing 15-3. Counting Vowels and Consonants

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing15-3.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 TextLine          PIC X(80).

01 VowelCount        PIC 99 VALUE ZERO.

01 ConsonantCount    PIC 99 VALUE ZERO.

PROCEDURE DIVISION.
Begin.
    DISPLAY "Enter text : " WITH NO ADVANCING
    ACCEPT TextLine
    INSPECT FUNCTION UPPER-CASE(TextLine) TALLYING
        VowelCount FOR ALL "A" "E" "I" "O" "U"
        ConsonantCount FOR ALL
            "B" "C" "D" "F" "G" "H" "J" "K" "L" "M" "N" "P"
            "Q" "R" "S" "T" "V" "W" "X" "Y" "Z"

    DISPLAY "The line contains " VowelCount " vowels and "
        ConsonantCount " consonants."
STOP RUN.
```

Listing 15-3 output

```
Enter text : When to the Sessions of Sweet Silent thought
The line contains 13 vowels and 24 consonants.
```

Programmatic Detour

There are a number of ways to solve the problem of finding the number of vowels and consonants in a line of text. Although it is not strictly string manipulation, I'd like to explore an alternative solution to Listing 15-3 here, because it allows me to introduce an aspect of condition names that you have not seen before. In the solution in Listing 15-4, TextLine is defined as an array of characters. A PERFORM is used to step through the array and, at each character, test whether it is a vowel or a consonant; whichever it is, the PERFORM then increments the appropriate total. The interesting part is the way you discover whether the character is a vowel or a consonant.

You may not have realized that a condition name can be set to monitor a table element. That is what the program in Listing 15-4 does. Once the condition names for vowels and consonants are set up, all the program needs to do is test which condition name is set to TRUE for the character under consideration and then increment the appropriate count.

Listing 15-4. Using a Table Element Condition to Count Vowels and Consonants

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing15-4.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
```

```
01 TextLine.
   02 Letter          PIC X OCCURS 80 TIMES.
   88 Vowel           VALUE "A" "E" "I" "O" "U".
   88 Consonant       VALUE "B" "C" "D" "F" "G" "H" "J" "K" "L" "M" "N" "P"
                       "Q" "R" "S" "T" "V" "W" "X" "Y" "Z".

01 VowelCount        PIC 99 VALUE ZERO.
01 ConsonantCount    PIC 99 VALUE ZERO.
01 idx                PIC 99.
```

```
PROCEDURE DIVISION.
```

```
Begin.
```

```
  DISPLAY "Enter text : " WITH NO ADVANCING
  ACCEPT TextLine
  MOVE FUNCTION UPPER-CASE(TextLine) TO TextLine
  PERFORM VARYING idx FROM 1 BY 1 UNTIL idx > 80
    IF Vowel(idx) ADD 1 TO VowelCount
    ELSE IF Consonant(idx) ADD 1 TO ConsonantCount
  END-IF
  END-PERFORM
  DISPLAY "The line contains " VowelCount " vowels and " ConsonantCount " consonants."
  STOP RUN.
```

Listing 15-4 output	
Enter text :	When in disgrace with fortune and men's eyes
	The line contains 13 vowels and 23 consonants.

INSPECT .. REPLACING: Format 2

INSPECT .. REPLACING replaces characters in the string with a replacement character. The metalanguage for this version of INSPECT is given in Figure 15-2.

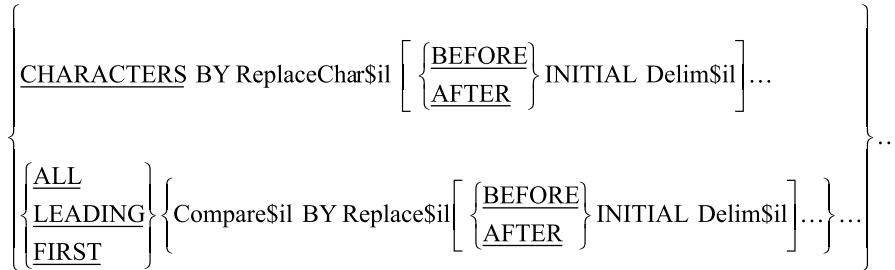
INSPECT SourceStr\$i REPLACING

Figure 15-2. Metalanguage for `INSPECT ..REPLACING`

This version of `INSPECT` works by scanning the source string `SourceStr$i` from left to right and replacing occurrences of all characters with a replacement character, or replacing specified characters with replacement characters:

- The behavior of the `INSPECT` is modified by the `LEADING`, `ALL`, `FIRST`, `BEFORE`, and `AFTER` phrases. An `ALL`, `LEADING`, `FIRST`, or `CHARACTERS` phrase may only be followed by one `BEFORE` phrase and one `AFTER` phrase.
- If `Compare$i` or `Delim$i` is a figurative constant, it is one character in size. But when `Replace$i` is a figurative constant, its size equals that of `Compare$i`.
- The sizes of `Compare$i` and `Replace$i` must be equal.
- When there is a `CHARACTERS` phrase, the size of `ReplaceChar$i` and the delimiter that may follow it (`Delim$i`) must be one character.

Modifying Phrases

Like `INSPECT ..TALLYING`, the operation of `INSPECT ..REPLACING` is governed by the modifying phrases used. The meaning of these phrases is as follows:

BEFORE: Designates the characters to the left of its associated delimiter (`Delim$i`) as valid. If the delimiter is not present in `SourceStr$i`, then using the `BEFORE` phrase implies that all the characters are valid.

AFTER: Designates the characters to the right of its associated delimiter (`Delim$i`) as valid. If the delimiter is not present in the `SourceStr$i`, then using the `AFTER` phrase implies that there are no valid characters in the string.

ALL: Replaces all `Compare$i` characters with the `Replace$i` characters from the first matching valid character to the first invalid one.

FIRST: Causes only the first valid character(s) to be replaced.

INSPECT ..REPLACING Examples

The `INSPECT ..REPLACING` statements in Example 15-2 work on the data in `StringData` to produce the results shown in the storage schematics. Assume that before each `INSPECT` executes, the value "FFFAFFFFFFQFFFZ" (shown in the Before row) is moved to `StringData`.

Example 15-2. Example INSPECT...REPLACING Statements with Results

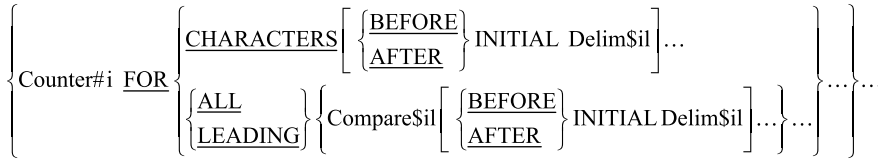
1. INSPECT StringData REPLACING ALL "F" BY "G"
AFTER INITIAL "A" BEFORE INITIAL "Q"
2. INSPECT StringData REPLACING ALL "F" BY "G"
AFTER INITIAL "A" BEFORE INITIAL "Z"
3. INSPECT StringData REPLACING FIRST "F" BY "G"
AFTER INITIAL "A" BEFORE INITIAL "Q"
4. INSPECT StringData REPLACING
ALL "FFFF" BY "DOGS"
AFTER INITIAL "A" BEFORE INITIAL "Z"
5. INSPECT StringData REPLACING
CHARACTERS BY "z" BEFORE INITIAL "Q"

	01 StringData PIC X(15).														
Before	F	F	F	A	F	F	F	F	F	F	Q	F	F	F	Z
After 1	F	F	F	A	G	G	G	G	G	G	Q	F	F	F	Z
After 2	F	F	F	A	G	G	G	G	G	G	Q	G	G	G	Z
After 3	F	F	F	A	G	F	F	F	F	F	Q	G	G	G	Z
After 4	F	F	F	A	D	O	G	S	F	F	Q	F	F	F	Z
After 5	z	z	z	z	z	z	z	z	z	z	Q	F	F	F	Z

INSPECT: Format 3

The third format of INSPECT simply allows you to combine the operation of the two previous formats in one statement. Please see those formats for explanations and examples. The metalanguage for the third INSPECT format is shown in Figure 15-3. This format is executed as though two successive INSPECT statements are applied to SourceStr*i*, the first being an INSPECT...TALLYING and the second an INSPECT...REPLACING.

INSPECT SourceStr\$i TALLYING



REPLACING

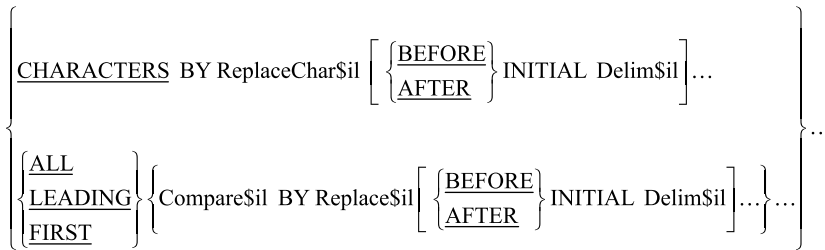


Figure 15-3. Metalanguage for format 3 of INSPECT

INSPECT .. CONVERTING: Format 4

INSPECT .. CONVERTING seems very similar to INSPECT .. REPLACING but actually works quite differently. It is used to convert one list of characters to another list of characters on a character-per-character basis. The metalanguage for this version of INSPECT is given in Figure 15-4.

INSPECT SourceStr\$i CONVERTING

Compare\$il TO Convert\$il



Figure 15-4. Metalanguage for INSPECT .. CONVERTING

Using INSPECT .. CONVERTING

INSPECT .. CONVERTING works on individual characters. If any of the Compare\$il list of characters are found in SourceStr\$i, they are replaced by the characters in Convert\$il on a one-for-one basis. For instance, in Figure 15-5, an *F* found in StringData is converted to *z*, *X* is converted to *y*, *T* is converted to *a*, and *D* is converted to *b*.

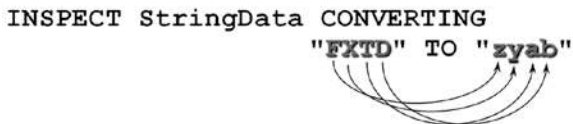


Figure 15-5. INSPECT .. CONVERTING showing the conversion strategy

The `INSPECT..CONVERTING` in Figure 15-5 is the equivalent of the following:

```
INSPECT StringData REPLACING
ALL "F" BY "z",
    "X" BY "y",
    "T" BY "a",
    "D" BY "b"
```

These are some rules for `INSPECT..CONVERTING`:

- `Compare$il` and `Convert$il` must be equal in size.
- When `Convert$il` is a figurative constant, its size equals that of `Compare$il`.
- The same character cannot appear more than once in `Compare$il`, because each character in the `Compare$il` string is associated with a replacement character. For instance, `INSPECT StringData CONVERTING "XTX" TO "abc"` is not allowed because the system won't know if `X` should be converted to `a` or `c`.

INSPECT..CONVERTING Examples

You saw an example of `INSPECT..CONVERTING` in Listing 15-1, where it was used to convert text to uppercase. That example is repeated in Listing 15-3, but here it demonstrates that `Compare$il` and `Convert$il` can be either strings or data items containing string values.

Example 15-3. Using `INSPECT..CONVERTING` to Convert Text to Uppercase or Lowercase

```
DATA DIVISION.
WORKING-STORAGE SECTION.
01 TextLine          PIC X(60).
01 LowerCase        PIC X(26) VALUE "abcdefghijklmnopqrstuvwxyz".
01 UpperCase        PIC X(26) VALUE "ABCDEFGHIJKLMNOPQRSTUVWXYZ".

PROCEDURE DIVISION.
Begin.
    DISPLAY "Enter text : " WITH NO ADVANCING
    ACCEPT TextLine

    INSPECT TextLine CONVERTING
        "abcdefghijklmnopqrstuvwxyz" TO
        "ABCDEFGHIJKLMNOPQRSTUVWXYZ"
    DISPLAY "Entered text in upper case = " TextLine

    INSPECT TextLine CONVERTING UpperCase TO LowerCase
    DISPLAY "Entered text in lower case = " TextLine.
```

Sometimes when you want to process the words in a line of text, especially if you want to recognize the words, you may need to get rid of the punctuation marks. Example 15-4 uses `INSPECT..CONVERTING` to convert punctuation marks in the text to spaces. `UNSTRING` is then used to unpack the words from the text.

Example 15-4. Using INSPECT..CONVERTING to Convert Punctuation Marks to Spaces

```
ACCEPT TextLine
INSPECT TextLine CONVERTING ",. ; : ? ! - _" TO SPACES
MOVE 1 TO UnstrPtr
PERFORM UNTIL EndOfText
    UNSTRING TextLine DELIMITED BY ALL SPACES
        INTO UnpackedWord
        WITH POINTER UnstrPtr
    DISPLAY UnpackedWord
END-PERFORM
```

The final example (Example 15-5) shows how you can use INSPECT..CONVERTING to implement a simple encoding mechanism. It converts the character 0 to character 5, 1 to 2, 2 to 9, 3 to 8, and so on. Conversion starts when the characters @> are encountered in the string and stops when <@ appears.

Example 15-5. Using INSPECT..CONVERTING to Implement an Encoding Mechanism

```
WORKING-STORAGE SECTION.
01 TextLine          PIC X(70).

01 UnEncodedText     PIC X(10) VALUE "0123456789".

01 EncodedText       PIC X(10) VALUE "5298317046".
```

```
PROCEDURE DIVISION.
Begin.
    DISPLAY "Text : "
        WITH NO ADVANCING
    ACCEPT TextLine
    INSPECT TextLine CONVERTING
        UnEncodedText TO EncodedText
        AFTER INITIAL "@>"
        BEFORE INITIAL "<@"

    DISPLAY "Encoded   = " TextLine

    INSPECT TextLine CONVERTING
        EncodedText TO UnEncodedText
        AFTER INITIAL "@>"
        BEFORE INITIAL "<@"

    DISPLAY "UnEncoded = " TextLine

    STOP RUN.
```

Example 15-5 output

```
Text : My home number is @> 353-61-43975689373 <@. Call me!
Encoded   = My home number is @> 818-72-38601746808 <@. Call me!
UnEncoded = My home number is @> 353-61-43975689373 <@. Call me!
```

String Concatenation

String concatenation involves joining the contents of two or more source strings or partial source strings to create a single destination string. In COBOL, string concatenation is done using the STRING verb. Before I discuss the STRING verb formally, let's look at some examples to get a feel for what it can do.

The first example concatenates the entire contents of the identifiers `String1` and `String2` with the literal "LM051" and puts the resulting string into `DestString`:

```
STRING String1, String2, "LM051" DELIMITED BY SIZE
      INTO DestString
END-STRING
```

The second example concatenates the entire contents of `String1`, the partial contents of `String2` (all the characters up to the first space), and the partial contents of `String3` (all the characters up to the word *unique*) and puts the concatenated string in `DestString`.

```
STRING
  String1 DELIMITED BY SIZE
  String2 DELIMITED BY SPACES
  String3 DELIMITED BY "unique"
INTO DestString
END-STRING
```

The STRING Verb

The metalanguage for the `STRING` verb is given in Figure 15-6.

```
STRING { SourceString$i1 ... DELIMITED BY { Delim$i1 } } ...
      INTO DestString$i
      [WITH POINTER Pointer#i]
      [ON OVERFLOW StatementBlock]
      [NOT ON OVERFLOW StatementBlock]
      [END-STRING]
```

Figure 15-6. Metalanguage for the `STRING` verb

The `STRING` verb moves characters from the source string (`SourceString$i1`) to the destination string (`DestString$i1`). Data movement is from left to right. The leftmost character of the source string is moved to the leftmost position of the destination string, then the next-leftmost character of the source string is moved to the next-leftmost position of the destination string, and so on. Note that no space filling occurs; and unless characters in the destination string are explicitly overwritten, they remain undisturbed.

When a number of source strings are concatenated, characters are moved from the leftmost source string first until either that string is exhausted or the delimiter (`Delim$i1`) is encountered in that string. When transfer from that source string finishes, characters are moved from the next-leftmost source string. This proceeds until either the strings are exhausted or the destination string is full. At that point, the `STRING` operation finishes.

The following rules apply to the operation of the `STRING` verb:

- The `ON OVERFLOW` clause executes if valid characters remain to be transferred in the source string but the destination string is full.
- When a `WITH POINTER` phrase is used, its value determines the starting character position for insertion into the destination string. As each character is inserted into the destination string, the pointer is incremented. When the pointer points beyond the end of the destination string, the `STRING` statement stops.

- When the WITH POINTER phrase is used, then before the STRING statement executes, the program must set Pointer#i to an initial value greater than zero and less than the length of the destination string.
- If the WITH POINTER phrase is not used, operation on the destination field starts from the leftmost position.
- Pointer#i must be an integer item, and its description must allow it to contain a value one greater than the size of the destination string. For instance, a pointer declared as PIC 9 is too small if the destination string is ten characters long.
- The DELIMITED BY SIZE clause causes the whole of the sending field to be added to the destination string.
- Where a literal can be used, you can use a figurative constant (such as SPACES) except for the ALL *literal* figurative constant.
- When a figurative constant is used, it is one character in size.
- The destination item DestString\$i must be either an elementary data item without editing symbols or the JUSTIFIED clause.
- Data movement from a particular source string ends when one of the following occurs:
 - The end of the source string is reached.
 - The end of the destination string is reached.
 - The delimiter is detected.
- The STRING statement ends when one of the following is true:
 - All the source strings have been processed.
 - The destination string is full.
 - The pointer points outside the string.

String Concatenation Example

Example 15-6 shows how you can build a destination string a piece at a time by executing several separate STRING statements. Each time a STRING statement executes, the current value of StrPtr governs where the characters from the source string are inserted into the destination string.

Example 15-6. STRING Examples Showing How to Use the WITH POINTER Phrase

```
DATA DIVISION.
WORKING-STORAGE SECTION.
01 DayStr      PIC XX VALUE "5".
01 MonthStr    PIC X(9) VALUE "September".
01 YearStr     PIC X(4) VALUE "2013".
01 DateStr     PIC X(16) VALUE ALL "@".
01 StrPtr      PIC 99.

PROCEDURE DIVISION.
Begin.
DISPLAY DateStr
MOVE 1 TO StrPtr
```

Example 15-6 output

```
@@@@@@@@@@@@@@@@@@
5 ,@@@@@@@@@@@@@@@@
5 ,September ,@@@
5 ,September ,2013
```

```

STRING DayStr  DELIMITED BY SPACES
      ", "      DELIMITED BY SIZE
      INTO DateStr WITH POINTER StrPtr
END-STRING
DISPLAY DateStr

```

```

STRING MonthStr DELIMITED BY SPACES
      ", "      DELIMITED BY SIZE
      INTO DateStr WITH POINTER StrPtr
END-STRING
DISPLAY DateStr

```

```

STRING YearStr  DELIMITED BY SIZE
      INTO DateStr WITH POINTER StrPtr
END-STRING
DISPLAY DateStr.

```

String Splitting

String splitting involves chopping a string into a number of smaller strings. In COBOL, string splitting is done using the UNSTRING verb. Before I discuss the UNSTRING verb formally, let's look at some examples to see what UNSTRING can do.

The first example uses UNSTRING to break a customer name into its three constituent parts: first name, middle name, and surname. For instance, the string "John Joseph Ryan" is broken into the three strings "John", "Joseph", and "Ryan":

```

UNSTRING CustomerName DELIMITED BY ALL SPACES
      INTO FirstName, SecondName, Surname
END-UNSTRING

```

The second example breaks an address string (where the parts of the address are separated from one another by commas) into separate address lines. The address lines are stored in a six-element table. Not all addresses have six parts exactly, but you can use the TALLYING clause to discover how many parts there are:

```

UNSTRING CustAddress DELIMITED BY ", "
      INTO AdrLine(1), AdrLine(2), AdrLine(3),
      AdrLine(4), AdrLine(5), AdrLine(6)
      TALLYING IN AdrLinesUsed
END-UNSTRING

```

The final example breaks a simple comma-delimited record into its constituent parts. Because the fields are not fixed length, they need to be validated for length—and that requires finding out how long each field is. The COUNT IN clause, which counts the number of characters transferred to a particular destination field, is used to determine the actual length of the field:

```

UNSTRING SupplierRec DELIMITED BY ", "
      INTO Supplier-Code  COUNT IN SuppCodeCount
      Supplier-Name      COUNT IN SuppNameCount
      Supplier-Address   COUNT IN SuppAdrCount
END-UNSTRING

```

The UNSTRING Verb

The metalanguage for the UNSTRING verb is given in Figure 15-7.

```
UNSTRING SourceStr$i
  [DELIMITED BY [ALL] Delim$i | [OR [ALL] Delim$i ]...]
  INTO {DestStr$i [DELIMITER IN HoldDelim$i ]
        [COUNT IN CharCounter#i ]}...
  [WITH POINTER Pointer#i ]
  [TALLYING IN DestCounter#i ]
  [ON OVERFLOW StatementBlock ]
  [NOT ON OVERFLOW StatementBlock ]
  [END - UNSTRING ]
```

Figure 15-7. Metalanguage for the UNSTRING verb

UNSTRING copies characters from the source string to the destination string until a condition is encountered that terminates data movement. When data movement ends for a particular destination string, the next destination string becomes the receiving area, and characters are copied into it until once again a terminating condition is encountered. Characters are copied from the source string to the destination strings according to the rules for MOVE, with space filling or truncation as necessary.

Strictly speaking, END-UNSTRING is only required to delimit the scope of the OVERFLOW statement block. You will notice, however, that I have a tendency to use it to indicate the end of every UNSTRING statement. This is just a personal preference.

Data-Movement Termination

When you use the DELIMITED BY clause, data movement from the source string to the current destination string ends when either of the following occurs:

- A delimiter is encountered in the source string
- The end of the source string is reached

When the DELIMITED BY clause is not used, data movement from the source string to the current destination string ends when either of these is true:

- The destination string is full.
- The end of the source string is reached.

UNSTRING Termination

The UNSTRING statement terminates in the following cases:

- All the characters in the source string have been examined.
- All the destination strings have been processed.
- Some error condition is encountered (such as the pointer pointing outside the source string).

UNSTRING Clauses

As you can see by examining the metalanguage, the operation of UNSTRING is modified by a number of clauses. These clauses affect the operation of UNSTRING as follows:

DELIMITED BY: When the DELIMITED BY clause is used, characters are examined in the source string and copied to the current destination string until one of the specified delimiters is encountered in the source string or the end the source string is reached. If there is not enough room in the destination string to take all the characters sent to it from the source string, the remaining characters are truncated/lost. When the delimiter is encountered in the source string, the next destination string becomes current, and characters are transferred into it from the source string. Delimiters are not transferred or counted in CharCounter#i.

ON OVERFLOW: When ON OVERFLOW activates, the statement block following it is executed. ON OVERFLOW activates if

- The unstring pointer (Pointer#i) is not pointing to a character position within the source string when UNSTRING executes (that is, Pointer#i is 0 or is greater than the size of the string).
- All the destination strings have been processed, but there are still valid unexamined characters in the source string.

The statements following NOT ON OVERFLOW are executed if UNSTRING is about to terminate successfully.

COUNT IN: The COUNT IN clause is associated with a particular destination string and holds a count of the number of characters passed to the destination string, regardless of whether they were truncated.

DELIMITER IN: A DELIMITER IN clause is associated with a particular destination string. HoldDelim\$i holds the delimiter that was encountered in the source string. If the DELIMITER IN phrase is used with the ALL phrase, then only one occurrence of the delimiter is moved to HoldDelim\$i.

TALLYING IN: Only one TALLYING clause can be used with each UNSTRING. It holds a count of the number of destination strings affected by the UNSTRING operation.

WITH POINTER: When the WITH POINTER clause is used, the Pointer#i data item holds the position of the next *non-delimiter* character to be examined in the source string. Pointer#i must be large enough to hold a value one greater than the size of the source string, because when UNSTRING ends, it will be pointing to one character position beyond the end of the string.

ALL: When the ALL phrase is used, contiguous delimiters are treated as if only one delimiter had been encountered. If ALL is not used, contiguous delimiters result in spaces being sent to some of the destination strings.

Notes on UNSTRING

Bear the following in mind when you use UNSTRING:

- Where a literal can be used, any figurative constant can be used except the ALL *literal* figurative constant.
- When a figurative constant is used, it is one character long.

- The delimiter is moved into HoldDelim\$i according to the rules for MOVE.
- The DELIMITER IN and COUNT IN phrases may be specified only if the DELIMITED BY phrase is used.

Language Knowledge Examples

This section presents a number of UNSTRING examples. These are not real-world examples but are rather intended to show how UNSTRING and its clauses operate.

UNSTRING: Demonstrating the COUNT IN Clause

Listing 15-5 demonstrates how to chop a string into separate strings based on a delimiter and how to keep a count of the number of characters transferred to each destination string. Note that DestStr2 is larger than the data copied to it and so is space filled. DestStr3 is too small to hold the characters transferred to it, so they are truncated; but the count still notes how many characters were transferred (08). The count for DestStr4 seems incorrect, but the literal assigned to xString is not long enough to fill it and so it is space filled. When UNSTRING copies “of sweet silent” to DestStr4, it copies these trailing spaces; they can’t all fit into DestStr4 and so are truncated but counted.

Listing 15-5. UNSTRING Example 1

IDENTIFICATION DIVISION.

PROGRAM-ID. Listing15-5.

AUTHOR. Michael Coughlan.

DATA DIVISION.

WORKING-STORAGE SECTION.

01 xString PIC X(45) VALUE "When,to the,sessions,of sweet silent".

01 DestinationStrings.

02 DestStr1 PIC X(4).

02 DestStr2 PIC X(10).

02 DestStr3 PIC X(3).

02 DestStr4 PIC X(18).

01 CharCounts.

02 CCount PIC 99 OCCURS 4 TIMES.

PROCEDURE DIVISION.

Begin.

UNSTRING xString delimited by ","

INTO DestStr1 COUNT IN CCount(1)

DestStr2 COUNT IN CCount(2)

DestStr3 COUNT IN CCount(3)

DestStr4 COUNT IN CCount(4)

END-UNSTRING

DISPLAY DestStr1 " = " CCount(1)

DISPLAY DestStr2 " = " CCount(2)

DISPLAY DestStr3 " = " CCount(3)

DISPLAY DestStr4 " = " CCount(4)

STOP RUN.

Listing 15-5 Output

```
When = 04
to the      = 06
ses = 08
of sweet silent = 24
```

UNSTRING: Demonstrating ON OVERFLOW and the Effect of Delimiters

Listing 15-6 contains three UNSTRING examples. Example 2 demonstrates the activation of the ON OVERFLOW clause. Because no delimiter is specified, all the text in DateStr is eligible for transfer; and as each destination item is filled, the next one becomes the current target. There are not enough destination items to take all the data: the remaining characters ("19" and the trailing spaces) are eligible for transfer, but there are no destination strings left to take them. So, ON OVERFLOW activates, and the message "Characters unexamined" is displayed.

Listing 15-6. The ON OVERFLOW Clause and the Effect of Delimiters

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing15-6.
AUTHOR. Michael Coughlan.
```

```
DATA DIVISION.
WORKING-STORAGE SECTION.
01 DateStr          PIC X(15).

01 DateRec.
   02 DayStr        PIC XX.
   02 MonthStr      PIC XX.
   02 YearStr       PIC X(4).
```

```
PROCEDURE DIVISION.
Begin.
*>Unstring example 2
   MOVE "19-08-2012" TO DateStr
   UNSTRING DateStr INTO DayStr, MonthStr, YearStr
       ON OVERFLOW DISPLAY "Characters unexamined"
   END-UNSTRING
   DISPLAY DayStr SPACE MonthStr SPACE YearStr
   DISPLAY "_____ "
   DISPLAY SPACES

*>Unstring example 3
   MOVE "25-07-2013lost" TO DateStr.
   UNSTRING DateStr DELIMITED BY "-"
       INTO DayStr, MonthStr, YearStr
       ON OVERFLOW DISPLAY "Characters unexamined"
   END-UNSTRING.
   DISPLAY DayStr SPACE MonthStr SPACE YearStr
   DISPLAY "_____ "
   DISPLAY SPACES

*>Unstring example 4
   MOVE "30end06end2014" TO DateStr
   UNSTRING DateStr DELIMITED BY "end"
       INTO DayStr, MonthStr, YearStr
       ON OVERFLOW DISPLAY "Characters unexamined"
   END-UNSTRING
   DISPLAY DayStr SPACE MonthStr SPACE YearStr

STOP RUN.
```

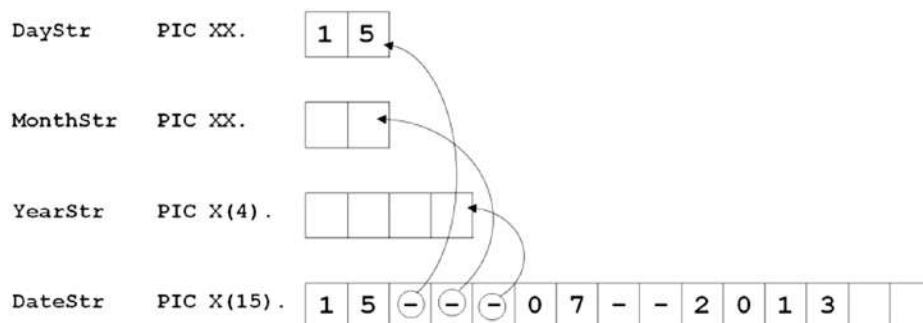
<u>Listing 15-6 Output</u>		
Characters unexamined		
19	-0	8-20
<hr/>		
25	07	2013
<hr/>		
30	06	2014

Example 3 demonstrates the difference when a delimiter is specified. ON OVERFLOW does not activate in this case because all the characters have been copied to the destination strings. UNSTRING tries to copy “2013lost” into YearStr, but because there is not sufficient room, some of the transferred characters are truncated.

Example 4 demonstrates that the delimiter does not have to be a single character. It can be a word or any other group of characters.

UNSTRING: The Effect of the ALL Delimiter

Listing 15-7 also contains three UNSTRING examples. Example 5 demonstrates the use of the ALL delimiter, which treats successive occurrences of a delimiter as one occurrence. This is contrasted with Example 6, where the same delimiter configuration is used but the ALL phrase is omitted. In this example, each occurrence of the delimiter is treated as separate instance; the result is shown in the following storage schematic.



Listing 15-7. The ALL Delimiter and the DELIMITER IN Phrase

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing15-7.
AUTHOR. Michael Coughlan.

DATA DIVISION.

WORKING-STORAGE SECTION.

01 DateStr PIC X(15).

01 DateRec.

02 DayStr PIC XX.

02 MonthStr PIC XX.

02 YearStr PIC X(4).

01 Delims.

02 HoldDelim OCCURS 3 TIMES PIC X.

PROCEDURE DIVISION.

Begin.

*>Unstring example 5

MOVE "15---07--2013" TO DateStr.

UNSTRING DateStr DELIMITED BY ALL "-"

INTO DayStr, MonthStr, YearStr

ON OVERFLOW DISPLAY "Characters unexamined"

Listing 15-7 Output

15 07 2013

Characters unexamined
15

/ delimits 15
- delimits 07
@ delimits 2013


```

END-UNSTRING
DISPLAY DayStr SPACE MonthStr SPACE YearStr
DISPLAY "_____ "
DISPLAY SPACES

*>Unstring example 6
MOVE "15---07--2013" TO DateStr.
UNSTRING DateStr DELIMITED BY "-"
    INTO DayStr
        MonthStr
        YearStr
    ON OVERFLOW DISPLAY "Characters unexamined"
END-UNSTRING
DISPLAY DayStr SPACE MonthStr SPACE YearStr
DISPLAY "_____ "
DISPLAY SPACES

*>Unstring example 7
MOVE "15/07-----2013@" TO DateStr
UNSTRING DateStr DELIMITED BY "/" OR "@" OR ALL "-"
    INTO DayStr DELIMITER IN HoldDelim(1)
        MonthStr DELIMITER IN HoldDelim(2)
        YearStr DELIMITER IN HoldDelim(3)
    ON OVERFLOW DISPLAY "Characters unexamined"
END-UNSTRING
DISPLAY HoldDelim(1) " delimits " DayStr
DISPLAY HoldDelim(2) " delimits " MonthStr
DISPLAY HoldDelim(3) " delimits " YearStr

STOP RUN.

```

Example 7 shows how you can use the DELIMITER IN clause to store a delimiter that causes character transfer to cease for a particular destination field.

String-Splitting Program

The examples so far have shown you aspects of the UNSTRING verb's operation. Listing 15-8 is a more real-world example. The problem specification is as follows: Write a program that accepts a person's full name from the user and reduces it to the initials of the first and middle names followed by the surname. For instance, William Henry Ford Power becomes W. H. F. Power.

Listing 15-8. UNSTRING and STRING Used in Combination

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing15-8.
AUTHOR. Michael Coughlan.

DATA DIVISION.
WORKING-STORAGE SECTION.
01 OldName PIC X(80).

```

```

01 TempName.
   02 NameInitial PIC X.
   02 FILLER      PIC X(19).

01 NewName      PIC X(30).

01 UnstrPtr     PIC 99.
   88 NameProcessed VALUE 81.

01 StrPtr       PIC 99.

```

PROCEDURE DIVISION.

```

ProcessName.
  DISPLAY "Enter a name - " WITH NO ADVANCING
  ACCEPT OldName
  MOVE 1 TO UnstrPtr, StrPtr
  UNSTRING OldName DELIMITED BY ALL SPACES
    INTO TempName WITH POINTER UnstrPtr
  END-UNSTRING
  PERFORM UNTIL NameProcessed
    STRING NameInitial "." SPACE DELIMITED BY SIZE
      INTO NewName WITH POINTER StrPtr
    END-STRING
    UNSTRING OldName DELIMITED BY ALL SPACES
      INTO TempName WITH POINTER UnstrPtr
    END-UNSTRING
  END-PERFORM
  STRING TempName DELIMITED BY SIZE
    INTO NewName WITH POINTER StrPtr
  END-STRING
  DISPLAY "Processed name = " NewName
  STOP RUN.

```

Reference Modification

Reference modification is a special COBOL facility that allows you to treat any USAGE IS DISPLAY item as if it were an array of characters but it defines access to the characters in a special way. To access substrings using reference modification, as shown in the metalanguage in Figure 15-8, you must specify the following:

- The name of the data item (DataItemName) to be referenced
- The start-character position of the substring (StartPos)
- The number of characters in the substring (SubStrLength)

DataItemName (StartPos[: SubStrLength])

Figure 15-8. Metalanguage syntax for reference modification

The metalanguage syntax is modified by the following semantic rules:

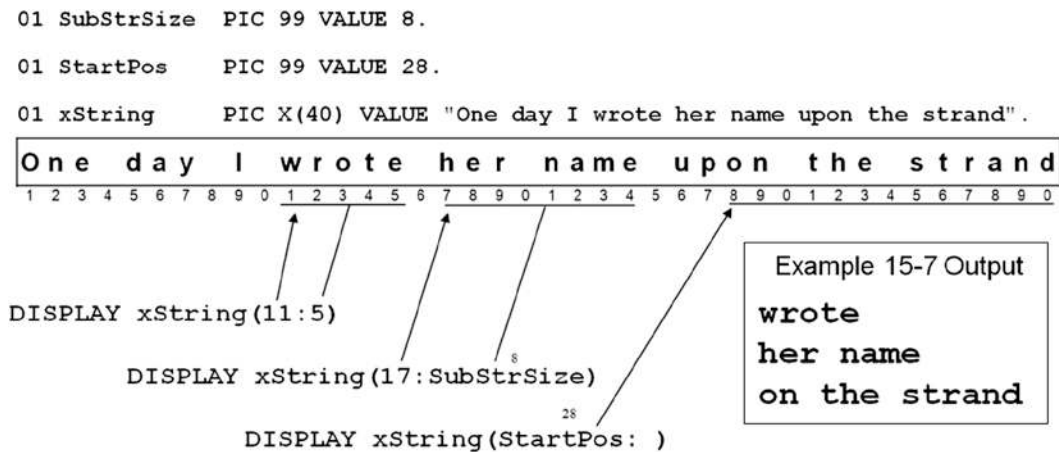
- StartPos is the character position of the first character in the substring, and SubStrLength is the number of characters in the substring. StartPos and SubStrLength must each be a positive integer or an expression that evaluates to one.
- DataItemName can be subscripted and/or qualified.
- DataItemName can be the alphanumeric value returned by a function.
- As indicated by the square brackets, SubStrLength may be omitted, in which case the substring from StartPos to the end of the string is assumed.
- You can use reference modification almost anywhere an alphanumeric data item is permitted.

To get a feel for the way reference modification works, let's look at some examples. You start with some abstract examples and then see how you can use reference modification in a more practical situation.

The three DISPLAYs in Example 15-7 use reference modification to display substrings of xString. The storage schematic shows how each example extracts the substring from xString:

- DISPLAY xString(11:5) displays a substring of five characters starting at the position of the eleventh character.
- DISPLAY xString(17:SubStrSize) demonstrates that you can use a numeric data item in place of the literal and displays eight characters starting with the seventeenth.
- DISPLAY xString(StartPos:) shows that when you omit SubStrLength, the substring consists of the characters from the start character to the end of the string.

Example 15-7. Extracting a Substring Using Reference Modification



The two DISPLAY statements in Example 15-8 demonstrate the other ways of defining the substring. The MOVE statement shows how you can use reference modification to insert characters into a string:

- DISPLAY xString(12:SubStrSize - 5) shows that you can use an arithmetic expression as SubStrLength.
- DISPLAY FUNCTION UPPER-CASE(xString)(Startpos - 7 : 4) demonstrates that you can apply reference modification to a function result. It also shows that StartPos may be an arithmetic expression.
- MOVE " text insert " TO xString(31:6) demonstrates how to use reference modification to insert text into a string. Note that the SubStrLength given specifies the number of characters in the string that will be overwritten. For instance, in this example only 6 characters are overwritten, even though there are 13 characters in the moved text.

Example 15-8. Applying Reference Modification to an Alphanumeric String

Example 15-8 Output

```
rot
NAME
One day I wrote her name upon text rand
```

```

01 SubStrSize PIC 99 VALUE 8.
01 StartPos PIC 99 VALUE 28.
01 xString PIC X(40) VALUE "One day I wrote her name upon the strand".

One day I wrote her name upon the strand
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

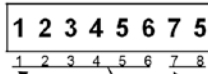
DISPLAY xString(12:SubStrSize - 5)
DISPLAY FUNCTION UPPER-CASE(xString)(Startpos - 7:4)
MOVE " text insert " TO xString(31:6)
DISPLAY xString
```

Example 15-9 shows how to apply reference modification to the numeric data item nString and the edited numeric data item enString:

- In nString, reference modification is used to display the dollars and cents parts of a numeric value.
- In enString, reference modification is used to overwrite the check-security asterisks with the @ symbol. Note that ALL "@" is a figurative constant that is used to fill the four character positions specified by the reference modifier.

Example 15-9. Applying Reference Modification to Numeric Data Items

```
01 nString    PIC 9(6)V99 VALUE 123456.75.
```

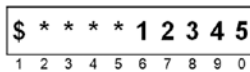


```
DISPLAY "Dollars = " nString(1:6)
```

```
    DISPLAY "Cents  = " nString(7: )
```

Example 15-9 Output	
Dollars =	123456
Cents =	75
\$@@@	123.45

```
01 enString   PIC $***,**9.99.
```



```
MOVE 123.45 TO enString
```

```
MOVE ALL "@" TO enString(2:4)
```

```
DISPLAY enString
```

Intrinsic Functions

User-defined functions of one sort or another are a standard part of many programming languages. The ANS 85 version of COBOL does not support user-defined functions, but it has introduced a library of standard functions called *intrinsic functions*.

Intrinsic functions fall into three broad categories: date functions, numeric functions, and string functions. Because this chapter is about string manipulation, I discuss the string functions in some detail. I also look at the date functions and some of the numeric functions that I have found particularly useful. For the remaining functions you should consult your implementer manual.

Using Intrinsic Functions

Like a function in another language, an intrinsic function is replaced by the function result in the position where the function occurs. Wherever you can use a literal, you can use an intrinsic function that returns a result of the same type.

An intrinsic function consists of three parts:

- The start of the function is signalled by the FUNCTION keyword.
- The FUNCTION keyword is followed by the name of the function.
- The name of the function is immediately followed by a bracketed list of parameters or arguments.

- The intrinsic function template is

```
FUNCTION FunctionName(Parameter)
```

where `FunctionName` is the name of the function and `Parameter` is one or more parameters/arguments supplied to the function.

For instance, the following examples show how to use intrinsic functions in a number of different contexts. In some cases, the result of the function is assigned to a data item; in others (as in the first example), it is used directly in the place of a literal or data item. Sometimes the parameters/arguments are numeric, and other times they are alphabetic. Some functions use only one parameter, others take multiple parameters, and still others do not require a parameter:

```
DISPLAY FUNCTION UPPER-CASE("this will be in upper case").
MOVE FUNCTION ORD("A") TO OrdPos
MOVE FUNCTION RANDOM(SeedValue) TO RandomNumber
MOVE FUNCTION RANDOM TO NextRndNumber
COMPUTE Result = FUNCTION MOD(25, 10)
MOVE FUNCTION ORD-MAX(12 23 03 78 65) TO MaxOrdPos
```

When you use intrinsic functions, you must bear in mind a number of things:

- Intrinsic functions return a result of Alphanumeric, Numeric (includes integer), or Integer (does not allow the decimal point).
- The result returned by an alphanumeric function has an implicit usage of `DISPLAY`. This is why the result returned by `FUNCTION UPPER-CASE` may be used directly with the `DISPLAY` verb.
- Intrinsic functions that return a numeric value are always considered to be signed and can only be used in an arithmetic expression or a `MOVE` statement.
- Intrinsic functions that return a non-integer numeric value can't be used where an integer value is required.

String Functions

Table 15-1 lists the intrinsic functions that allow manipulation of strings. The table uses the parameter name to indicate the type of the parameter required, as follows:

Alpha indicates Alphanumeric.

Num indicates any Numeric.

PosNum indicates a positive Numeric.

Int indicates any Integer.

PosInt indicates a positive Integer.

Any indicates that the parameter may be of any type.

Table 15-1. *String Functions, Grouped by Type of Operation*

Function Name	Result Type	Comment
CHAR(PosInt)	Alphanumeric	Returns the character in the collating sequence at ordinal position PosInt.
ORD(Alpha)	Integer	Returns the ordinal position of character Alpha.
ORD-MAX({Any}...)	Integer	Returns the ordinal position of whichever parameter in the list has the highest value. All parameters must be of the same type. The parameter list may be replaced by an array. If an array is used, the reserved word ALL may be used as the array subscript to indicate all the elements of the array.
ORD-MIN({Any}...)	Integer	Returns the ordinal position of whichever parameter in the list has the lowest value. All parameters must be of the same type. The parameter list may be replaced by an array.
LENGTH(Any)	Integer	Returns the number of characters in the data item Any. Not as useful as it sounds. It returns the value given in the item's picture clause. For instance, Length(StrItem) returns 18 if the picture clause is PIC X(18).
REVERSE(Alpha)	Alphanumeric	Returns a character string with the characters in Alpha reversed.
LOWER-CASE(Alpha)	Alphanumeric	Returns a character string with the characters in Alpha changed to their lowercase equivalents.
UPPER-CASE(Alpha)	Alphanumeric	Returns a character string with the characters in Alpha changed to their uppercase equivalents.

If a function takes a parameter list (indicated by {Any}... in the function definition), the parameter list may be replaced by an array. The reserved word ALL is used as the array subscript to indicate all the elements of the array.

For instance, the ORD-MAX function may take a parameter list, or you can use an array as the parameter, as shown in the following example:

```
MOVE FUNCTION ORD-MAX(12 23 03 78 65) TO OrdPos
```

or

```
MOVE FUNCTION ORD-MAX(IntElement(ALL)) TO OrdPos
```

String Intrinsic Function Examples

Listing 15-9 solves no specific problem. It merely consists of a number of intrinsic function examples.

Listing 15-9. String Manipulation with Intrinsic Functions

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing15-9.
AUTHOR. Michael Coughlan.
*> Intrinsic Function examples
```

DATA DIVISION.

WORKING-STORAGE SECTION.

01 OrdPos PIC 99.

01 TableValues VALUE "123411457429130938637306851419883522700467".
02 Num PIC 99 OCCURS 21 TIMES.

01 idx PIC 9.

01 xString PIC X(45)
 VALUE "This string is 33 characters long".

01 xWord PIC X(10).

01 CharCount PIC 99.

01 TextLength PIC 99.

PROCEDURE DIVISION.

Begin.

*> eg1. In the ASCII collating sequence W has a code of 87 but an ordinal
*> position of 88.

DISPLAY "eg1. The character in position 88 is = " FUNCTION CHAR(88)

*> eg2. Using ordinal positions to spell out my name

DISPLAY SPACES

 DISPLAY "eg2. My name is " FUNCTION CHAR(78) FUNCTION CHAR(106)
 FUNCTION CHAR(108) FUNCTION CHAR(102)

*> eg3. Finding the ordinal position of a particular character

DISPLAY SPACES

MOVE FUNCTION ORD("A") TO OrdPos

DISPLAY "eg3. The ordinal position of A is = " OrdPos

*> eg4. Using CHAR and ORD in combination to display the sixth letter of the alphabet

DISPLAY SPACES

 DISPLAY "eg4. The sixth letter of the alphabet is "
 FUNCTION CHAR(FUNCTION ORD("A") + 5)

*> eg5. Finding the position of the highest value in a list of parameters

DISPLAY SPACES

MOVE FUNCTION ORD-MAX("t" "b" "x" "B" "4" "s" "b") TO OrdPos

DISPLAY "eg5. Highest character in the list is at pos " OrdPos

*> eg6. Finding the position of the lowest value in a list of parameters

DISPLAY SPACES

MOVE FUNCTION ORD-MIN("t" "b" "x" "B" "4" "s" "b") TO OrdPos

DISPLAY "eg6. Lowest character in the list is at pos " OrdPos

Listing 15-9 Output

eg1. The character in position 88 is = W

eg2. My name is Mike

eg3. The ordinal position of A is = 66

eg4. The sixth letter of the alphabet is F


```
*> eg7. Finding the position of the highest value
in a table
DISPLAY SPACES
MOVE FUNCTION ORD-MAX(Num(ALL)) TO OrdPos
DISPLAY "eg7. Highest value in the table is at pos "
      OrdPos
```

```
*> eg8. Finding the highest value in a table
DISPLAY SPACES
DISPLAY "eg8. Highest value in the table = "
Num(FUNCTION ORD-MAX(Num(ALL)))
```

```
*> eg9. Finds the top three values in a table by finding the top
*> overwrites it with zeros to remove it from consideration
*> then finds the next top and so on
DISPLAY SPACES
DISPLAY "eg9."
PERFORM VARYING idx FROM 1 BY 1 UNTIL idx > 3
  DISPLAY "TopPos " idx " = " Num(FUNCTION ORD-MAX(Num(ALL)))
  MOVE ZEROS TO Num(FUNCTION ORD-MAX(Num(ALL)))
END-PERFORM
```

```
*> eg10. Finding the length of a string
DISPLAY SPACES
DISPLAY "eg10. The length of xString is " FUNCTION LENGTH(xString) " characters"
```

```
*> eg11. Finding the length of the text in a string
DISPLAY SPACES
INSPECT FUNCTION REVERSE(xString) TALLYING CharCount
      FOR LEADING SPACES
COMPUTE TextLength = FUNCTION LENGTH(xString) - CharCount
DISPLAY "eg11. The length of text in xString is " TextLength " characters"
```

```
*> eg12. Discover if a word is a palindrome
DISPLAY SPACES
DISPLAY "eg12."
MOVE ZEROS TO CharCount
DISPLAY "Enter a word - " WITH NO ADVANCING
ACCEPT xWord
INSPECT FUNCTION REVERSE(xWord)
      TALLYING CharCount FOR LEADING SPACES
IF FUNCTION UPPER-CASE(xWord(1:FUNCTION LENGTH(xWord) - CharCount)) EQUAL TO
  FUNCTION UPPER-CASE(FUNCTION REVERSE(xWord(1:FUNCTION LENGTH(xWord)- CharCount)))
  DISPLAY xWord " is a palindrome"
ELSE
  DISPLAY xWord " is not a palindrome"
END-IF
STOP RUN.
```

Listing 15-9 Output

```
eg5. Highest character in the list is at pos 03
eg6. Lowest character in the list is at pos 05
eg7. Highest value in the table is at pos 16
eg8. Highest value in the table = 88

eg9.
TopPos 1 = 88
TopPos 2 = 85
TopPos 3 = 74
```

Listing 15-9 Output

```
eg10. The length of xString is 45 characters
eg11. The length of text in xString is 33 characters

eg12.
Enter a word - RoTatOr
RoTatOr is a palindrome
```

Program Explanation

These examples build on one another so that although the early ones are straightforward, the later ones are somewhat more complex and require explanation. One thing you will realize from these examples is that COBOL's intrinsic functions are not as effective as functions in other languages. For one thing, the requirement to precede every intrinsic function with the word `FUNCTION` makes nesting functions cumbersome. For another, the function library is incomplete. You often have to use `INSPECT`, `UNSTRING`, and `STRING` to compensate for omissions. On the other hand, not being able to nest functions deeply may be a good thing. For instance, `eg12` would require more typing but would be easier to understand and debug if coded as follows:

```
*>eg12. Discover if a word is a palindrome
  DISPLAY SPACES
  DISPLAY "eg12."
  MOVE ZEROS TO CharCount
  DISPLAY "Enter a word - " WITH NO ADVANCING
  ACCEPT xWord

  INSPECT FUNCTION REVERSE(xWord) TALLYING CharCount
    FOR LEADING SPACES

  MOVE FUNCTION UPPER-CASE(xWord) TO xWord

  COMPUTE TextLength = FUNCTION LENGTH(xWord) - CharCount

  IF xWord(1:TextLength) EQUAL TO FUNCTION REVERSE(xWord(1:TextLength))
    DISPLAY xWord " is a palindrome"
  ELSE
    DISPLAY xWord " is not a palindrome"
  END-IF
```

Let's look at how these examples work:

- `eg1` uses the `CHAR` function to return the eighty-eighth character (*W*) of the ASCII collating sequence. In most languages, you would be required to supply the ASCII value, whereas in COBOL you supply the ordinal position. If you are used to dealing with ASCII values, the ordinal position will seem to be off by one: for example, the ASCII value of *W* is 87.
- `eg2` uses the `CHAR` function to display the name *Mike*.
- `eg3` demonstrates that the `ORD` function is the opposite of `CHAR`. Whereas `CHAR` returns the character at the ordinal position supplied, `ORD` returns the ordinal position of the character supplied. As you no doubt know, *A* is ASCII value 65, but its ordinal position is returned as 66.
- `eg4` is the first use of nested functions. `CHAR` and `ORD` are used in combination. `ORD("A")` returns the position of the first letter in the alphabet, and the sixth is five letters on from that.
- `eg5` and `eg6` demonstrate using the `ORD-MAX` function to find the position of the highest value in the supplied list.
- `eg7` demonstrates how to use `ORD-MAX` to find the position of the highest value in a table.
- `eg8` uses nesting and `ORD-MAX` to find the highest *value in a table*.
- `Eg9` uses the techniques demonstrated in `eg7` and `eg8` to find the top three values in a table. Each time through the loop, the highest value is found, displayed, and then overwritten with zeros to remove it from consideration the next time around. This solution does have the drawback of destroying some of the values in the table.

- eg10 and eg11: one problem COBOL has is that alphanumeric data items are fixed in length, so if the text does not fill the data item, the data item is space-filled to the right. For certain kinds of processing, this is a problem. eg10 shows how to get the length of a data item, and eg11 shows how to use the length of the data item to get the *length of the text* in that data item.
- eg12 brings together much of the material covered in this chapter. The task is to discover whether a word entered by the user is a palindrome (reads the same backward as forward). As I noted earlier, the nesting of functions makes the program much more difficult to understand.

This is the algorithm: using the technique of eg11, find the actual length of the word. Use reference modification to select only the word from the data item `xWord`, change it to uppercase, and compare it to a reversed, uppercased, version of the word. If they are equal, then the word is a palindrome.

DATE Functions

Date functions are a homogeneous group of functions that are often very useful. Table 15-2 lists the functions. The table uses the same parameter type indicators as Table 15-1 (Alpha, Num, PosNum, Int, PosInt, Any).

Table 15-2. *Date Functions*

Function Name	Result Type	Comment
CURRENT-DATE	Alphanumeric	Returns a 21-character string representing the current date and time, and the difference between the local time and Greenwich Mean Time. The format of the string is YYYYMMDDHHMMsshhxhmm, where YYYY is the year, MM is the month, DD is the day of the month, HH is the hour (24-hour time), MM is the minutes, ss is the seconds, and hh is the hundredths of a second. In addition, xhmm is the number of hours and minutes the local time is ahead of or behind GMT (x = + or - or 0). If x = 0, the hardware cannot provide this information.
DATE-OF-INTEGER(PosInt)	Integer of the form YYYYMMDD	Converts the integer date PosInt (representing the number of days that have passed since Dec 31, 1600 in the Gregorian calendar) to a standard date. Returns the standard date in the form YYYYMMDD. This function can be useful when you are calculating the number of days between two dates.
DAY-OF-INTEGER(PosInt)	Integer of the form YYYYDDD	Converts the integer date PosInt (representing the number of days that have passed since Dec 31, 1600 in the Gregorian calendar) to a standard date of the form YYYYDDD (sometimes called a Julian date).
INTEGER-OF-DATE(PosInt)	Integer	Converts the standard date PosInt (in the form YYYYMMDD) into the equivalent integer date. If PosInt is not a valid date, then zeros are returned.
INTEGER-OF-DAY(PosInt)	Integer	Converts the standard date PosInt (in the form YYYYDDD—a Julian date) into the equivalent integer date.
WHEN-COMPILED	Integer	Returns the date and time the program was compiled. Uses the same format as CURRENT-DATE.

DATE Examples

Like the previous listing, Listing 15-10 solves no specific problem but is instead a collection of examples that show how to use intrinsic functions to manipulate dates.

Listing 15-10. Using Intrinsic Functions to Manipulate Dates

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing15-10.
AUTHOR. Michael Coughlan.
*> Date Functions

DATA DIVISION.
WORKING-STORAGE SECTION.
01 DateAndTimeNow.
    02 DateNow.
        03 YearNow          PIC 9(4).
        03 MonthNow        PIC 99.
        03 DayNow          PIC 99.
    02 TimeC.
        03 HourNow        PIC 99.
        03 MinNow         PIC 99.
        03 SecNow         PIC 99.
        03 FILLER         PIC 99.
    02 GMT.
        03 GMTDiff        PIC X.
        88 GMTNotSupported VALUE "0".
        03 GMTHours       PIC 99.
        03 GMTMins        PIC 99.

01 BillDate              PIC 9(8).
01 DateNowInt            PIC 9(8).
01 DaysOverdue          PIC S999.
01 NumOfDays            PIC 999.

01 IntFutureDate        PIC 9(8).
01 FutureDate           PIC 9(8).
01 DisplayDate REDEFINES FutureDate.
    02 YearD             PIC 9999.
    02 MonthD           PIC 99.
    02 DayD             PIC 99.

01 DateCheck            PIC 9(8) VALUE ZEROS.
    88 DateIsNotValid   VALUE ZEROS.
    88 DateIsValid     VALUE 1 THRU 99999999.

PROCEDURE DIVISION.
Begin.
*> eg1 This example gets the current date and displays
*> the constituent parts.
    DISPLAY "eg1 - get the current date"
    MOVE FUNCTION CURRENT-DATE TO DateAndTimeNow
```

```

DISPLAY "Current Date is "
    MonthNow "/" DayNow "/" YearNow
DISPLAY "Current Time is "
    HourNow ":" MinNow ":" SecNow
IF GMTNotSupported
    DISPLAY "This computer cannot supply the time"
    DISPLAY "difference between local and GMT."
ELSE
    DISPLAY "The local time is - GMT "
        GMTDiff GMTHours ":" GMTmins
END-IF.

```

*> eg2. In this example bills fall due 30 days

*> from the billing date.

```

DISPLAY SPACES
DISPLAY "eg2 - find the difference between two dates"
DISPLAY "Enter the date of the bill (yyyymmdd) - " WITH NO ADVANCING
ACCEPT BillDate
MOVE DateNow TO DateNowInt
COMPUTE DaysOverDue =
    (FUNCTION INTEGER-OF-DATE(DateNowInt))
    - (FUNCTION INTEGER-OF-DATE(BillDate) + 30)

EVALUATE TRUE
    WHEN DaysOverDue > ZERO
        DISPLAY "This bill is overdue."
    WHEN DaysOverDue = ZERO
        DISPLAY "This bill is due today."
    WHEN DaysOverDue < ZERO
        DISPLAY "This bill is not yet due."
END-EVALUATE

```

*> eg3. This example displays the date NumOfDays days

*> from the current date

```

DISPLAY SPACES
DISPLAY "eg3 - find the date x days from now"
DISPLAY "Enter the number of days - " WITH NO ADVANCING
ACCEPT NumOfDays
COMPUTE IntFutureDate = FUNCTION INTEGER-OF-DATE(DateNowInt) + NumOfDays + 1
MOVE FUNCTION DATE-OF-INTEGGER(IntFutureDate) TO FutureDate
DISPLAY "The date in " NumOfDays " days time will be "
    MonthD "/" DayD "/" YearD

```

*> eg4. This takes advantage of the fact that DATE-OF-INTEGGER

*> requires a valid date to do some easy date validation

```

DISPLAY SPACES
DISPLAY "eg4 - validate the date"
PERFORM WITH TEST AFTER UNTIL DateIsValid
    DISPLAY "Enter a valid date (yyyymmdd) - " WITH NO ADVANCING
    ACCEPT DateNowInt

```

```

COMPUTE DateCheck = FUNCTION INTEGER-OF-DATE(DateNowInt)
IF DateIsNotValid
  DISPLAY DateNowInt " is not a valid date"
  DISPLAY SPACES
END-IF
END-PERFORM
DISPLAY "Thank you! " DateNowInt " is a valid date."

STOP RUN.

```

Listing 15-10 Output

```

eg1 - get the current date
Current Date is 12/18/2013
Current Time is 11:51:10
The local time is - GMT +00:00

eg2 - find the difference between two dates
Enter the date of the bill (yyyymmdd) - 20131117
This bill is overdue.

eg3 - find the date x days from now
Enter the number of days - 13
The date in 013 days time will be 01/01/2014

eg4 - validate the date
Enter a valid date (yyyymmdd) - 20131305
20131305 is not a valid date

Enter a valid date (yyyymmdd) - 20130931
20130931 is not a valid date

Enter a valid date (yyyymmdd) - 20130930
Thank you! 20130930 is a valid date.

```

DATE Program Explanation

Most of these examples are straightforward and require little explanation. Only eg2 and eg4 should present any difficulty:

- eg2 calculates the difference between the due date (bill date + 30) and today's date and, by subtracting one from the other, determines whether the bill is overdue (more than 30 days old).
- eg4 invokes the INTEGER-OF-DATE function for the sole purpose of checking whether the date is valid. If an invalid date is supplied to INTEGER-OF-DATE, the function returns zeros.

Summary

This chapter introduced COBOL string manipulation. You discovered how to use `INSPECT` to count, convert, and replace characters in a string. You saw how to use the `STRING` verb to concatenate strings and `UNSTRING` to split a string into substrings. In addition to learning the basics of the string-handling verbs, you saw how to augment their capabilities by using reference modification and intrinsic functions.

All the examples you have examined so far have been small, stand-alone programs. But in a large COBOL system, the executables usually consist of a number of programs, separately compiled and linked together to produce a single run unit. In the next chapter, you learn how to use contained and external subprograms to create a single run unit from a number of COBOL programs. COBOL subprograms introduce a number of data-declaration issues, so Chapter 16 also examines the `COPY` verb and the `IS GLOBAL` and `IS EXTERNAL` clauses.

LANGUAGE KNOWLEDGE EXERCISES

Ah! Exercise time again. Now, where did you put your 2B pencil?

Q1 Assume that for each `INSPECT` statement, `StringVar1` has the value shown in the **Ref** row of the following table. Show what value `StringVar1` holds after each `INSPECT` statement is executed:

1. `INSPECT StringVar1 REPLACING LEADING "W" BY "6"`
2. `INSPECT StringVar1 REPLACING ALL "W" BY "7" AFTER INITIAL "Z" BEFORE INITIAL "Q"`
3. `INSPECT StringVar1 REPLACING ALL "WW" BY "me" BEFORE INITIAL "ZZ"`
4. `INSPECT StringVar1 CONVERTING "WZQ" TO "abc"`

Ref	W	W	W	W	Z	W	W	W	W	W	Z	Q	Z	Z	Z	Z
1																
2																
3																
4																

Q2 Assume that for each `STRING` statement, `StringVar2` has the value shown in the **Ref** row of the following table. Show what value `StringVar2` holds after each `STRING` statement is executed:

```
01 Source1 PIC X(10) VALUE "the grass".
01 Source2 PIC X(6) VALUE "is ris".
01 StrPtr PIC 99 VALUE 3.
```

1. `STRING Source2 DELIMITED BY SPACES
SPACE DELIMITED BY SIZE
Source1 DELIMITED BY SIZE
INTO StringVar2`

2. STRING SPACE, "See" DELIMITED BY SIZE

Source1 DELIMITED BY SPACES

INTO StringVar2 WITH POINTER StrPtr

	01 StringVar2 PIC X(16) VALUE "Spring is sprung".															
Ref	S	p	r	i	n	g		i	s		s	p	r	u	n	g
1																
2																

- Q3** A four-line poem is accepted into `StringVar3` as a single line of text. Each line of the poem is separated from the others by a comma. Using the declarations that follow, write an `UNSTRING` statement to unpack the poem into individual poem lines and then display each poem line as well the number of characters in the line. For instance, given the poem

"I eat my peas with honey,I've done it all my life,It makes the peas taste funny,But it keeps them on the knife,"

Display

```
24 - I eat my peas with honey
24 - I've done it all my life
29 - It makes the peas taste funny
30 - But it keeps them on the knife
01 StringVar3      PIC X(120).
01 PoemLine OCCURS 4 TIMES.
  02 PLine        PIC X(40)
  02 CCount       PIC 99.
```

- Q4** Given these strings, write what will be displayed by the following `DISPLAY` statement:

```
01 Str1 PIC X(25) VALUE "I never saw a purple cow".
01 Str2 PIC X(25) VALUE "I never hope to see one".

DISPLAY Str3((36 - 12) + 1:)
DISPLAY Str1(1:2) Str2(9:5) Str2(1:7) Str2(16:4) Str1(12:)
```

- Q5** Given the following string description, write what will be displayed by the following `DISPLAY` statement:

```
01 Str3      PIC X(36) VALUE "abcdefghijklmnopqrstuvwxy0123456789".

DISPLAY Str3((36 - 12) + 1:)
```


- Q6** Given the following ACCEPT statement, using INSPECT, reference modification, and intrinsic functions, write a set of statements to discover the actual size of the string entered and store it in `StrSize`. Hint: The actual string is followed by trailing spaces:

```
01 Str4    PIC X(60).
01 StrSize PIC 99.
```

ACCEPT Str4.

- Q7** Given `Str4` and the ACCEPT statement in Q6, write statements to trim any leading spaces from the string entered and then store the trimmed string back in `Str4`.

LANGUAGE KNOWLEDGE EXERCISES: ANSWERS

- Q1** Assume that for each INSPECT statement, `StringVar1` has the value shown in the **Ref** row of the following table. Show what value `StringVar1` holds after each INSPECT statement is executed:
1. INSPECT `StringVar1` REPLACING LEADING "W" BY "6"
 2. INSPECT `StringVar1` REPLACING ALL "W" BY "7"
AFTER INITIAL "Z" BEFORE INITIAL "Q"
 3. INSPECT `StringVar1` REPLACING ALL "wW" BY "me" BEFORE INITIAL "ZZ"

4. INSPECT StringVar1 CONVERTING "WZQ" TO "abc"

Ref	W	W	W	W	Z	W	W	W	W	W	Z	Q	Z	Z	Z	Z
01	StringVar1 PIC X(16) VALUE "WWWZWWWZQZZZ".															
1	6	6	6	6	Z	W	W	W	W	W	Z	Q	Z	Z	Z	Z
2	W	W	W	W	Z	7	7	7	7	7	Z	Q	Z	Z	Z	Z
3	m	e	m	e	Z	m	e	m	e	W	Z	Q	Z	Z	Z	Z
4	a	a	a	a	b	a	a	a	a	a	b	c	b	b	b	b

Q2 Assume that for each STRING statement, StringVar2 has the value shown in the **Ref** row of the following table. Show what value StringVar2 holds after each STRING statement is executed:

```
01 Source1 PIC X(10) VALUE "the grass".
01 Source2 PIC X(6) VALUE "is ris".
01 StrPtr PIC 99 VALUE 3.
```

1. STRING Source2 DELIMITED BY SPACES
SPACE DELIMITED BY SIZE
Source1 DELIMITED BY SIZE
INTO StringVar2

```
STRING SPACE, "See" DELIMITED BY SIZE
Source1 DELIMITED BY SPACES
INTO StringVar2 WITH POINTER StrPtr
```

Ref	S	p	r	i	n	g		I	s		s	p	r	u	n	g
01	StringVar2 PIC X(16) VALUE "Spring is sprung".															
1	i	s		t	h	e		g	r	a	s	s		u	n	g
2	S	p		S	e	e	t	h	e		s	p	r	u	n	g

Q3 A four-line poem is accepted into StringVar3 as a single line of text. Each line of the poem is separated from the others by a comma. Using the declarations that follow, write an UNSTRING statement to unpack the poem into individual poem lines and then display each poem line as well the number of characters in the line. For instance, given the poem

```
"I eat my peas with honey,I've done it all my life,It makes the peas taste funny,But it keeps them on the knife,"
```

Display

```
24 - I eat my peas with honey
24 - I've done it all my life
29 - It makes the peas taste funny
30 - But it keeps them on the knife
```

```

01 StringVar3      PIC X(120).
01 PoemLine OCCURS 4 TIMES.
   02 PLine        PIC X(40)
   02 CCount       PIC 99.
UNSTRING StringVar3 DELIMITED BY "," INTO
   PLine(1) COUNT IN CCount(1)
   PLine(2) COUNT IN CCount(2)
   PLine(3) COUNT IN CCount(3)
   PLine(4) COUNT IN CCount(4)
END-UNSTRING

```

Q4 Given these strings, write what will be displayed by the following DISPLAY statement:

```

01 Str1 PIC X(25) VALUE "I never saw a purple cow".
01 Str2 PIC X(25) VALUE "I never hope to see one".

DISPLAY Str3((36 - 12) + 1:)
DISPLAY Str1(1:2) Str2(9:5) Str2(1:7) Str2(16:4) Str1(12:)

```

I hope I never see a purple cow

Q5 Given the following string description, write what will be displayed by the following DISPLAY statement:

```

01 Str3 PIC X(36) VALUE "abcdefghijklmnopqrstuvwxy0123456789".

DISPLAY Str3((36 - 12) + 1:)

```

yz0123456789

Q6 Given the following ACCEPT statement, using INSPECT, reference modification, and intrinsic functions, write a set of statements to discover the actual size of the string entered and store it in StrSize. Hint: The actual string is followed by trailing spaces:

```

01 Str4 PIC X(60).
01 StrSize PIC 99.
01 NumOfChars PIC 99.

```

ACCEPT Str4.

ACCEPT Str4.

INSPECT FUNCTION REVERSE(Str4) TALLYING NumOfChars
FOR LEADING SPACES

COMPUTE StrSize = (60 - NumOfChars)

DISPLAY Str4(1:StrSize) ": is " StrSize " characters in size."

Q7 Given Str4 and the ACCEPT statement in Q6, write statements to trim any leading spaces from the string entered and then store the trimmed string back in Str4.

DISPLAY "Old string is - " Str4

MOVE 1 TO NumOfChars

INSPECT Str4 TALLYING NumOfChars FOR LEADING SPACES

MOVE Str4(NumOfChars :) TO Str4

DISPLAY "New string is - " Str4



Creating Large Systems

All the programs you have seen so far in this book have been small stand-alone programs. But a large software system is not usually written as a single monolithic program. Instead, it consists of a main program and many independently compiled subprograms, linked together to form one executable run-unit. In COBOL, a program that is invoked from another program is called a *subprogram*. In other languages, these might be called procedures or methods.

This chapter shows you how to create a software system that consists of a number of programs linked together into one executable run-unit. You see how to create contained (internal) and external subprograms and how to use the CALL verb to pass control to them. You discover how to pass data to a subprogram through its parameter list, and you learn about state memory and how to create subprograms that exhibit state memory and subprograms that do not. Because COBOL subprograms introduce a number of data-declaration issues, this chapter also examines the COPY verb and the IS GLOBAL and IS EXTERNAL clauses.

Subprograms and the COPY Verb

Prior to the ANS 74 version, a large software system written in COBOL consisted of a series of large monolithic programs that ran under the control of a Job Control Language. Each program in the series did a piece of work and then passed the resulting data to the next program through the medium of files. The Job Control Language controlled the order of execution of the programs and provided access to the required files. For instance, a validation program might validate the data in a file to create a validated file that was then passed to the next program for processing.

The ANS 74 version of COBOL introduced external subprograms and the CALL and COPY verbs. These changes allowed you to create software systems that consisted of the following:

- A main program
- Record, file, and table descriptions imported from a central source text library
- A number of independently compiled external subprograms

These elements were linked together to form one executable run-unit.

The ANS 85 version of COBOL improved on this by introducing the concept of *contained subprograms*. These subprograms are called *contained* because their source code is contained within the source code of the main program. Contained subprograms are closed subroutines. They are very similar to the procedures or methods found in other languages. As you will discover, OO-COBOL methods are so similar to contained subprograms that once you have learned how to create one, the other requires little additional instruction.

It is easy to see how a system that consists of a main program and its contained subprograms can be compiled to create one executable image. It is perhaps not so obvious how a system that consists of a number of external subprograms, all independently compiled at different times, can be made into a single executable.

To create a single executable from a number of independently compiled programs, the object code (binary compiled code) of the main program and the subprograms must be bound together by a special program called a *linker*. One purpose of the linker is to resolve the subprogram names (given in the PROGRAM-ID clause) into actual

physical addresses so that the computer can find a particular subprogram when it is invoked. Nowadays many software development environments hide the linker step in this traditional sequence:

source code (.cbl) -> **compiler** -> object code (.obj) -> **linker** -> executable code (.exe)

A system that consists of a main program and linked subprograms requires a mechanism that allows one program to invoke another and to pass data to it. In many programming languages, the procedure or function call serves this purpose. In COBOL, the CALL verb is used to invoke one program from another.

The CALL Verb

The CALL verb is used to transfer control (program execution) to an external, independently compiled subprogram or a contained subprogram. When the subprogram terminates, control reverts to the statement after CALL. The metalanguage for the CALL verb is given in Figure 16-1.

$$\begin{array}{l} \text{CALL} \left\{ \begin{array}{l} \text{ProgNameIdentifier} \\ \text{ProgNameLiteral} \end{array} \right\} \\ \left[\text{USING} \left\{ \left\{ \begin{array}{l} \text{BY REFERENCE} \\ \text{BY CONTENT} \end{array} \right\} \text{ParamIdentifier} \dots \right\} \dots \right] \\ \left\{ \begin{array}{l} \text{[ON EXCEPTION StatementBlock]} \\ \text{[NOT ON EXCEPTION StatementBlock]} \\ \text{[ON OVERFLOW StatementBlock]} \end{array} \right\} \\ \text{[END - CALL]} \end{array}$$

Figure 16-1. Metalanguage for the CALL verb

Some notes relating to the metalanguage follow:

- BY REFERENCE and BY CONTENT are parameter-passing mechanisms. BY REFERENCE is the default and so is sometimes omitted (hence the square brackets).
- If the called program has not been linked (does not exist in the executable image), the statements following ON EXCEPTION execute. Otherwise, the program terminates abnormally.
- If the CALL passes parameters, then the called subprogram must have a USING phrase after the PROCEDURE DIVISION header and a LINKAGE SECTION to describe the parameters that are passed.
- The CALL statement may only have a USING phrase if the PROCEDURE DIVISION header of the called subprogram also has a USING phrase.
- Both USING phrases must have the same number of parameters.
- Unlike some languages, COBOL does not check the type of the parameters passed to a called subprogram. It is your responsibility to make sure that only parameters of the correct type and size are passed.
- As shown in Figure 16-2, the parameters passed from the calling program to the called subprogram correspond by position, not by name. That is, the first parameter in the USING phrase of the CALL corresponds to the first parameter in the USING phrase of the called program, and so on.

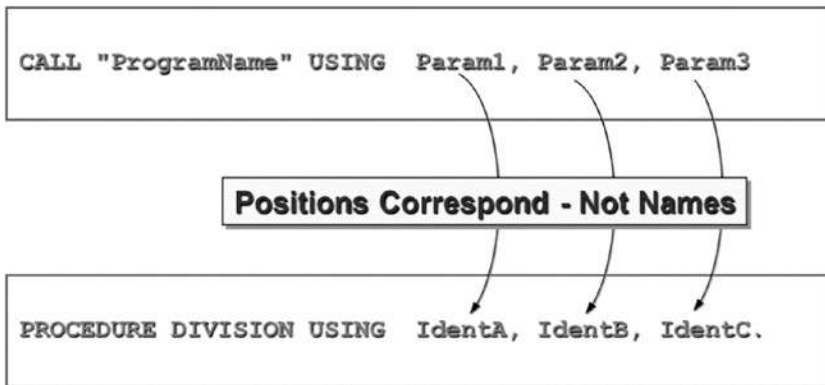


Figure 16-2. *CALL parameters correspond by position not name*

- Implementers often extend CALL by introducing BY VALUE parameter passing and by including a GIVING phrase. These are nonstandard extensions.

Parameter-Passing Mechanisms

As you can see from the metalanguage in Figure 16-1, the CALL verb has two parameter-passing mechanisms: BY REFERENCE and BY CONTENT. You should use BY REFERENCE only when the called subprogram needs to pass data back to the caller. You should always use BY CONTENT when data needs to be passed to, but not received from, the called program.

It is a principle of good program design that you should not expose a subprogram to more data than it needs in order to work. If you pass your data BY REFERENCE, the possibility exists that it may be corrupted by the called subprogram. When you pass data BY CONTENT, there is no possibility of that happening.

Figure 16-3 and Figure 16-4 show how each of these mechanisms works.

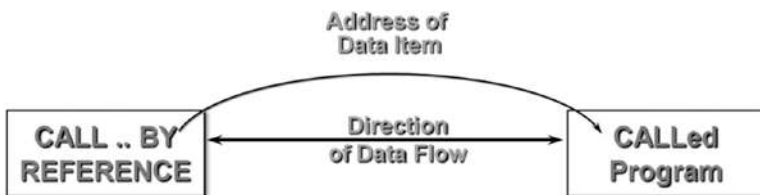


Figure 16-3. *The CALL .. BY REFERENCE parameter-passing mechanism*

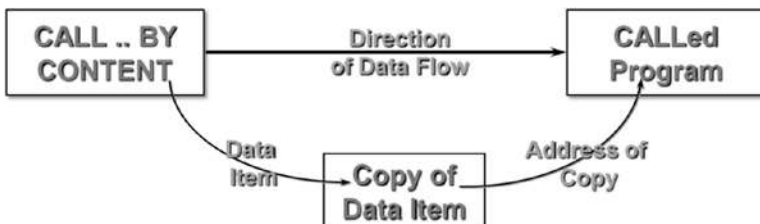


Figure 16-4. *The CALL .. BY CONTENT parameter-passing mechanism*

CALL..BY REFERENCE

When data is passed BY REFERENCE, the address of the data item is supplied to the called subprogram (see Figure 16-3). Therefore, any changes made to the data item in the subprogram are also made to the data item in the main program, because both items refer to the same memory location.

CALL..BY CONTENT

When a parameter is passed BY CONTENT, a copy of the data item is made, and the address of the copy is supplied to subprogram (see Figure 16-4). Any changes made to the data item in the subprogram affect only the copy.

Subprograms

I have said that a subprogram is just a program that is invoked by another program rather than by the user/operator. In most ways, this is true. A subprogram may have all the divisions, sections, and paragraphs that a program has, but subprograms may also have additional sections and phrases. In addition, because it is contained within the source text of a containing program, a contained subprogram is not quite the same as an external subprogram (one whose source code is in a document separate from the main program source).

Example 16-1 is a template for a subprogram that shows the additional sections and clauses in bold. The subprogram in Example 16-1 might be invoked with a CALL statement such as this:

```
CALL "ValidateCheckDigit" USING BY CONTENT StudentId
                                BY REFERENCE CKD-Result
```

Note that the CALL uses a literal value to identify the subprogram being invoked and that therefore the name is enclosed in quotes. This is the usual way a subprogram is invoked, because when you write a program, you usually know which subprogram you want to call. If you wanted to choose dynamically which program to call, you would use a data item to hold the program name. For instance:

```
DISPLAY "Enter the subprogram name - " WITH NO ADVANCING
ACCEPT SubprogramName
CALL SubprogramName
```

Example 16-1. Subprogram Template

```
IDENTIFICATION DIVISION.
PROGRAM-ID. ValidateCheckDigit IS INITIAL.
DATA DIVISION.
WORKING-STORAGE SECTION.
:      :      :      :      :      :
:      :      :      :      :      :
LINKAGE SECTION.
01 NumToValidate      PIC 9(7).
01 Result             PIC 99.

PROCEDURE DIVISION USING NumToValidate, Result.
Begin.
:      :      :      :      :      :
:      :      :      :      :      :
EXIT PROGRAM.
```

Note that the name given in the CALL statement (ValidateCheckDigit) corresponds to the name given in the PROGRAM-ID of the called program. The main purpose of the PROGRAM-ID clause is to identify programs in a run-unit (the group of programs that have been compiled and linked into one executable image). The CALL transfers control from one program in the run-unit to another.

In this template, the IS INITIAL clause is attached to the PROGRAM-ID. I discuss the IS INITIAL clause and the problem of state memory, which it solves, in the next section.

This template uses a LINKAGE SECTION. A LINKAGE SECTION (which comes after the WORKING-STORAGE SECTION) is always required if parameters are passed to a subprogram. The LINKAGE SECTION is used to define the parameters and reserve storage for them. If a LINKAGE SECTION is required, then the subprogram's PROCEDURE DIVISION header requires a USING phrase. The USING phrase matches the *actual parameters* of the CALL (by position in the parameter list) to the *formal parameters* in the subprogram.

■ **Note** You probably know what I mean by *actual parameters* and *formal parameters*; but in case you don't, here is an explanation. Any useful subprogram is likely to be called from a number of different places and for different purposes. For instance, the check-digit validation subprogram might be called by various programs to validate NewStudentId, OldStudentId, GraduatedStudentId, TransferStudentId, or even (because it validates any seven-digit number) StockId. These data-item names are the names of the *actual parameters* that are passed to the subprogram. When you write the subprogram, you don't always know the names of the data items that will be passed as parameters (a maintenance programmer, for instance, might write a new routine and call your subprogram); and in any case, there are multiple names—which do you choose? So, the name that you use in the subprogram is a placeholder (or *formal parameter*) for the *actual parameter* that is passed to the subprogram.

The EXIT PROGRAM statement in Example 16-1 stops the execution of the subprogram and transfers control back to the caller. You place the EXIT PROGRAM statement where you would normally place STOP RUN. The difference between STOP RUN and an EXIT PROGRAM statement is that STOP RUN causes the entire run-unit to stop (even if STOP RUN is encountered in a subprogram) instead of just the subprogram.

Contained Subprograms

As I explained earlier, a contained subprogram is a program contained within the source code of another program. When you use contained subprograms, the END PROGRAM header is required to delimit the scope of each subprogram and to wrap your subprograms within the scope of the main (container) program. The END PROGRAM header has this format: END PROGRAM ProgramIdName.

Example 16-2 shows the ValidateCheckDigit subprogram implemented as a contained subprogram. In this instance, it is contained within a main program called CheckDigitDrv.

Example 16-2. Outline of a Main Program and Its Contained Subprogram

```
IDENTIFICATION DIVISION.
PROGRAM-ID. CheckDigitDrv.
:      :      :      :      :      :
:      :      :      :      :      :
      CALL "ValidateCheckDigit" USING BY CONTENT StockId
                                      BY REFERENCE CKD-Result
:      :      :      :      :      :
:      :      :      :      :      :
```


IDENTIFICATION DIVISION.

PROGRAM-ID. ValidateCheckDigit IS INITIAL.

```
:      :      :      :      :      :      :
:      :      :      :      :      :      :
```

PROCEDURE DIVISION USING NumToValidate, Result.

```
:      :      :      :      :      :      :
:      :      :      :      :      :      :
```

END PROGRAM ValidateCheckDigit.

END PROGRAM CheckDigitDrv.

Contained Subprograms vs. External Subprograms

I mentioned that contained subprograms are not quite the same as external subprograms. You have already seen one difference: the `END PROGRAM` header. Another difference is the visibility of data. In an external subprogram, it is obvious that it can't see data declared in the main program or other subprograms (although this is not entirely true, as you will see when you examine the `IS EXTERNAL` clause), because it is a separate, independent program. But because the text of a contained subprogram is contained within the text of the main (container) program, you may wonder whether the subprogram can see the data declared in the main program and whether the main program can see the data declared in the subprogram. In COBOL, data declared in a subprogram cannot be seen outside it, and data declared in the main (containing) program cannot be seen in the subprogram, unless ... unless what? For the answer, you have to wait for the explanation of the `IS GLOBAL` clause later in this chapter.

An issue that does not arise in relation to external subprograms but is a burning issue for contained subprograms is invocability. Contained subprograms can be nested: that is, a contained subprogram may itself contain a subprogram. So the question arises, can a nested subprogram be called from anywhere? Or are there restrictions? Sadly, there are restrictions. A contained subprogram can only be called by its immediate parent (container) program or by a subprogram at the same level. Even this isn't entirely true; a subprogram can only be called by a subprogram (sibling) at the same level if the called program uses the `IS COMMON PROGRAM` clause (see the next section) in its `PROGRAM-ID`.

State Memory and the `IS INITIAL` Phrase

The first time a subprogram is called, it is in its initial state: all files are closed, and the data items are initialized to their `VALUE` clauses. The next time the subprogram is called, it remembers its state from the previous call. Any files that were opened are still open, and any data items that were assigned values still contain those values.

Although it can be useful for a subprogram to remember its state from call to call, systems that contain subprograms with *state memory* are often less reliable and more difficult to debug than those that do not. A subprogram that does not have state memory is predictable, because for the same input value, it produces the same result. Subprograms that have state memory are more difficult to debug because they may produce different results for the same input values.

You can force a subprogram into its initial state each time it is called by including the `IS INITIAL` clause in the `PROGRAM-ID`. The metalanguage for the `IS INITIAL` clause is given in Figure 16-5. Note that `INITIAL` is only one of the clauses that can be attached to the `PROGRAM-ID`. `IS COMMON PROGRAM` may also be applied to a subprogram. I examine the `IS COMMON PROGRAM` clause in more detail later in the chapter.

```
IS [ COMMON ] [ INITIAL ] PROGRAM.
```

Figure 16-5. Metalanguage for the `IS COMMON` and `IS INITIAL` clauses

Listing 16-1 has a dual purpose. It shows how contained subprograms are created and used, and it demonstrates the difference between a subprogram that has state memory and one that does not. The listing consists of a main program and two subprograms named *Steady* and *Dynamic*. *Steady* is so named because every time you call it with the same parameter values, it produces the same results. But *Dynamic*, because it remembers its state from the previous call, produces different results when it is called with the same input values.

Listing 16-1. State Memory Demonstration with *Steady* and *Dynamic*

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing16-1.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 Increment      PIC 99 VALUE ZERO.
   88 EndOfData   VALUE ZERO.

PROCEDURE DIVISION.
Begin.
*> Demonstrates the difference between Steady
*> and Dynamic. Entering a zero ends the iteration
  DISPLAY "Enter an increment value (0-99) - " WITH NO ADVANCING
  ACCEPT Increment
  PERFORM UNTIL EndOfData
    CALL "Steady" USING BY CONTENT Increment
    CALL "Dynamic" USING BY CONTENT Increment
    DISPLAY SPACES
    DISPLAY "Enter an increment value (0-99) - " WITH NO ADVANCING
    ACCEPT Increment
  END-PERFORM
STOP RUN.
```

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Dynamic.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 RunningTotal  PIC 9(5) VALUE ZERO.
01 PrnTotal      PIC ZZ,ZZ9.

LINKAGE SECTION.
01 ValueToAdd    PIC 99.
PROCEDURE DIVISION USING ValueToAdd.
Begin.
  ADD ValueToAdd TO RunningTotal
  MOVE RunningTotal TO PrnTotal
  DISPLAY "Dynamic total = " PrnTotal
  EXIT PROGRAM.
END PROGRAM Dynamic.
```

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Steady IS INITIAL.
DATA DIVISION.
```

<u>Listing 16-1 Output</u>	
Enter an increment value (0-99) -	66
Steady total =	66
Dynamic total =	66
Enter an increment value (0-99) -	66
Steady total =	66
Dynamic total =	132
Enter an increment value (0-99) -	66
Steady total =	66
Dynamic total =	198
Enter an increment value (0-99) -	22
Steady total =	22
Dynamic total =	220
Enter an increment value (0-99) -	22
Steady total =	22
Dynamic total =	242
Enter an increment value (0-99) -	

WORKING-STORAGE SECTION.

```
01 RunningTotal PIC 9(5) VALUE ZERO.
01 PrnTotal PIC ZZ,ZZ9.
```

LINKAGE SECTION.

```
01 ValueToAdd PIC 99.
```

```
PROCEDURE DIVISION USING ValueToAdd .
```

```
Begin.
```

```
ADD ValueToAdd TO RunningTotal
MOVE RunningTotal TO PrnTotal
DISPLAY "Steady total = " PrnTotal
EXIT PROGRAM.
```

```
END PROGRAM Steady.
```

```
END PROGRAM Listing16-1.
```

Notice that each time `Steady` is passed the same value, it produces the same result; but each time `Dynamic` is passed the same value, it produces a different result, because it remembers the state of the data items from the previous invocation. Sometimes, such as when you need to keep a running total, you want the subprogram to have state memory. But as a rule, unless you explicitly want a subprogram to remember its state, you should use the `IS INITIAL` phrase to set the program to its initial state each time it is called.

The CANCEL Verb

A program may need state memory only part of the time. That is, it needs to be reset to its initial state periodically. In COBOL, you can do this using the `CANCEL` verb. The metalanguage for the `CANCEL` verb is given in Figure 16-6.

```
CANCEL {ProgNameIdentifier}
      {ProgNameLiteral }...
```

Figure 16-6. Metalanguage for the `CANCEL` verb

When the `CANCEL` command is executed, the memory space occupied by the subprogram is freed. If the subprogram is called again, it is in its initial state (all files declared in the subprogram are closed, and all data items are initialized to their `VALUE` clauses). As shown in Example 16-3, you can use the `CANCEL` verb to force `Dynamic` to act like `Steady`.

Example 16-3. Using the `CANCEL` Verb to Force `Dynamic` to Act Like `Steady`

```
DISPLAY "First Call"
CALL "Dynamic" USING BY CONTENT 77.
CANCEL "Dynamic"
DISPLAY SPACES
DISPLAY "Second Call"
CALL " Dynamic" USING BY CONTENT 77.
```

<u>Example 16-3 Output</u>	
First Call	
Dynamic total =	77
Second Call	
Dynamic total =	77

The IS GLOBAL Clause

I noted earlier that data declared in a contained subprogram cannot be seen in the main (containing) program, and data declared in the main program cannot be seen inside a contained subprogram. In general, this is true; but sometimes you may want to share a data item with a number of contained subprograms. For instance, consider

the program fragments in Example 16-4. This program produces a report showing the purchases of new automobiles in the United States. The data is accumulated in a table and then printed.

The program is partitioned into a main program and two subprograms. One subprogram adds the value of each new car purchase to the appropriate state in the table. The other subprogram prints the report when the new car purchases have been processed. Both subprograms need access to the table. The table cannot be declared local to the subprogram because any local declarations cannot be seen outside the subprogram. So the table must be declared in the outer scope: the main (container) program. The problem then is how to allow the table to be seen by the subprograms.

One approach might be to pass the table through the parameter list. The problem with this approach is that there is a lot of data in the table, and every time `AddToStateTotal` is called, the table must be passed. A better solution is to make the table visible inside the subprograms. You can do this using the `IS GLOBAL` clause. Any data item to which the `IS GLOBAL` clause is attached is visible within the subordinate subprograms.

Example 16-4. Program Outline Showing the Use of the `IS GLOBAL` Clause

```
IDENTIFICATION DIVISION.
PROGRAM-ID. CarPurchasesReport.
:      :      :      :      :      :
01 StateTable IS GLOBAL.
   02 State OCCURS 50 TIMES.
      03 TotalCarPurchases PIC 9(9)V99.
:      :      :      :      :      :
PROCEDURE DIVISION.
:      :      :      :      :      :
   CALL AddToStateTotal USING BY CONTENT StateNo, ValueOfCarPurchase
:      :      :      :      :      :
   CALL PrintTotalCarPurchases
STOP RUN.

IDENTIFICATION DIVISION.
PROGRAM-ID. AddToStateTotal.
:      :      :      :      :      :
END-PROGRAM AddToStateTotal.

IDENTIFICATION DIVISION.
PROGRAM-ID. PrintTotalCarPurchases.
:      :      :      :      :      :
END PROGRAM PrintTotalCarPurchases.
END PROGRAM CarPurchasesReport.
```

The `IS COMMON PROGRAM` Clause

I mentioned earlier that a contained subprogram can only be called by its immediate parent (container) program or by a subprogram at the same level. I noted that even then, a contained subprogram can call a subprogram at the same level only if the subprogram to be called uses the `IS COMMON PROGRAM` clause in its `PROGRAM-ID`. You already saw the metalanguage for the `IS COMMON PROGRAM` clause in Figure 16-5, but it is repeated here for convenience:

```
IS[ COMMON ] [ INITIAL ] PROGRAM.
```

When `IS COMMON PROGRAM` is attached to the `PROGRAM-ID` clause of a contained subprogram, that subprogram may be invoked by any subprograms at the same level (siblings) but only by them. As you can see from the metalanguage, both the `COMMON` and `INITIAL` clauses may be used in combination. The words `IS` and `PROGRAM` are noise words that may be omitted. The `IS COMMON PROGRAM` clause can be used only in nested programs.

Example Programs and Their Subprograms

Listing 16-2, Listing 16-3, and Listing 16-4 are programs that consist of simple examples to demonstrate some of the issues discussed so far. Listing 16-5 is a more practical example that implements a game to test your knowledge of the American states. Listing 16-6 is a demonstrator for the external subprogram used by Listing 16-5.

External Subprogram

Listing 16-2 is an example program that calls an external subprogram to validate Student IDs. It is followed by the external subprogram Listing 16-2sub, which applies check-digit validation to any seven-digit number supplied to it.

Listing 16-2. Creating and Calling an External Subprogram

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing16-2.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 StudentId                PIC 9(7).

01 ValidationResult         PIC 9.
   88 ValidStudentId       VALUE ZERO.
   88 InvalidStudentId     VALUE 1.
```

```
PROCEDURE DIVISION.
Begin.
  PERFORM 3 TIMES
    DISPLAY "Enter a Student Id : " WITH NO ADVANCING
    ACCEPT StudentId
    CALL "ValidateCheckDigit" USING BY CONTENT StudentID
                                     BY REFERENCE ValidationResult

    IF ValidStudentId
      DISPLAY "The Student id - " StudentId " - is valid"
    ELSE
      DISPLAY "The Student id - " StudentId " - is not valid"
    END-IF
    DISPLAY SPACES
  END-PERFORM
STOP RUN.
```

Listing 16-2 Output

```
Enter a Student Id : 1234567
The Student id - 1234567 - is not valid

Enter a Student Id : 7654321
The Student id - 7654321 - is not valid

Enter a Student Id : 9320288
The Student id - 9320288 - is valid
```

Listing 16-2sub. The ValidateCheckDigit External Subprogram

```
IDENTIFICATION DIVISION.
PROGRAM-ID. ValidateCheckDigit IS INITIAL.
DATA DIVISION.
WORKING-STORAGE SECTION.
```

```

01 SumOfNums          PIC 9(5).
01 Quotient           PIC 9(5).
01 CalcResult        PIC 99.

```

LINKAGE SECTION.

```

01 NumToValidate.
  02 D1               PIC 9.
  02 D2               PIC 9.
  02 D3               PIC 9.
  02 D4               PIC 9.
  02 D5               PIC 9.
  02 D6               PIC 9.
  02 D7               PIC 9.

```

```

01 Result             PIC 9.
  88 InvalidCheckDigit VALUE 1.
  88 ValidCheckDigit  VALUE 0.

```

PROCEDURE DIVISION USING NumToValidate, Result.

*> Returns a Result of 1 (invalid check digit) or 0 (valid check digit)

Begin.

```

  COMPUTE SumOfNums = (D1 * 7) + (D2 * 6) + (D3 * 5) + (D4 * 4) +
                    (D5 * 3) + (D6 * 2) + (D7).

```

```

  DIVIDE SumOfNums BY 11 GIVING Quotient REMAINDER CalcResult

```

```

  IF CalcResult EQUAL TO ZERO

```

```

    SET ValidCheckDigit TO TRUE

```

```

  ELSE

```

```

    SET InvalidCheckDigit TO TRUE

```

```

  END-IF

```

```

  EXIT PROGRAM.

```

Parameter Passing and Data Visibility

Listing 16-3 is an abstract example that demonstrates how to create contained subprograms. It shows the various kinds of parameters and parameter-passing mechanisms you can use and demonstrates the visibility of any data item declared with the IS GLOBAL clause.

Listing 16-3. Contained Subprograms and Parameter Passing and Data Visibility

IDENTIFICATION DIVISION.

PROGRAM-ID. Listing16-3.

AUTHOR. Michael Coughlan.

DATA DIVISION.

WORKING-STORAGE SECTION.

```

01 DaysOfTheWeek VALUE "MonTueWedThuFriSatSun" IS GLOBAL.

```

```

  02 DayName      PIC XXX OCCURS 7 TIMES.

```

```

01 Parameters.

```

```

  02 Number1      PIC 9(3) VALUE 456.

```

```

  02 Number2      PIC 9(3) VALUE 321.

```

```

  02 FirstString  PIC X(20) VALUE "First parameter = ".

```

```

02 SecondString      PIC X(20) VALUE "Second parameter = ".
02 Result            PIC 9(6)  USAGE IS COMP.
02 DiscountTable VALUE "12430713862362".
   03 Discount       PIC 99 OCCURS 7 TIMES.

01 PrnResult         PIC ZZZ,ZZ9.

```

PROCEDURE DIVISION.

DemoParameterPassing.

```

DISPLAY "FirstString value is - " FirstString
DISPLAY "SecondString value is - " SecondString

```

```

CALL "MultiplyNums"
   USING BY CONTENT Number1, Number2, FirstString,
        BY REFERENCE SecondString, Result
        BY CONTENT DiscountTable

```

DISPLAY SPACES

```

DISPLAY "FirstString value is - " FirstString
DISPLAY "SecondString value is - " SecondString
MOVE Result TO PrnResult
DISPLAY "COMP value is " PrnResult
STOP RUN.

```

IDENTIFICATION DIVISION.

PROGRAM-ID. MultiplyNums.

AUTHOR. Michael Coughlan.

DATA DIVISION.

WORKING-STORAGE SECTION.

01 idx PIC 9.

LINKAGE SECTION.

```

01 Param1        PIC 9(3).
01 Param2        PIC 9(3).
01 Answer        PIC 9(6) USAGE IS COMP.
01 StrA          PIC X(20).
01 StrB          PIC X(20).
01 TableIn.
   02 TNum       PIC 99 OCCURS 7 TIMES.

```

```

PROCEDURE DIVISION USING Param1, Param2, StrA,
StrB, Answer, TableIn.
Begin.

```

```

DISPLAY SPACES
DISPLAY ">>> In the MultiplyNums subprogram"
DISPLAY StrA Param1
DISPLAY StrB Param2
MULTIPLY Param1 BY Param2 GIVING Answer.

```

Listing 16-3 Output

```

FirstString value is - First parameter =
SecondString value is - Second parameter =

```

```

>>> In the MultiplyNums subprogram
First parameter = 456
Second parameter = 321

```

```

Mon discount is 12%
Tue discount is 43%
Wed discount is 07%
Thu discount is 13%
Fri discount is 86%
Sat discount is 23%
Sun discount is 62%

```

```

>>>> In InnerSubProg
Days of the week = MonTueWedThuFriSatSun
<<<< Leaving InnerSubProg

```

```

<<<< Leaving MultiplyNums

```

```

FirstString value is - First parameter =
SecondString value is - VALUE OVERWRITTEN
COMP value is 146,376

```

```
*> Displays table values. One passed as a parameter and the other global
DISPLAY SPACES
PERFORM VARYING idx FROM 1 BY 1 UNTIL idx > 7
    DISPLAY DayName(idx) " discount is " Tnum(idx) "%"
END-PERFORM

*> Transfer control to a subprogram contained within MultiplyNums
CALL "InnerSubProg"

*> Demonstrates the difference between BY CONTENT and BY REFERENCE.
MOVE "VALUE OVERWRITTEN" TO StrA
MOVE "VALUE OVERWRITTEN" TO StrB
DISPLAY SPACES
DISPLAY "<<<< Leaving MultiplyNums"
EXIT PROGRAM.
```

IDENTIFICATION DIVISION.

PROGRAM-ID. InnerSubProg.

AUTHOR. Michael Coughlan.

PROCEDURE DIVISION.

Begin.

```
*> Demonstrates that the GLOBAL data item is even visible here
DISPLAY SPACES
DISPLAY ">>>> In InnerSubProg"
DISPLAY "Days of the week = " DaysOfTheWeek
DISPLAY "<<<< Leaving InnerSubProg"
EXIT PROGRAM.
```

END PROGRAM InnerSubProg.

END PROGRAM MultiplyNums.

END PROGRAM LISTING16-3.

The first displayed items show the current value of the two strings in the main program. There is a purpose to this. One string is passed BY REFERENCE and the other BY CONTENT. When these strings are displayed after the CALL has executed, the one passed BY REFERENCE has been corrupted. The lesson should be obvious.

In addition to normal numeric items, one of the parameters is a USAGE IS COMP data item. It holds the result of multiplying the two numbers Param1 and Param2. One thing I must stress here is that the description of numeric items in the main program must be the same as the description in the LINKAGE SECTION. If you describe an item as signed in the subprogram, it must be signed in the main program. If it is a USAGE IS COMP item in the subprogram, it must be the same in the main program. Be aware that the compiler provides you with absolutely no protection in this regard. It is up to you to make sure the data types and sizes correspond. Working with COBOL subprograms is akin to driving down a twisty mountain road with no protection barrier—one mistake, and you plunge into the abyss.

The percentage displays are used to show that an array can be passed as a parameter. But in this example I also take the opportunity to show that the DaysOfTheWeek table, which is declared as GLOBAL in the outer scope (main program), is also visible inside the contained subprogram.

Just to emphasize the visibility of GLOBAL data items, the subprogram InnerSubProg is nested within the subprogram MultiplyNums. Even in InnerSubProg, the DaysOfTheWeek table is visible.

Using IS COMMON PROGRAM

Listing 16-4 shows that the program to be called can be assigned at runtime. In this example, instead of using a literal value as the target of the CALL, a data item containing the name of the subprogram to be called is used. The name of the subprogram is supplied by the user. Because the user is supplying the name of the program, there is a possibility that they will get the name wrong; the ON EXCEPTION clause is used to make sure the named program exists.

Listing 16-4. Creating and Using a COMMON Subprogram

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing16-4.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 Operation          PIC XXX.
01 NumericValue       PIC 999.
   88 EndOfData       VALUE ZEROS.
```

```
01 FILLER             PIC 9.
   88 ValidSubprogName VALUE ZERO.
   88 InvalidSubprogName VALUE 1.
```

```
PROCEDURE DIVISION.
```

```
Begin.
```

```
PERFORM 3 TIMES
```

```
SET ValidSubprogName TO TRUE
```

```
DISPLAY SPACES
```

```
DISPLAY "Enter the required operation (Dec or Inc) : " WITH NO ADVANCING
```

```
ACCEPT Operation
```

```
DISPLAY "Enter a three digit value : " WITH NO ADVANCING
```

```
ACCEPT NumericValue
```

```
PERFORM UNTIL EndofData OR InvalidSubprogName
```

```
CALL Operation USING BY CONTENT NumericValue
```

```
ON EXCEPTION DISPLAY Operation " is not a valid operation"
```

```
SET InvalidSubprogName TO TRUE
```

```
NOT ON EXCEPTION SET ValidSubprogName TO TRUE
```

```
DISPLAY "Enter a three digit value : "
```

```
WITH NO ADVANCING
```

```
ACCEPT NumericValue
```

```
END-CALL
```

```
END-PERFORM
```

```
CANCEL Operation
```

```
END-PERFORM
```

```
STOP RUN.
```

```
IDENTIFICATION DIVISION.
```

```
PROGRAM-ID. Inc.
```

```
AUTHOR. Michael Coughlan.
```

Listing 16-4 Output

```
Enter the required operation (Dec or Inc) : Dec
Enter a three digit value : 234
The current value is -234
Enter a three digit value : 111
The current value is -345
Enter a three digit value : 222
The current value is -567
Enter a three digit value :
```

```
Enter the required operation (Dec or Inc) : Div
Enter a three digit value : 111
Div is not a valid operation
```

```
Enter the required operation (Dec or Inc) : Inc
Enter a three digit value : 111
The current value is +111
Enter a three digit value : 222
The current value is +333
Enter a three digit value : 999
The current value is +1,332
Enter a three digit value :
```

```

DATA DIVISION.
WORKING-STORAGE SECTION.
01 RunningTotal    PIC S9(5) VALUE ZEROS.

LINKAGE SECTION.
01 ValueIn        PIC 9(3).

PROCEDURE DIVISION USING ValueIn.
Begin.
    ADD ValueIn TO RunningTotal
    CALL "DisplayTotal" USING BY CONTENT RunningTotal
    EXIT PROGRAM.
END PROGRAM Inc.

IDENTIFICATION DIVISION.
PROGRAM-ID. Dec.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 RunningTotal    PIC S9(5) VALUE ZEROS.

LINKAGE SECTION.
01 ValueIn        PIC 9(3).

PROCEDURE DIVISION USING ValueIn.
Begin.
    SUBTRACT ValueIn FROM RunningTotal
    CALL "DisplayTotal" USING BY CONTENT RunningTotal
    EXIT PROGRAM.
END PROGRAM Dec.

IDENTIFICATION DIVISION.
PROGRAM-ID. DisplayTotal IS COMMON INITIAL PROGRAM.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 PrnValue        PIC +++,++9.

LINKAGE SECTION.
01 ValueIn        PIC S9(5).

PROCEDURE DIVISION USING ValueIn.
Begin.
    MOVE ValueIn TO PrnValue
    DISPLAY "The current value is " PrnValue
    EXIT PROGRAM.
END PROGRAM DisplayTotal.
END PROGRAM LISTING16-4.

```

In this example, both Inc and Dec display RunningTotal via a CALL to their sibling program DisplayTotal, which has the IS COMMON PROGRAM clause.

A Practical Example

In Chapter 13, I introduced a table that held the codes, names, and capitals of all the states in America. You might have thought at the time that that information could prove useful in a number of programs. In the next example I take that table, expand it to include the population of each state and from it create an external subprogram called GetStateInfo. Listing 16-5 and Listing 16-6 both use GetStateInfo, but in different ways. Listing 16-5 is a game that uses GetStateInfo to test your knowledge of the American states. Listing 16-6 simply returns the other information about a state when you give it one piece of information, such as the state name.

GetStateInfo External Subprogram

Before examining Listing 16-5 and Listing 16-6, let's look at the external subprogram that both of these programs call (see Listing 16-5sub).

Listing 16-5sub. External Subprogram to Supply Information About the States

```
IDENTIFICATION DIVISION.
PROGRAM-ID. GetStateInfo IS INITIAL.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 StatesTable.
   02 StateValues.
      03 FILLER PIC X(38) VALUE "ALAlabama      Montgomery  04822023".
      03 FILLER PIC X(38) VALUE "AKAlaska      Juneau     00731449".
      03 FILLER PIC X(38) VALUE "AZArizona    Phoenix    06553255".
      03 FILLER PIC X(38) VALUE "ARArkansas  Little Rock 02949131".
      03 FILLER PIC X(38) VALUE "CACalifornia Sacramento 38041430".
      03 FILLER PIC X(38) VALUE "COColorado  Denver     05187582".
      03 FILLER PIC X(38) VALUE "CTConnecticut Hartford    03590347".
      03 FILLER PIC X(38) VALUE "DEDelaware  Dover       00917092".
      03 FILLER PIC X(38) VALUE "FLFlorida   Tallahassee 19317568".
      03 FILLER PIC X(38) VALUE "GAGeorgia   Atlanta      09919945".
      03 FILLER PIC X(38) VALUE "HIHawaii    Honolulu     01392313".
      03 FILLER PIC X(38) VALUE "IDIdaho     Boise        01595728".
      03 FILLER PIC X(38) VALUE "ILIllinois   Springfield 12875255".
      03 FILLER PIC X(38) VALUE "INIndiana   Indianapolis 06537334".
      03 FILLER PIC X(38) VALUE "IAIowa      Des Moines  03074186".
      03 FILLER PIC X(38) VALUE "KSKansas    Topeka      02885905".
      03 FILLER PIC X(38) VALUE "KYKentucky  Frankfort   04380415".
      03 FILLER PIC X(38) VALUE "LALouisiana  Baton Rouge 04601893".
      03 FILLER PIC X(38) VALUE "MEMaine     Augusta     01329192".
      03 FILLER PIC X(38) VALUE "MDMaryland  Annapolis   05884563".
      03 FILLER PIC X(38) VALUE "MAMassachusetts Boston      06646144".
      03 FILLER PIC X(38) VALUE "MIMichigan  Lansing     09883360".
      03 FILLER PIC X(38) VALUE "MNMinnesota  Saint Paul  05379139".
      03 FILLER PIC X(38) VALUE "MSMississippi Jackson     02984926".
      03 FILLER PIC X(38) VALUE "MOMissouri   Jefferson City06021988".
```

```

03 FILLER PIC X(38) VALUE "MTMontana      Helena      01005141".
03 FILLER PIC X(38) VALUE "NENebraska   Lincoln     01855525".
03 FILLER PIC X(38) VALUE "NVNevada    Carson City 02758931".
03 FILLER PIC X(38) VALUE "NHNew Hampshire Concord    01320718".
03 FILLER PIC X(38) VALUE "NJNew Jersey  Trenton    08864590".
03 FILLER PIC X(38) VALUE "NMNew Mexico  Santa Fe   02085538".
03 FILLER PIC X(38) VALUE "NYNew York   Albany     19570261".
03 FILLER PIC X(38) VALUE "NCNorth Carolina Raleigh    09752073".
03 FILLER PIC X(38) VALUE "NDNorth Dakota Bismarck   00699628".
03 FILLER PIC X(38) VALUE "OHOhio      Columbus   11544225".
03 FILLER PIC X(38) VALUE "OKOklahoma  Oklahoma City 03814820".
03 FILLER PIC X(38) VALUE "OROregon    Salem     03899353".
03 FILLER PIC X(38) VALUE "PAPennsylvania Harrisburg 12763536".
03 FILLER PIC X(38) VALUE "RIRhode Island Providence 01050292".
03 FILLER PIC X(38) VALUE "SCSouth Carolina Columbia 04723723".
03 FILLER PIC X(38) VALUE "SDSouth Dakota Pierre     00833354".
03 FILLER PIC X(38) VALUE "TNTennessee Nashville 06456243".
03 FILLER PIC X(38) VALUE "TXTexas      Austin     26059203".
03 FILLER PIC X(38) VALUE "UTUtah       Salt Lake City02855287".
03 FILLER PIC X(38) VALUE "VTVermont    Montpelier 00626011".
03 FILLER PIC X(38) VALUE "VAVirginia   Richmond   08185867".
03 FILLER PIC X(38) VALUE "WAWashington  Olympia    06897012".
03 FILLER PIC X(38) VALUE "WVWest Virginia Charleston 01855413".
03 FILLER PIC X(38) VALUE "WIWisconsin  Madison    05726398".
03 FILLER PIC X(38) VALUE "WYWyoming     Cheyenne   00576412".
02 FILLER REDEFINES StateValues.
03 State OCCURS 50 TIMES
    INDEXED BY StateIdx.
    04 StateCode PIC XX.
    04 StateName PIC X(14).
    04 StateCapital PIC X(14).
    04 StatePop PIC 9(8).

```

LINKAGE SECTION.

```

01 StateNum-IO PIC 99.
    88 ValidStateNum VALUE 1 THRU 50.
01 StateCode-IO PIC XX.
01 StateName-IO PIC X(14).
01 StateCapital-IO PIC X(14).
01 StatePop-IO PIC 9(8).
01 ErrorFlag PIC 9.
    88 NoErrorFound VALUE ZERO.
    88 InvalidStateNum VALUE 1.
    88 NoSearchItems VALUE 2.
    88 NoSuchStateCode VALUE 3.
    88 NoSuchStateName VALUE 4.
    88 NoSuchCapital VALUE 5.

```

```

PROCEDURE DIVISION USING StateNum-IO, StateCode-IO, StateName-IO,
    StateCapital-IO, StatePop-IO, ErrorFlag.

```

Begin.

```

SET NoErrorFound TO TRUE
SET StateIdx TO 1
EVALUATE TRUE
  WHEN StateNum-IO NOT EQUAL ZEROS PERFORM SearchUsingStateNum
  WHEN StateCode-IO NOT EQUAL SPACES PERFORM SearchUsingStateCode
  WHEN StateName-IO NOT EQUAL SPACES PERFORM SearchUsingStateName
  WHEN StateCapital-IO NOT EQUAL SPACES PERFORM SearchUsingStateCapital
  WHEN OTHER SET NoSearchItems TO TRUE
END-EVALUATE
EXIT PROGRAM.

```

SearchUsingStateNum.

```

IF NOT ValidStateNum SET InvalidStateNum TO TRUE
ELSE
  MOVE StateCode(StateNum-IO) TO StateCode-IO
  MOVE StateName(StateNum-IO) TO StateName-IO
  MOVE StateCapital(StateNum-IO) TO StateCapital-IO
  MOVE StatePop(StateNum-IO) TO StatePop-IO
END-IF.

```

SearchUsingStateCode.

```

SEARCH State
  AT END SET NoSuchStateCode TO TRUE
  WHEN FUNCTION UPPER-CASE(StateCode(StateIdx)) EQUAL TO
    FUNCTION UPPER-CASE(StateCode-IO)
    SET StateNum-IO TO StateIdx
    MOVE StateCode(StateIdx) TO StateCode-IO
    MOVE StateName(StateIdx) TO StateName-IO
    MOVE StateCapital(StateIdx) TO StateCapital-IO
    MOVE StatePop(StateIdx) TO StatePop-IO
END-SEARCH.

```

SearchUsingStateName.

```

SEARCH State
  AT END SET NoSuchStateName TO TRUE
  WHEN FUNCTION UPPER-CASE(StateName(StateIdx)) EQUAL TO
    FUNCTION UPPER-CASE(StateName-IO)
    SET StateNum-IO TO StateIdx
    MOVE StateCode(StateIdx) TO StateCode-IO
    MOVE StateName(StateIdx) TO StateName-IO
    MOVE StateCapital(StateIdx) TO StateCapital-IO
    MOVE StatePop(StateIdx) TO StatePop-IO
END-SEARCH.

```

SearchUsingStateCapital.

```

SEARCH State
  AT END SET NoSuchCapital TO TRUE
  WHEN FUNCTION UPPER-CASE(StateCapital(StateIdx)) EQUAL TO
    FUNCTION UPPER-CASE(StateCapital-IO)
    SET StateNum-IO TO StateIdx

```

```

MOVE StateCode(StateIdx) TO StateCode-IO
MOVE StateName(StateIdx) TO StateName-IO
MOVE StateCapital(StateIdx) TO StateCapital-IO
MOVE StatePop(StateIdx) TO StatePop-IO
END-SEARCH.

```

This program takes as parameters StateNum-IO, StateCode-IO, StateName-IO, StateCapital-IO, StatePop-IO, and ErrorFlag. Whichever of the first four parameters has a value is used as the search term to find the other information about the state. For instance, if StateName-IO has a value, then that is used as the search term to find the state number, state code, state capital, and state population.

If an error condition is detected, such as none of the fields having a value, then the appropriate error condition is set; this results in an error code being returned in the ErrorFlag parameter. If ErrorFlag contains zero, then no error was detected. The errors detected are given by the following condition names:

```

88 NoErrorFound VALUE ZERO.
88 InvalidStateNum VALUE 1.
88 NoSearchItems VALUE 2.
88 NoSuchStateCode VALUE 3.
88 NoSuchStateName VALUE 4.
88 NoSuchCapital VALUE 5.

```

The State Knowledge Game

Listing 16-5 is a game to test your knowledge of the names, codes, capitals, and populations of American states. It uses the GetStateInfo external subprogram.

Listing 16-5. A Game to Test Your Knowledge of American States

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing16-5.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 Parameters.
   02 StateNum PIC 99.
   02 StateCode PIC XX.
   02 StateName PIC X(14).
   02 StateCapital PIC X(14).
   02 StatePop PIC 9(8).
   02 ErrorFlag PIC 9.

01 idx PIC 99.

01 CurrentTime.
   02 FILLER PIC 9(4).
   02 Seed PIC 9(4).
01 RandState PIC 99.
01 RandChoice PIC 9.

```

```

Listing 16-5 Output

Of what state is Santa Fe the capital? New mexico
That is correct

What is the population of Georgia? 6500300
That is incorrect. The population of Georgia is 9,919,945

What is the population of New Jersey? 8900500
That answer is close enough. The actual population is 8,864,590

Of what state is Madison the capital? texas
That is incorrect. The state for Madison is Wisconsin

What is the capital of Pennsylvania? harrisburg
That is correct

What is the capital of Illinois? dublin
That is incorrect. The capital of Illinois is Springfield

What is the state code for Tennessee? tn
That is correct

What is the population of Illinois? 12500500
That answer is close enough. The actual population is 12,875,255

```

```

01 Answer          PIC X(14).
01 PopAnswer       PIC 9(8).
01 MinPop          PIC 9(8).
01 MaxPop          PIC 9(8).
01 PrnStatePop     PIC ZZ,ZZZ,ZZ9.
01 StrLength       PIC 99.

```

PROCEDURE DIVISION.

Begin.

```

ACCEPT CurrentTime FROM TIME
COMPUTE RandState = FUNCTION RANDOM(Seed)
PERFORM 8 TIMES
    COMPUTE RandState = (FUNCTION RANDOM * 50) + 1
    COMPUTE RandChoice = (FUNCTION RANDOM * 4) + 1
    CALL "GetStateInfo"
        USING BY REFERENCE RandState, StateCode, StateName,
            StateCapital, StatePop, ErrorFlag
    EVALUATE RandChoice
        WHEN 1 PERFORM TestCapitalFromState
        WHEN 2 PERFORM TestCodeFromState
        WHEN 3 PERFORM TestPopFromState
        WHEN 4 PERFORM TestStateFromCapital
    END-EVALUATE
    DISPLAY SPACES
END-PERFORM
STOP RUN.

```

TestCapitalFromState.

```

CALL "GetStringLength" USING BY CONTENT StateName
    BY REFERENCE StrLength
DISPLAY "What is the capital of " StateName(1:StrLength) "? "
    WITH NO ADVANCING
ACCEPT Answer
IF FUNCTION UPPER-CASE(Answer) = FUNCTION UPPER-CASE(StateCapital)
    DISPLAY "That is correct"
ELSE
    DISPLAY "That is incorrect. The capital of " StateName(1:StrLength)
        " is " StateCapital
END-IF.

```

TestCodeFromState.

```

CALL "GetStringLength" USING BY CONTENT StateName
    BY REFERENCE StrLength
DISPLAY "What is the state code for " StateName(1:StrLength) "? "
    WITH NO ADVANCING
ACCEPT Answer
IF FUNCTION UPPER-CASE(Answer) = FUNCTION UPPER-CASE(StateCode)
    DISPLAY "That is correct"
ELSE
    DISPLAY "That is incorrect. The code for " StateName(1:StrLength)
        " is " StateCode
END-IF.

```

TestPopFromState.

```
CALL "GetStringLength" USING BY CONTENT StateName
                          BY REFERENCE StrLength
DISPLAY "What is the population of " StateName(1:StrLength) "? "
      WITH NO ADVANCING
ACCEPT PopAnswer
COMPUTE MinPop = PopAnswer - (PopAnswer * 0.25)
COMPUTE MaxPop = PopAnswer + (PopAnswer * 0.25)
MOVE StatePop TO PrnStatePop
IF StatePop > MinPop AND < MaxPop
  DISPLAY "That answer is close enough. The actual population is " PrnStatePop
ELSE
  DISPLAY "That is incorrect. The population of " StateName(1:StrLength)
    " is " PrnStatePop
END-IF.
```

TestStateFromCapital.

```
CALL "GetStringLength" USING BY CONTENT StateCapital
                          BY REFERENCE StrLength
DISPLAY "Of what state is " StateCapital(1:StrLength) " the capital? "
      WITH NO ADVANCING
ACCEPT Answer
IF FUNCTION UPPER-CASE(Answer) = FUNCTION UPPER-CASE(StateName)
  DISPLAY "That is correct"
ELSE
  DISPLAY "That is incorrect. The state for " StateCapital(1:StrLength)
    " is " StateName
END-IF.
```

IDENTIFICATION DIVISION.

PROGRAM-ID. GetStringLength IS INITIAL.

AUTHOR. Michael Coughlan.

DATA DIVISION.

WORKING-STORAGE SECTION.

01 CharCount PIC 99 VALUE ZEROS.

LINKAGE SECTION.

01 StringParam PIC X(14).

01 StringLength PIC 99.

PROCEDURE DIVISION USING StringParam, StringLength.

Begin.

```
INSPECT FUNCTION REVERSE(StringParam) TALLYING CharCount
      FOR LEADING SPACES
```

```
COMPUTE StringLength = 14 - CharCount
```

```
EXIT PROGRAM.
```

END PROGRAM GetStringLength.

END PROGRAM Listing16-5.

This program contains a number of interesting features. First, it uses the `RANDOM` intrinsic function. The first time `RANDOM` is invoked, it generates a sequence of pseudo-random numbers using the current time as a seed. Subsequent uses of `RANDOM` return instances of those numbers.

The program gets two random numbers: one to choose which state to ask about and the other to choose what kind of question to ask. Once the program has chosen the number of the state to ask about, it uses the `CALL` verb to get all the other information about the state. Depending on what question is asked, the program gets an answer from the user and then compares it with state information returned by the `CALL`.

Although most answers must be exact, conversion to uppercase is done so the letter case of the answer is not an issue. And because you can't expect users to know the exact population of a state, any answer within 25 percent (higher or lower) of the actual value is accepted as correct.

An interesting problem is caused by displaying state names and capitals when the text does not fill the data item. In that case, the data item is space filled, which causes unsightly output when the text is displayed. For instance, a question about the capital of Delaware might display as follows:

```
: Of what state is Dover           the capital?
```

To solve this issue, reference modification is used to slice out the actual text. To enable this slicing, the program calculates the length of the text. Because this operation is performed a number of times, it is removed to the contained subprogram `GetStringLength`.

Getting State Information

Listing 16-6 also uses the subprogram `GetStateInfo`, but in a more straightforward way. When the user provides a piece of information, such as a state name, the program displays all the other information about the state. The state number and the state code are two of the items displayed and you might think that having both of these items in the table is redundant. However, the importance of the state code is obvious and when I wrote the game in Listing 16-5 the state number proved useful because it made it easy to select the state at random. One other advantage of the state number is that you can use it to dump out all the values in the table (see Example 16-5).

Example 16-5. Fragment Showing How to Display the State Table Values

```
PERFORM VARYING idx FROM 1 BY 1 UNTIL idx > 50
  MOVE idx TO StateNum
  CALL "GetStateInfo"
    USING BY REFERENCE StateNum, StateCode, StateName,
      StateCapital, StatePop, ErrorFlag
  DISPLAY StateNum ". " StateCode SPACE StateName
    SPACE StateCapital SPACE StatePop
END-PERFORM
```

Listing 16-6. Using the `GetStateInfo` Subprogram as Intended

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing16-6.
AUTHOR. Michael Coughlan.
DATA DIVISION.
WORKING-STORAGE SECTION.
01 Parameters.
   02 StateNum      PIC 99.
   02 StateCode     PIC XX.
   02 StateName     PIC X(14).
```

```

02 StateCapital PIC X(14).
02 StatePop PIC 9(8).
02 ErrorFlag PIC 9.
   88 NoError VALUE ZERO.

01 CurrentTime.
   02 FILLER PIC 9(4).
   02 Seed PIC 9(4).
01 RandChoice PIC 9.
01 PrnStatePop PIC ZZ,ZZZ,ZZ9.

```

```
PROCEDURE DIVISION.
```

```
Begin.
```

```
ACCEPT CurrentTime FROM TIME
```

```
COMPUTE RandChoice = FUNCTION RANDOM(Seed)
```

```
PERFORM 8 TIMES
```

```
DISPLAY SPACES
```

```
INITIALIZE Parameters
```

```
COMPUTE RandChoice = (FUNCTION RANDOM * 4) + 1
```

```
EVALUATE RandChoice
```

```

WHEN 1 DISPLAY "Enter a state number - " WITH NO ADVANCING
      ACCEPT StateNum
WHEN 2 DISPLAY "Enter a two letter code - " WITH NO ADVANCING
      ACCEPT StateCode
WHEN 3 DISPLAY "Enter a state name - " WITH NO ADVANCING
      ACCEPT StateName
WHEN 4 DISPLAY "Enter a state capital - " WITH NO ADVANCING
      ACCEPT StateCapital

```

```
END-EVALUATE
```

```
CALL "GetStateInfo"
```

```

USING BY REFERENCE StateNum, StateCode, StateName,
                   StateCapital, StatePop, ErrorFlag

```

```
IF NoError
```

```
MOVE StatePop TO PrnStatePop
```

```

DISPLAY StateNum ". " StateCode SPACE StateName
      SPACE StateCapital SPACE PrnStatePop

```

```
ELSE
```

```
DISPLAY "There was an error. Error Code = " ErrorFlag
```

```
END-IF
```

```
END-PERFORM
```

```
STOP RUN.
```

Listing 16-6 Output

Enter a state name - maryland		
20. MD Maryland	Annapolis	5,884,563
Enter a state number - 23		
23. MN Minnesota	Saint Paul	5,379,139
Enter a state number - 12		
12. ID Idaho	Boise	1,595,728
Enter a state capital - topeka		
16. KS Kansas	Topeka	2,885,905
Enter a state name - arkansas		
04. AR Arkansas	Little Rock	2,949,131
Enter a state name - Mane		
There was an error. Error Code = 4		
Enter a two letter code - me		
19. ME Maine	Augusta	1,329,192
Enter a state number - 50		
50. WY Wyoming	Cheyenne	576,412

In this program the search term type is chosen at random, the user is asked to supply a value for it, and then GetStateInfo is called to return the appropriate values for that search term.

The IS EXTERNAL Clause

The IS GLOBAL clause allows a program and its contained subprograms to share access to a data item. The IS EXTERNAL clause does the same for any subprogram in a run-unit (that is, any linked subprogram), but it has restrictions that make it much more cumbersome to use than the IS GLOBAL phrase. Whereas a data item that uses the IS GLOBAL phrase only has to be declared in one place, each of the subprograms that wish to access an EXTERNAL shared item must declare the item—and it must be declared *exactly the same way* in each subprogram. Figure 16-7 illustrates the IS EXTERNAL data-sharing mechanism.

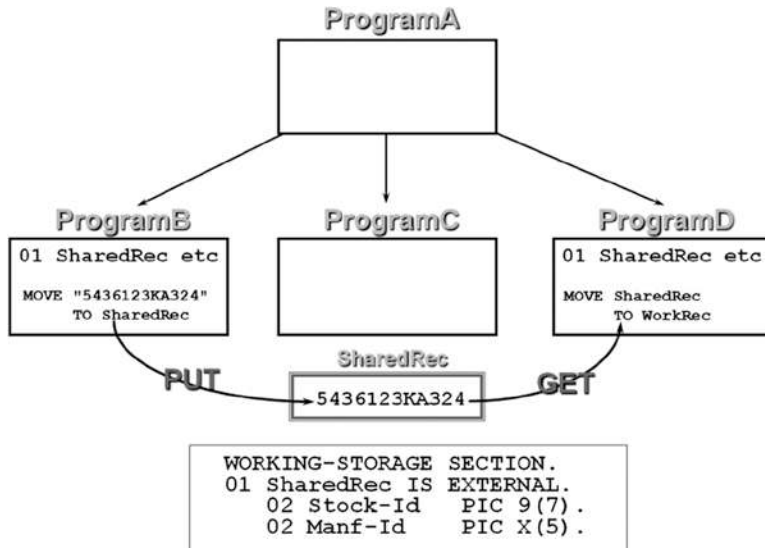


Figure 16-7. The IS EXTERNAL data-sharing mechanism

Figure 16-7 shows the calling structure of a run-unit that consists of four linked programs: a main program (ProgramA) and three subprograms. In the illustration, ProgramB and ProgramD share data using the IS EXTERNAL mechanism. In order to share the data, both subprograms must declare the data, and the declarations have to be exactly the same. That is, they must each have the following declaration:

```
01 SharedRec IS EXTERNAL.
02 Stock-Id PIC 9(7).
02 Manf-Id PIC X(5).
```

In this system, ProgramB communicates with ProgramD by passing it data through the shared data item SharedRec. This might work as follows: ProgramA does some work and then calls ProgramB, which moves a value into SharedRec as part of its work. When control returns to ProgramA, it does some more work, calls ProgramC to do some work, and then calls ProgramD. ProgramD then uses the data from the shared area SharedRec to perform its task.

IS EXTERNAL Problems

The problem with using the IS EXTERNAL phrase is that the transfer of data between ProgramB and ProgramD is detectable only by inspecting B and D. Even though ProgramA invokes B and D, a programmer inspecting A will not realize that B and D are secretly communicating. Even worse, at some point in the future, a maintenance programmer may decide that ProgramC needs to communicate with ProgramD using the shared area and may overwrite the data placed there by ProgramB.

The kind of hidden data communication between subprograms that you see when you use the IS EXTERNAL clause is generally regarded as very poor practice. According to the measures of module goodness discussed by Myers¹ *common coupling* is almost the worst kind of data connection you can have between modules. Subprograms that use the IS EXTERNAL clause to create shared data items are common coupled. Common-coupled modules exhibit a number of problems, such as naming dependencies, creation of dummy structures, and exposure to unnecessary data. Most of these issues are caused by the requirement that each subprogram that wants to use the shared area must describe it exactly the same way.

To illustrate the problem, consider the following scenario. A programmer creates a module to do check digit validation for the Stock-Id. Instead of using the parameter list to get the number to be validated, the programmer takes advantage of the fact that the Stock-Id is an EXTERNAL shared data item and gets access to the Stock-Id using this shared area. The first problem the programmer has is to make sure that their module is not overwriting the data moved into the shared area by some other subprogram. The second problem the programmer has is that their module has to describe the shared area as follows:

```
01 SharedRec IS EXTERNAL.
   02 Stock-Id  PIC 9(7).
   02 Manf-Id   PIC X(5).
```

Even though the module only requires access to the Stock-Id, the programmer has to create a dummy Manf-Id data item also. A maintenance programmer who was trying to understand how this subprogram worked might spend quite a bit of time trying to figure out the role of the dummy Manf-Id. A naming dependency problem might occur later.

Suppose a programmer writing a subprogram for the system to validate customer records discovers that the seven-digit Customer-Id uses a check digit for validation; so, the programmer decides to use the check-digit validation subprogram that has already been written. To use the subprogram, the programmer must pass the number to be validated through the shared data item. This requires the use of the following declaration:

```
01 SharedRec IS EXTERNAL.
   02 Stock-Id  PIC 9(7).
   02 Manf-Id   PIC X(5).
```

Again, a maintenance programmer examining the ValidateCustomerRecord subprogram might wonder why the program includes references to Stock-Id and Manf-Id when it is about validating customer records. The maintenance programmer might also wonder why the subprogram has the statement `MOVE Customer-Id TO Stock-Id` when these are clearly two very different items.

Using IS EXTERNAL Data Items

Even though using the IS EXTERNAL phrase to create a shared data item has many drawbacks, it may still be preferable to alternative solutions. For instance, sometimes a data item may need to be accessed by many of the subprograms in a system. In that case, your alternatives are to use the IS EXTERNAL phrase to allow the data item to be seen by

¹Myers G. Composite/structured design. New York: Van Nostrand Reinhold; 1978.

any subprogram that requires it or to pass the data item as a parameter. The problem with passing the data item as a parameter is that many of the subprograms that do not require access to the data item then only serve as conduits through which the data item is passed to a subordinate subprogram. This kind of data is called *tramp data*.

Tramp data has a number of drawbacks. It widens the parameter list for subprograms that don't directly use the data; it exposes those subprograms to unnecessary data, which increases the risk that the data will be compromised; and it unnecessarily complicates the code of those subprograms. Figure 16-8 illustrates the problem. In this system, the data item used by ProgG, ProgI, and ProgK is created in ProgJ. Because none of the subprograms that use the data item are directly called by ProgJ, the data item has to be passed up and down the calling chain as tramp data.

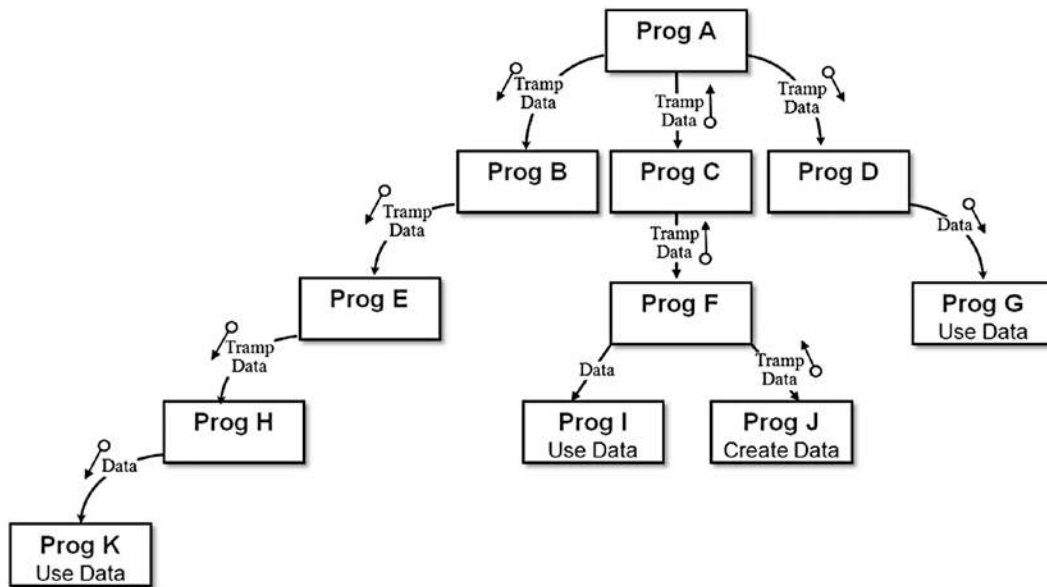


Figure 16-8. The problem of tramp data. Connecting arrows show the direction of calls. Circle arrows show the direction of data flow

If you have to use the IS EXTERNAL phrase, there are some things you can do to ameliorate the problems. First, to eliminate the need to create dummy structures, and to reduce exposure to unnecessary data, you should use IS EXTERNAL only with elementary data items. Second, only one subprogram should be permitted to assign a value to an IS EXTERNAL data item. All other subprograms should only be allowed to read that value.

The COPY Verb

The COPY verb is a library statement that includes prewritten library source code in a COBOL program or a subprogram. It is generally used when creating large software systems. These systems are subject to a number of problems that the COPY verb helps to alleviate. For instance, many of the files in a large software system are processed by more than one program. One issue with this is that if each programmer who creates a program or subprogram is allowed to define the files and records used, then there is a strong possibility that in some cases they will get the definitions wrong. They may make errors in defining the key fields (Indexed files); the file organization; the type of access allowed; or the number, type, and size of the fields in a record. At the very least, these kinds of errors will likely result in the failure of the program that contains the erroneous descriptions; but if the program writes to a file,

bugs may result that are much harder to find. For instance, if one program writes to a file using an incorrect record description while other programs read from the file using the correct description, a crash may occur in one of the correct subprograms rather than in the one that actually has the problem.

In a large software system, when file, record, or other data descriptions are common to a number of programs, it is very important that those descriptions be described in a central source text library under the control of a copy librarian. In such a system, only the copy librarian has permission to change the data definitions, but any programmer who needs to use the data resource can copy its description into their program using the COPY verb. Using copy libraries makes it more difficult for programmers to make ad hoc changes to file and record formats and makes implementation simpler by reducing the amount of coding required and by eliminating transcription errors. For instance, when a number of programs need to access the same file, the relevant file and record descriptions can be copied from a copy library instead of each programmer having to type their own (and possibly get them wrong).

The COPY verb can also make some maintenance tasks easier and safer. For instance, if a record description in a copy library is changed, then all that is required for that change to take effect is for each affected program to be recompiled.

The COPY Metalanguage

The metalanguage for the COPY verb is given in Figure 16-9. Text can be copied from the copy file or copy library and inserted into the program source code as is, or *text words* in the copied text can be replaced by the text specified in the REPLACING phrase. If REPLACING is used, then the items before the word BY are the text-matching arguments used to identify the text words in the copied text that should be replaced by the text specified.

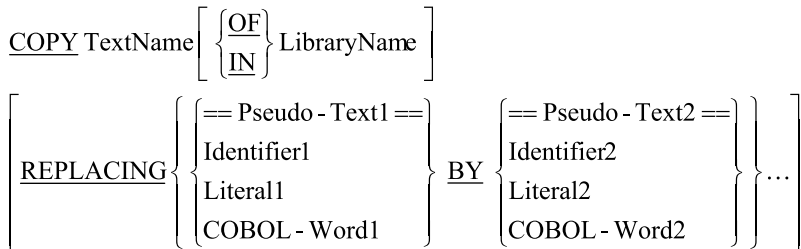


Figure 16-9. COPY verb metalanguage

How COPY Works

The COPY verb operates in an unusual way. Whereas other COBOL statements are executed at runtime, a COPY statement is executed at compile time. A COPY statement allows programmers to include in their programs the text of frequently used file, record, or other data descriptions. The included text is copied from a copy file or a copy library. The COPY statement is similar to the #include used in C or C++.

When a COPY statement is used in a COBOL program, the source-code text is copied into the program from a copy file or from a copy library before the program is compiled. A *copy file* is a file containing a segment of COBOL code. A *copy library* is a collection of code segments, each of which can be referenced using a name. Each client program that wants to use the items described in the copy library uses the COPY verb to include the descriptions it requires. When COPY statements copy source code into a program, the code can be included without change or the text can be changed as it is copied into the program. The ability to change the code as it is being included greatly adds to the versatility of the COPY verb.

How the REPLACING Phrase Works

When the REPLACING phrase is used, as the text is copied from the copy file, each properly matched occurrence of Pseudo-Text1, Identifier1, Literal1, and COBOL-Word1 in the library text is replaced by the corresponding Pseudo-Text2, Identifier2, Literal2, or COBOL-Word2 in the REPLACING phrase:

- Pseudo-Text is any COBOL text enclosed in double equal signs (for example, ==ADD 1==). It allows you to replace a series of words or characters as opposed to individual items.
- COBOL-Word is any single COBOL reserved word.

For the purposes of matching, the REPLACING phrase operates on text words. A text word may be defined as follows:

- Any literal, including opening and closing quotes
- Any separator except a space, a pseudo-text delimiter (==), a comma, or a semicolon
- Any other sequence of contiguous characters bounded by separators, except comment lines

COPY Examples

It can be very difficult to get a feel for how REPLACING works by reading textual descriptions alone, so this section presents a number of examples that I hope help your understanding. Listing 16-7 is a simple example that shows how you can use the COPY statement to copy a record description from a copy file. It also shows how to copy a table description from a copy file in a copy library. The REPLACING phrase is used with the second COPY statement to change the size of the table when the text is copied. Don't look for any significant meaning in this program—it simply shows how you can use the COPY statement to include text in your program source code.

Listing 16-7. Using the COPY Statement to Include Text

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing16-7.
AUTHOR. Michael Coughlan.
```

```
ENVIRONMENT DIVISION.
FILE-CONTROL.
    SELECT StudentFile ASSIGN TO "STUDENTS.DAT"
    ORGANIZATION IS LINE SEQUENTIAL.
```

```
DATA DIVISION.
FILE SECTION.
FD StudentFile.
COPY StudentRec.
```

```
WORKING-STORAGE SECTION.
01 Idx      PIC 9(3).
```

```
01 NameTable.
COPY StudentNameTable IN EG-Lib
    REPLACING XYZ BY 120.
```

```

StudentRec Copy File
01 StudentRec.
   88 EndOfSF VALUE HIGH-VALUES.
   02 StudentNumber      PIC 9(7) .
   02 StudentName.
       03 Surname       PIC X(12) .
       03 Initials      PIC XX.
   02 CourseCode        PIC X(5) .
   02 Gender             PIC X.
```

```

StudentNameTable Copy File in EG-Lib
StudSurname PIC X(12) OCCURS XYZ TIMES.
```

```

PROCEDURE DIVISION.
BeginProg.
  OPEN INPUT StudentFile
  READ StudentFile
  AT END SET EndOfSF TO TRUE
END-READ
PERFORM VARYING Idx FROM 1 BY 1 UNTIL EndOfSF
  MOVE Surname TO StudSurname(Idx)
  DISPLAY StudentNumber SPACE StudentName SPACE CourseCode
  READ StudentFile
  AT END SET EndOfSF TO TRUE
END-READ
END-PERFORM
CLOSE StudentFile
STOP RUN.

```

Listing 16-8 is a program used as a container for a number of COPY . .REPLACING examples. I inserted comments into the program to indicate the purpose of the particular example, and the output shows that the replacements have been made.

Listing 16-8. COPY Statements with REPLACEMENT Text

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing16-8
AUTHOR. Michael Coughlan.

```

```

DATA DIVISION.
WORKING-STORAGE SECTION.
01 CopyData.

```

```

COPY Copybook1
  REPLACING S BY 15.
* Changes the size of a data item

```

```

COPY Copybook2 REPLACING ==V99== BY ==.
* Changes the type of a data item to an integer

```

```

COPY Copybook3 REPLACING "CustKey" BY "MyValue".
COPY Copybook3 REPLACING CustKey BY NewKey.
* demonstrates the difference between a literal and a COBOL-Word

```

```

COPY Copybook3 REPLACING CustKey BY
==CustAddress.
  03 ADR1          PIC X(10).
  03 ADR2          PIC X(10).
  03 ADR3          PIC X(10).
02 CustId==.

```

Copybook1

```

02 CustomerName  PIC X(S).
* S is a textword because it is
* bounded by the ( and ) delimiters

```

Copybook2

```

02 CustomerOrder PIC 9(6)V99.
* V99 is a textword because it is
* bounded by ) and . delimiters

```


*Changes the CustKey declaration to add some new data items.

*After REPLACEMENT the included text will be -

```
* 02 CustAddress.
* 03 ADR1          PIC X(10).
* 03 ADR2          PIC X(10).
* 03 ADR3          PIC X(10).
* 02 CustID       PIC X(7) VALUE "CustKey".
```

Copybook3

```
02 CustKey          PIC X(7) VALUE "CustKey".
* "CustKey" including the quotes is a text word
* CustKey is a different text word
```

PROCEDURE DIVISION.

BeginProg.

```
MOVE "123456789012345678901234567890" TO CustomerName
DISPLAY "CustomerName - " CustomerName
```

```
MOVE 1234.56 TO CustomerOrder
DISPLAY "CustomerOrder - " CustomerOrder
```

```
DISPLAY "CustKey value changed to - " CustKey
```

```
DISPLAY "NewKey value - " NewKey
```

```
MOVE "Dublin" TO ADR3
```

```
DISPLAY "CustID value - "CustID
```

STOP RUN.

Listing 16-8 Output

```
CustomerName - 123456789012345
CustomerOrder - 001234
CustKey value changed to - MyValue
NewKey value - CustKey
CustID value - CustKey
```

Summary

This chapter introduced you to the COBOL elements required when you create a large software system. You learned about subprograms and how to create both contained and external subprograms. The chapter discussed the COBOL parameter-passing mechanisms and introduced the LINKAGE SECTION. You learned about state memory and saw how to use the IS INITIAL phrase or the CANCEL verb to create a subprogram that does not have state memory. The chapter covered the need for some shared data items in a system partitioned into subprograms and introduced the IS GLOBAL and IS EXTERNAL clauses.

The final section explored the benefits of holding file, record, and other data descriptions in a centralized library. You also learned about the COPY verb, which allows you to include such descriptions in your program's source code. You saw how to use the COPY verb to include the text from a copy file or copy library in your program.

The next chapter returns to the subject of file handling. You learn about COBOL's direct-access file organizations: relative files and indexed files. These direct-access file organizations are more versatile than sequential files, and to take advantage of that versatility, COBOL introduces a number of new verbs and makes changes to some of the file-handling verbs with which you are already familiar. Chapter 17 introduces the DELETE, REWRITE, and START verbs and the concepts of the *key of reference* and the *next record pointer*. The chapter concludes with a discussion of the advantages and disadvantages of all the COBOL file organizations and when to use one rather than another.

PROGRAMMING EXERCISE

Ah! Exercise time again. If only I had shares in a 2B pencil company.

Introduction

It has long been suspected that compatibility of Zodiac signs (also called star signs or birth signs) is a strong indicator of sexual and emotional compatibility. By processing the information in the Married Persons Date of Birth file, the program you write will test this hypothesis empirically. For each record in the file, the program will use the couple's dates of birth to identify their signs and discover whether those signs are compatible.

The program should display the following items:

- The count of the total number of records in the file
- The count of the total number of valid records (that is, records where neither is a cusp birth)
- The count of the number of compatible pairs, and the percentage of the total valid records that this represents
- The count of the number of incompatible pairs, and the percentage of the total valid records that this represents

Every Zodiac sign is compatible with itself and five other signs. A chance selection of life partner should therefore result in 50% of the pairings having compatible Zodiac signs. A significant deviation either way would be of interest, but if significantly more than 50% of the pairings have compatible signs, you would have to conclude that Zodiac signs are a good indicator of compatibility.

The File

The Census Office has made available to you the Married Persons Date of Birth file (`Listing16-9MPDOB.Dat`). This file consists of information extracted from the most recent census. The file is an unordered sequential file; each record contains the dates of birth of a married couple. The records have the following description:

Field	Type	Length	Value
MaleDOB	9	8	Date in mmddyyyy format
FemaleDOB	9	8	Date in mmddyyyy format

The Problem of the Cusp

In astrology, people whose birth dates fall near the changeover from one sign to the next are said to be “born on the cusp.” The problem is that these persons may exhibit characteristics from both signs. If this is true, then being born on the cusp may distort the compatibility results. To prevent this, the program should treat as invalid all records where one or both of the dates of birth fall on the cusp.

The Zodiac Table

The Zodiac Table is given next. It contains the `SignName`, `SignType`, `StartDate`, and `EndDate` of each sign. The cusp is defined as a two-day gap between the `EndDate` of one sign and the `StartDate` of the next and is built into the dates shown in the table.

SignType indicates sign compatibility where

- Air and Fire signs are compatible with themselves and with each other.
- Earth and Water signs are compatible with themselves and with each other.

The Zodiac Table

SignCode	Sign	SignType	StartDate	EndDate
1	Aquarius	Air	01-22	02-18
2	Pisces	Water	02-21	03-19
3	Aries	Fire	03-22	04-19
4	Taurus	Earth	04-22	05-20
5	Gemini	Air	05-23	06-20
6	Cancer	Water	06-23	07-22
7	Leo	Fire	07-25	08-22
8	Virgo	Earth	08-25	09-22
9	Libra	Air	09-25	10-22
10	Scorpio	Water	10-25	11-21
11	Sagittarius	Fire	11-24	12-20
12	Capricorn	Earth	12-23	01-19
13	Cusp	Cusp	Cusp	Cusp

Processing

Write a contained subprogram called `IdentifySign` to identify the Zodiac sign for a given birth date. The `IdentifySign` subprogram should take `DateOfBirth` as an input parameter and should return `SignCode` (shown in the previous table) as its return/output parameter. A code of 13 should be returned for cusp births.

For each record in the file, do the following:

- Increment the `TotalRecords` count.
- Call `IdentifySign` to get `ZodiacSign` for `MaleDOB`.
- Call `IdentifySign` to get `ZodiacSign` for `FemaleDOB`.

If either spouse had a cusp birth, then ignore the record. Otherwise, if the signs are compatible, increment the `CompatiblePairs` count; and if they are incompatible, increment the `IncompatiblePairs` count.

PROGRAMMING EXERCISE: ANSWER

Listing 16-9. Zodiac Sign Compatibility Tester

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing16-9.
AUTHOR. Michael Coughlan.

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT BirthsFile ASSIGN TO "Listing16-9MPDOB.DAT"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD BirthsFile.
01 BirthsRec.
    88 EndOfFile VALUE HIGH-VALUES.
    02 MaleDOB PIC X(8).
    02 FemaleDOB PIC X(8).

WORKING-STORAGE SECTION.
01 Counts.
    02 CompatiblePairs PIC 9(7) VALUE ZEROS.
    02 CompatiblePrn PIC ZZZZ,ZZ9.
    02 CompatiblePercent PIC ZZ9.
    02 IncompatiblePairs PIC 9(7) VALUE ZEROS.
    02 IncompatiblePrn PIC ZZZZ,ZZ9.
    02 IncompatiblePercent PIC ZZ9.
    02 ValidRecs PIC 9(8) VALUE ZEROS.
    02 ValidRecsPrn PIC ZZ,ZZZ,ZZ9.
    02 TotalRecs PIC 9(9) VALUE ZEROS.
    02 TotalRecsPrn PIC ZZ,ZZZ,ZZ9.

01 MaleSignType PIC 99.
    88 ValidMale VALUE 1 THRU 12.

01 FemaleSignType PIC 99.
    88 ValidFemale VALUE 1 THRU 12.

01 SumOfSigns PIC 99.

PROCEDURE DIVISION.
Begin.
    OPEN INPUT BirthsFile.
    READ BirthsFile
        AT END SET EndOfFile TO TRUE
    END-READ
    PERFORM ProcessBirthRecs UNTIL EndOfFile

```

```

COMPUTE ValidRecs = CompatiblePairs + IncompatiblePairs
COMPUTE CompatiblePercent ROUNDED = CompatiblePairs / ValidRecs * 100
COMPUTE InCompatiblePercent ROUNDED = InCompatiblePairs / ValidRecs * 100

```

```
PERFORM DisplayResults
```

```

CLOSE BirthsFile.
STOP RUN.

```

```
DisplayResults.
```

```

MOVE CompatiblePairs TO CompatiblePrn
MOVE IncompatiblePairs TO IncompatiblePrn
MOVE TotalRecs TO TotalRecsPrn
MOVE ValidRecs TO ValidRecsPrn

```

```

DISPLAY "Total records = " TotalRecsPrn
DISPLAY "Valid records = " ValidRecsPrn
DISPLAY "Compatible pairs = " CompatiblePrn
    " which is " CompatiblePercent "% of total".
DISPLAY "Incompatible pairs = " IncompatiblePrn
    " which is " InCompatiblePercent "% of total".

```

```
ProcessBirthRecs.
```

```

* Get the two sign types and add them together
* If the result is even then they are compatible
ADD 1 TO TotalRecs
CALL "IdentifySign" USING BY CONTENT MaleDOB
    BY REFERENCE MaleSignType

CALL "IdentifySign" USING BY CONTENT FemaleDOB
    BY REFERENCE FemaleSignType
IF ValidMale AND ValidFemale
    COMPUTE SumOfSigns = MaleSignType + FemaleSignType
    IF FUNCTION REM(SumOfSigns 2) = ZERO
        ADD 1 TO CompatiblePairs
    ELSE
        ADD 1 TO IncompatiblePairs
    END-IF
END-IF
READ BirthsFile
    AT END SET EndOfFile TO TRUE
END-READ.

```

```
IDENTIFICATION DIVISION.
```

```
PROGRAM-ID. IdentifySign IS INITIAL.
```

```
DATA DIVISION.
```

```
WORKING-STORAGE SECTION.
```

```
01 WorkDate.
```

```

88 Aquarius VALUE "0122" THRU "0218".
88 Pisces VALUE "0221" THRU "0319".
88 Aries VALUE "0322" THRU "0419".

```

```

88 Taurus      VALUE "0422" THRU "0520".
88 Gemini      VALUE "0523" THRU "0620".
88 Cancer     VALUE "0623" THRU "0722".
88 Leo        VALUE "0725" THRU "0822".
88 Virgo      VALUE "0825" THRU "0922".
88 Libra      VALUE "0925" THRU "1022".
88 Scorpio    VALUE "1025" THRU "1121".
88 Sagittarius VALUE "1124" THRU "1220".
88 Capricorn  VALUE "1223" THRU "1231", "0101" THRU "0119".
02 WorkMonth  PIC XX.
02 WorkDay    PIC XX.

```

LINKAGE SECTION.

```

01 DateOfBirth.
  02 BirthMonth PIC XX.
  02 BirthDay   PIC XX.
  02 FILLER     PIC 9(4).

```

```

01 SignType      PIC 99.

```

PROCEDURE DIVISION USING DateOfBirth, SignType.

Begin.

```

  MOVE BirthDay TO WorkDay.
  MOVE BirthMonth TO WorkMonth.
  EVALUATE TRUE
    WHEN Aquarius   MOVE 1 TO SignType
    WHEN Pisces     MOVE 2 TO SignType
    WHEN Aries      MOVE 3 TO SignType
    WHEN Taurus     MOVE 4 TO SignType
    WHEN Gemini      MOVE 5 TO SignType
    WHEN Cancer     MOVE 6 TO SignType
    WHEN Leo        MOVE 7 TO SignType
    WHEN Virgo      MOVE 8 TO SignType
    WHEN Libra      MOVE 9 TO SignType
    WHEN Scorpio    MOVE 10 TO SignType
    WHEN Sagittarius MOVE 11 TO SignType
    WHEN Capricorn  MOVE 12 TO SignType
    WHEN OTHER      MOVE 13 TO SignType

```

END-EVALUATE.

EXIT PROGRAM.

END PROGRAM IdentifySign.

END PROGRAM Listing16-9.



Direct Access Files

When I learned COBOL many years ago, direct access files, and particularly indexed files, were the jewel in COBOL's crown. No other mainstream programming language provided native support for file organizations of such versatility. Nowadays, the predominance of databases means that the importance of direct access files in modern COBOL programming is greatly reduced. Nevertheless, the huge inventory of legacy programs that still use direct access files makes these file organizations a worthwhile topic of discussion.

This chapter introduces you to COBOL's direct access file organizations: indexed and relative files. These organizations are called *direct access organizations* because they allow you to access data records directly based on a key field. Direct access files are more versatile than sequential files. They let you update or delete records in situ and access records sequentially or directly using a key field. Needless to say, direct access files only work on direct access media such as hard disks. You can't use indexed or relative files with serial media such as magnetic tapes. To take advantage of the versatility of direct access files, you use a number of new COBOL verbs and concepts. This chapter introduces the DELETE, REWRITE, and START verbs and the concepts of *file status*, the *key of reference*, and the *next-record pointer*.

Sequential, indexed, and relative file organizations all have strengths and weaknesses. No one organization is best for all situations. This chapter concludes with a discussion of the advantages and disadvantages of all the COBOL file organizations and when you should use one rather than another.

Direct Access vs. Sequential Files

As you learned in Chapter 10, access to records in a sequential file is serial. To reach a particular record, you must read all the preceding records. You also learned that if the sequential file is unordered, the only practical operations are to read records from the file or add records to the end of the file. It is impractical to update records or delete records in an unordered sequential file. In addition, even if the file is ordered, inserting, updating, or deleting records is a problem because when you apply these operations, you must preserve the ordering of the file—and the only way to do that is to create a copy of the file to which these operations have been applied.

Although sequential files have a number of advantages over other types of file organization (as discussed in the final section of this chapter), the fact that you must create a new file when you delete, update, or insert records is problematic.

These problems are addressed by direct access files. Direct access files allow you to read, update, delete, and insert individual records in situ on the basis of a key value. For instance, to delete a customer record in a direct access file, you supply the customer ID of the record to be deleted and then execute a DELETE statement.

In COBOL, there are two direct access file organizations: relative files and indexed files.

Organization of Relative Files

Before you see how relative files are declared and used, let's look at how they are organized. As you can see from the schematic representation in Figure 17-1, the records in a relative file are organized on ascending *relative record number*. You can visualize a relative file as a one-dimensional table stored on disk, and you can think of the relative record number as the index into that table.

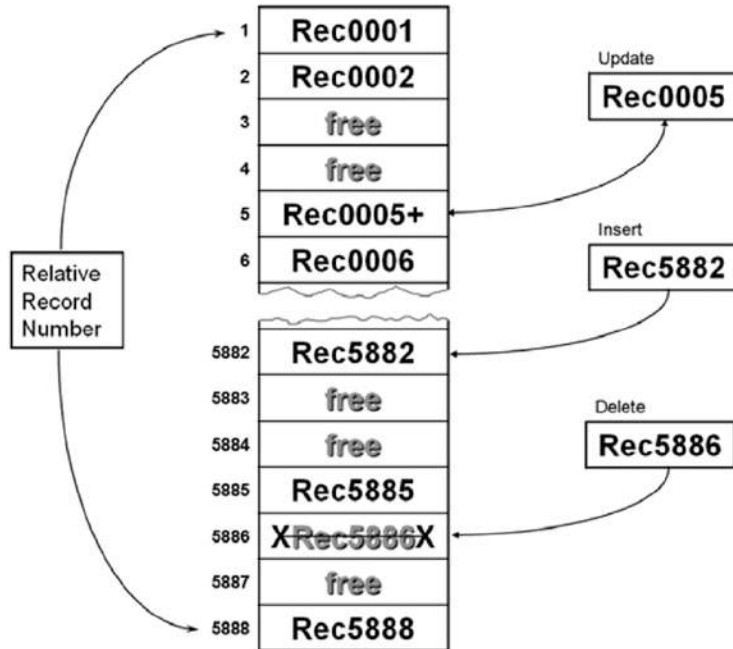


Figure 17-1. Schematic representation of a relative file

Some restrictions should be obvious from Figure 17-1. First, only one relative key is supported, and that key must be numeric and take a value between 1 and the number of the highest relative record written to the file. Another restriction is that, even when the file is only sparsely populated, enough disk space has to be allocated to hold all the records between 1 and the record with the highest relative record number. For instance, if a record with a relative record number of 150,000 is written to the file, then room sufficient for 150,000 records is allocated to the file—even though that may be the only record actually written to the file. You can see this illustrated in Figure 17-1. In the example file, the record with the highest relative record number is 5,888, so disk space sufficient to store 5,888 records has been allocated. However, not all the record locations contain records. The record areas labelled “free” have been allocated but have not yet had record values written to them.

Being restricted to a single numeric key in a defined range is onerous, but there are ways to loosen the shackles. For instance, you might add a base value to the relative record number to change the range. For instance, in Figure 17-1 you could use a base of 10,000 so that the first record key value would be 10,001 and the last would be 15,888. Obviously, before you used the key, you would subtract 10,000 to convert it into the relative record number.

Using a base value is a very simple key transformation, and in COBOL this is probably about as much manipulation as you want to do. In other languages, you might write a sophisticated hashing algorithm to map even alphanumeric keys onto range of relative record numbers; but in COBOL, when you need keys with this level of sophistication, you use indexed files.

In addition to showing how records are organized in a relative file, Figure 17-1 also shows how updates, insertions and, deletions are applied:

- To update a record, you use the relative record number to READ the record from the file into the record buffer. Then you make the changes to the record data and REWRITE the record to the file.
- To insert a record, you use the relative record number to tell the system where to WRITE the record. Obviously, the allocated space must be free, or an error condition will occur.
- To delete a record, you use the relative record number to tell the system which record to DELETE. Obviously, the record must exist. For instance, in Figure 17-1, an error condition would occur if you tried to delete the record with the relative record number 5,887 because there is no record in that position. In a relative file, when you delete a record, all the file system does is to mark it as deleted. It does not really delete the record.

Processing Relative Files

As mentioned at the beginning of this chapter, direct access files are declared and processed using a number of new declaration clauses and verbs. Instead of boring you with a dry, formal introduction, this section shows you some simple examples. Once you have a feel for how it all works, I introduce the required clauses and verbs more formally.

Let's start with a simple program that reads a relative file both sequentially and directly. Then you learn how to create a relative file from a sequential file. Most programming environments have tools that allow you to do this, but it is interesting to see how to do it by hand. The final example shows you how to apply a file of transactions to the relative file.

Reading a Relative File

The program in Listing 17-1 reads a relative file either sequentially or directly, depending on the choice made by the user.

Listing 17-1. Reading a Relative File Sequentially or Directly Using a Key

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing17-1.
AUTHOR. MICHAEL COUGHLAN.
* Reads a Relative file directly or in sequence

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT VehicleFile ASSIGN TO "Listing17-1.DAT"
        ORGANIZATION IS RELATIVE
        ACCESS MODE IS DYNAMIC
        RELATIVE KEY IS VehicleKey
        FILE STATUS IS VehicleStatus.

DATA DIVISION.
FILE SECTION.
FD VehicleFile.
01 VehicleRec.
    88 EndOfVehiclefile          VALUE HIGH-VALUES.
    02 VehicleNum                PIC 9(4).
    02 VehicleDesc               PIC X(25).
    02 ManfName                  PIC X(20).
```

WORKING-STORAGE SECTION.

```

01 VehicleStatus          PIC X(2).
   88 RecordFound        VALUE "00".

01 VehicleKey             PIC 9(4).

01 ReadType               PIC 9.
   88 DirectRead         VALUE 1.
   88 SequentialRead     VALUE 2.

01 PrnVehicleRecord.
   02 PrnVehicleNum      PIC 9(4).
   02 PrnVehicleDesc    PIC BBX(25).
   02 PrnManfName       PIC BBX(20).

```

PROCEDURE DIVISION.

BEGIN.

```

OPEN INPUT VehicleFile
DISPLAY "Read type : Direct read = 1, Sequential read = 2 --> "
      WITH NO ADVANCING.

```

```

ACCEPT ReadType
IF DirectRead
  DISPLAY "Enter vehicle key (4 digits) --> " WITH NO ADVANCING
  ACCEPT VehicleKey
  READ VehicleFile
  INVALID KEY DISPLAY "Vehicle file status = " VehicleStatus
  END-READ
  PERFORM DisplayRecord
END-IF

```

```

IF SequentialRead
  READ VehicleFile NEXT RECORD
  AT END SET EndOfVehiclefile TO TRUE
  END-READ
  PERFORM UNTIL EndOfVehiclefile
    PERFORM DisplayRecord
    READ VehicleFile NEXT RECORD
    AT END SET EndOfVehiclefile TO TRUE
  END-READ
  END-PERFORM
END-IF
CLOSE VehicleFile
STOP RUN.

```

DisplayRecord.

```

IF RecordFound
  MOVE VehicleNum TO PrnVehicleNum
  MOVE VehicleDesc TO PrnVehicleDesc
  MOVE ManfName TO PrnManfName
  DISPLAY PrnVehicleRecord
END-IF.

```

```

Listing 17-1 Output
Run 1
Read type : Direct read = 1, Sequential read = 2 --> 2
0001 Roadster          Tesla Motors
0002 Volt              Chevrolet
0005 ZOE               Renault
0007 Focus Electric   Ford
0011 Fit EV           Honda
0016 Model S          Tesla Motors
0017 Prius            Toyota
0018 Spark EV         Chevrolet
0113 i-MiEV           Mitsubishi
0124 Twizzy           Renault
0126 BMW i3           BMW
0133 Fluence Z.E     Renault
0135 C-Zero           Citroen
0136 Model X          Tesla Motors
0200 Leaf             Nissan
0210 e-Golf           Volkswagen
2301ON                Peugeot

Run 2
Read type : Direct read = 1, Sequential read = 2 --> 1
Enter vehicle key (4 digits) --> 0016
0016 Model S          Tesla Motors

```

The first thing to note is that the SELECT and ASSIGN clause has a number of new entries. First, ORGANIZATION is now RELATIVE. Second, because a relative file allows you to access the records in the file directly or sequentially, you must have an ACCESS MODE phrase to say what kind of access you desire on the file. Three types of access are available: RANDOM (key-based access only), SEQUENTIAL (sequential only), and DYNAMIC (a mixture of keyed and sequential access). Third, to allow key-based access, you must specify a RELATIVE KEY phrase to tell the system where it can find the key value used for direct access. Note that the key mentioned here *cannot* be part of the record description.

The final entry is the FILE STATUS clause. The FILE STATUS clause allows you to identify a two-character area of storage to hold the result of every I/O operation for the file. The FILE STATUS data item is declared as PIC X(2) in the WORKING-STORAGE SECTION. Whenever an I/O operation is performed on the file, some value is returned to FILE STATUS indicating whether the operation was successful. I introduce these FILE STATUS values as and when they occur; for this program, you only need to know that a value of "00" indicates that the operation (READ, in this case) was successful.

The FILE STATUS clause is not restricted to direct access files. You can use it with sequential files, but that isn't necessary because with those files there are not many states that you need to detect. However, with direct access files, a number of file states need to be detected. For instance, you need to detect when an attempt is made to READ, DELETE, or REWRITE a record when a record with that key value does not exist in the file. Similarly, you need to be able to detect when an attempt to WRITE a record finds that there is *already* a record with that key value in the file.

The next item of note is the change to the READ verb. The direct READ now takes the INVALID KEY clause. This clause allows you to execute some code when an error condition is detected. The sequential read may now use the NEXT RECORD phrase. This phrase is required when ACCESS MODE is DYNAMIC, to indicate that this is a sequential read. If ACCESS MODE is SEQUENTIAL, then you use the standard READ statement.

Creating a Relative File from a Sequential File

Listing 17-2 shows how to create a relative file from a sequential file. A relative file is a binary file. It can't be edited in a standard text editor. This makes it a bit awkward to create test data, but most COBOL programming environments have tools that allow you to generate a relative file from a sequential one. Of course, you don't have to use the tools; you can write a program to do it, as in this example.

Listing 17-2. Creating a Relative File from a Sequential File

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing17-2.
AUTHOR. MICHAEL COUGHLAN.
* Reads a Relative file directly or in sequence

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT VehicleFile ASSIGN TO "Listing17-2.DAT"
        ORGANIZATION IS RELATIVE
        ACCESS MODE IS RANDOM
        RELATIVE KEY IS VehicleKey
        FILE STATUS IS VehicleStatus.

    SELECT Seqfile ASSIGN TO "Listing17-2.SEQ"
        ORGANIZATION IS LINE SEQUENTIAL.
```

```

DATA DIVISION.
FILE SECTION.
FD VehicleFile.
01 VehicleRec.
   02 VehicleNum           PIC 9(4).
   02 VehicleDesc         PIC X(25).
   02 ManfName             PIC X(20).

FD SeqFile.
01 VehicleRec-SF.
   88 EndOfSeqfile        VALUE HIGH-VALUES.
   02 VehicleNum-SF       PIC 9(4).
   02 VehicleDesc-SF      PIC X(25).
   02 ManfName-SF         PIC X(20).

WORKING-STORAGE SECTION.
01 VehicleStatus          PIC X(2).
   88 RecordFound         VALUE "00".

01 VehicleKey             PIC 9(4).

PROCEDURE DIVISION.
BEGIN.
  OPEN INPUT SeqFile
  OPEN OUTPUT VehicleFile
  READ SeqFile
    AT END SET EndOfSeqFile TO TRUE
  END-READ
  PERFORM UNTIL EndOfSeqFile
    MOVE VehicleNum-SF TO VehicleKey
    WRITE VehicleRec FROM VehicleRec-SF
      INVALID KEY DISPLAY "Vehicle file status = " VehicleStatus
    END-WRITE
    READ SeqFile
      AT END SET EndOfSeqFile TO TRUE
    END-READ
  END-PERFORM

  CLOSE SeqFile, VehicleFile
  STOP RUN.

```

In this program, the first thing to note is that because the relative file only uses direct access, the ACCESS MODE specified is RANDOM.

The relative file is created as follows. For each record in the sequential file, the program reads the record, moves the contents of the VehicleNum field to the relative key VehicleKey, and then writes the relative record from the sequential record. The record is written into the position indicated by the relative record number in VehicleKey.

Applying Transactions to a Relative File

In this final example program (see Listing 17-3), you see how to apply a sequential file of transactions to the relative vehicle master file. The transaction file contains only enough transactions to demonstrate valid and invalid insertions, valid and invalid updates (VehicleDesc is updated), and valid and invalid deletions. To keep the program short, it uses displays to report transaction errors. To make the updates clear, the contents of the vehicle master file are displayed before and after the transactions are applied. The contents of the transaction file are shown in Example 17-1.

Example 17-1. Contents of the Transaction File

```
I0001 *** invalid insert ***  Tesla Motors
D0006 *** invalid delete ***
U0017FCV +valid update
U0117 *** invalid update ***
D0135 +valid delete
I0205Model C +valid insert  Tesla Motors
I0230 *** invalid insert ***  Peugeot
```

Listing 17-3. Applying a Sequential File of Transactions to a Relative File

```
IDENTIFICATION DIVISION.
PROGRAM-ID.  Listing17-3.
AUTHOR.  MICHAEL COUGHLAN.

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT VehicleMasterFile ASSIGN TO "Listing17-3.DAT"
        ORGANIZATION IS RELATIVE
        ACCESS MODE IS DYNAMIC
        RELATIVE KEY IS VehicleKey
        FILE STATUS  IS VehicleFileStatus.

    SELECT TransFile ASSIGN TO "Listing17-3Trans.DAT"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD  VehicleMasterFile.
01  VehicleRec-VMF.
    88  EndOfVehiclefile  VALUE HIGH-VALUES.
    02  VehicleNum-VMF      PIC 9(4).
    02  VehicleDesc-VMF    PIC X(25).
    02  ManfName-VMF       PIC X(20).
```

FD TransFile.

```
01 InsertionRec.
   88 EndOfTransFile      VALUE HIGH-VALUES.
   02 TransType           PIC X.
       88 InsertRecord    VALUE "I".
       88 DeleteRecord    VALUE "D".
       88 UpdateRecord    VALUE "U".
   02 VehicleNum-IR      PIC 9(4).
   02 VehicleDesc-IR     PIC X(25).
   02 ManfName-IR        PIC X(20).
```

```
01 DeletionRec          PIC X(5).
```

```
01 UpdateRec.
   02 FILLER              PIC X(5).
   02 VehicleDesc-UR     PIC X(25).
```

WORKING-STORAGE SECTION.

```
01 VehicleFileStatus   PIC X(2).
   88 OperationSuccessful VALUE "00".
   88 VehicleRecExists   VALUE "22".
   88 NoVehicleRec       VALUE "23".
```

```
01 VehicleKey          PIC 9(4).
```

```
01 ReadType            PIC 9.
```

PROCEDURE DIVISION.

Begin.

```
OPEN INPUT TransFile
OPEN I-O VehicleMasterFile
DISPLAY "Vehicle Master File records before transactions"
PERFORM DisplayVehicleRecords
DISPLAY SPACES
```

```
READ TransFile
  AT END SET EndOfTransFile TO TRUE
END-READ
PERFORM UNTIL EndOfTransFile
  MOVE VehicleNum-IR TO VehicleKey
  EVALUATE TRUE
    WHEN InsertRecord PERFORM InsertVehicleRec
    WHEN DeleteRecord PERFORM DeleteVehicleRec
    WHEN UpdateRecord PERFORM UpdateVehicleRec
    WHEN OTHER        DISPLAY "Error - Invalid Transaction Code"
  END-EVALUATE
  READ TransFile
  AT END SET EndOfTransFile TO TRUE
END-READ
END-PERFORM
```

Listing 17-3 Output

```
Vehicle Master File records before transactions
0001 Roadster      Tesla Motors
0002 Volt          Chevrolet
0005 ZOE           Renault
0007 Focus Electric Ford
0011 Fit EV        Honda
0016 Model S       Tesla Motors
0017 Prius         Toyota
0018 Spark EV      Chevrolet
0113 i-MiEV        Mitsubishi
0124 Twizzy        Renault
0126 BMW i3        BMW
0133 Fluence Z.E  Renault
0135 C-Zero        Citroen
0136 Model X       Tesla Motors
0200 Leaf          Nissan
0210 e-Golf        Volkswagen
0230 iON           Peugeot
```

```
InsertError - Record at - 0001 - already exists
DeleteError - No record at - 0006
UpdateError - No record at - 0117
InsertError - Record at - 0230 - already exists
```

```
Vehicle Master File records after transactions
0001 Roadster      Tesla Motors
0002 Volt          Chevrolet
0005 ZOE           Renault
0007 Focus Electric Ford
0011 Fit EV        Honda
0016 Model S       Tesla Motors
0017 FCV +valid update Toyota
0018 Spark EV      Chevrolet
0113 i-MiEV        Mitsubishi
0124 Twizzy        Renault
0126 BMW i3        BMW
0133 Fluence Z.E  Renault
0136 Model X       Tesla Motors
0200 Leaf          Nissan
0205 Model C +valid insert Tesla Motors
0210 e-Golf        Volkswagen
0230 iON           Peugeot
```

```

DISPLAY SPACES
DISPLAY "Vehicle Master File records after transactions"
PERFORM DisplayVehicleRecords

```

```

CLOSE TransFile, VehicleMasterFile
STOP RUN.

```

InsertVehicleRec.

```

MOVE ManfName-IR TO ManfName-VMF
MOVE VehicleDesc-IR TO VehicleDesc-VMF
MOVE VehicleNum-IR TO VehicleNum-VMF
WRITE VehicleRec-VMF
  INVALID KEY
    IF VehicleRecExists
      DISPLAY "InsertError - Record at - " VehicleNum-IR " - already exists"
    ELSE
      DISPLAY "Unexpected error. File Status is - " VehicleFileStatus
    END-IF
  END-WRITE.

```

DeleteVehicleRec.

```

DELETE VehicleMasterFile RECORD
  INVALID KEY
    IF NoVehicleRec
      DISPLAY "DeleteError - No record at - " VehicleNum-IR
    ELSE
      DISPLAY "Unexpected error1. File Status is - " VehicleFileStatus
    END-IF
  END-DELETE.

```

UpdateVehicleRec.

```

READ VehicleMasterFile
  INVALID KEY
    IF NoVehicleRec
      DISPLAY "UpdateError - No record at - " VehicleNum-IR
    ELSE
      DISPLAY "Unexpected error2. File Status is - " VehicleFileStatus
    END-IF
  END-READ
  IF OperationSuccessful
    MOVE VehicleDesc-UR TO VehicleDesc-VMF
    REWRITE VehicleRec-VMF
    INVALID KEY DISPLAY "Unexpected error3. File Status is - " VehicleFileStatus
  END-REWRITE
END-IF.

```

DisplayVehicleRecords.

```

* Position the Next Record Pointer to the start of the file
MOVE ZEROS TO VehicleKey
START VehicleMasterFile KEY IS GREATER THAN VehicleKey

```

```

        INVALID KEY DISPLAY "Unexpected error on START"
END-START
READ VehicleMasterFile NEXT RECORD
    AT END SET EndOfVehiclefile TO TRUE
END-READ

PERFORM UNTIL EndOfVehiclefile
    DISPLAY VehicleNum-VMF SPACE VehicleDesc-VMF SPACE ManfName-VMF
    READ VehicleMasterFile NEXT RECORD
        AT END SET EndOfVehiclefile TO TRUE
    END-READ
END-PERFORM.

```

The most interesting thing about this program is that it uses all five of the direct access file processing verbs: READ, WRITE, REWRITE, DELETE, and START. The program begins by displaying the current contents of the vehicle master file. You may wonder what the purpose of the START verb is at the beginning of `DisplayVehicleRecords`. For relative files, the START verb is used to position the next-record pointer. When a file is accessed sequentially, the next-record pointer points to the position in the file where the next record will be read from or written to.

This first time through `DisplayVehicleRecords`, the START verb is not strictly necessary, because when you open the file, the next-record pointer points to the first record in the file by default. But the second time through the file, the START verb is required in order to position the next-record pointer at the beginning of the file—when you read through the file the first time, the next-record pointer was left pointing to the last record in the file. Closing the file and opening it again also positions the next-record pointer at the first record in the file, but doing so carries a significant processing penalty.

Note how you use the START verb. You move zeros into the relative-key data item; then, when START executes, its meaning is this: position the next-record pointer such that the relative record number of the record pointed to is greater than the current value of the relative-key data item. Because the current value of the relative-key data item is zero, the first valid record in the file satisfies the condition.

The first statement in the `PERFORM UNTIL EndOfTransFile` iteration is `MOVE VehicleNum-IR TO VehicleKey`. This takes the key value in the transaction record and places it in the relative-key data item. Now any direct access operation such as WRITE, REWRITE, or DELETE will use that key value.

If the transaction is an insertion, then a direct WRITE is used to write the transaction record to the vehicle master file at the relative record number indicated by the value in `VehicleKey`. If the WRITE fails, then INVALID KEY activates, and the file status is checked to see if it has failed because there is already a record in that relative record number position or because of an unexpected error. If the anticipated error condition occurs, an error message is displayed, indicating the offending record's key value; otherwise, an error message and the current value of the file status are displayed. The second part of the IF statement is there as an alert regarding a possible programming or test data error; you don't expect this branch of IF to be triggered.

If the transaction is a deletion, then the direct DELETE is used to delete the record at the relative record number position pointed to by the value in `VehicleKey`. If there is no record at that position, INVALID KEY activates.

If the transaction is an update, then a direct READ is used to fetch the record from the file and place it in the record buffer. If the record exists, the `VehicleDesc-VMF` field is updated, and REWRITE is used to write the record back to the file. REWRITE has to be used because WRITE would return an error if it found a record already in place.

Relative Files: Syntax and Semantics

This section provides a formal introduction to the file-processing verbs and declarations specific to relative files.

Relative Files: SELECT and ASSIGN Clause

The metalanguage for the SELECT and ASSIGN clause for relative files is shown in Figure 17-2.


```

SELECT [OPTIONAL] FileName
    ASSIGN TO FileSpec
    [ORGANIZATION IS] RELATIVE
    [ACCESS MODE IS { SEQUENTIAL [RELATIVE KEY IS RelKey]
                    { RANDOM
                    { DYNAMIC } RELATIVE KEY IS RelKey } } ]
    [FILE STATUS IS FileStatus]

```

Figure 17-2. Metalanguage for the specific relative SELECT and ASSIGN clause

Normally, when a file is opened for INPUT, I-O, or EXTEND, the file must exist or an error condition occurs. The OPTIONAL phrase allows you to specify that the file does not have to exist (presumably because you are going to write records to and read records from it) when OPEN INPUT, OPEN I-O, or OPEN EXTEND executes.

ACCESS MODE refers to the way in which the file is to be used. If you specify that ACCESS MODE is SEQUENTIAL, then it is only possible to process the records in the file sequentially. If RANDOM is specified, it is only possible to access the file directly. If DYNAMIC is specified, the file may be accessed both directly and sequentially.

The RECORD KEY phrase is used to define the relative key. There can be only one key in a relative file. RelKey must be a numeric data item and *must not be* part of the file's record description, although it may be part of another file's record description. It is normally described in the WORKING-STORAGE SECTION.

The FILE STATUS clause identifies a two-character area of storage that holds the result of every I/O operation for the file. The FILE STATUS data item is declared as PIC X(2) in the WORKING-STORAGE SECTION. Whenever an I/O operation is performed, some value is returned to FILE STATUS, indicating whether the operation was successful.

There are a large number of FILE STATUS values, but three of major interest for relative files are as follows:

- "00" means the operation was successful.
- "22" indicates a duplicate key. That is, you are trying to write a record, but a record already exists in that position.
- "23" means the record was not found. That is, you are trying to access a record, but there is no record in that position.

Relative File Verbs

Direct access files are more versatile than sequential files and support a greater range of operations. In addition to the new file-processing verbs DELETE, REWRITE, and START, many of the verbs you already know—such as OPEN, CLOSE, READ, and WRITE—operate differently when processing direct access files.

INVALID KEY Clause

If you examine the metalanguage of any of the direct access verbs, you see that the INVALID KEY clause is in square brackets, indicating that this clause is optional. In reality, the INVALID KEY clause is mandatory *unless* declaratives have been specified. Declaratives allow you to create specialized exception-handling code. You explore declaratives in the next chapter.

When the INVALID KEY clause is specified, any I/O error, such as attempting to read or delete a record that does not exist or write a record that already exists, activates the clause and causes the statement block following it to be executed.

OPEN/CLOSE

The CLOSE syntax is the same for all file organizations.

The syntax for OPEN changes when used with direct access files: an I-O (input/output) entry is added. I-O is used with direct access files when you intend to update or both read from and write to the file. The full metalanguage for the OPEN verb is given in Figure 17-3.

$$\text{OPEN} \left\{ \begin{array}{l} \text{INPUT} \\ \text{OUTPUT} \\ \text{I - O} \\ \text{EXTEND} \end{array} \right\} \text{FileName} \dots$$

Figure 17-3. Full metalanguage for the OPEN verb

Consider the following:

- If the file is opened for INPUT, then only READ and START are allowed.
- If the file is opened for OUTPUT, then only WRITE is allowed.
- If the file is opened for I-O, then READ, WRITE, START, REWRITE, and DELETE are allowed.
- If OPEN INPUT is used, and the file does not possess the OPTIONAL clause, the file must exist or the OPEN will fail.
- If OPEN OUTPUT or I-O is used, the file will be created if it does not already exist, as long as the file possesses the OPTIONAL clause.

READ Verb

There are two new formats for the READ verb. One format is used for a direct READ on a relative file, and the other is used when you want to read the file sequentially but an ACCESS MODE of DYNAMIC has been specified for the file. When an ACCESS MODE of SEQUENTIAL is specified, all file organizations use the standard READ format.

The metalanguage in Figure 17-4 shows the READ format used to read a relative file sequentially when an ACCESS MODE of DYNAMIC has been specified. The only difference between this format and the format of the ordinary sequential READ is the NEXT RECORD phrase. This format of READ reads the record pointed to by the next-record pointer (the current record if positioned by START, or the next record if positioned by a direct READ).

```
READ FileName NEXT RECORD [INTO DestItemSi]
      [AT END StatementBlock ]
[END-READ]
```

Figure 17-4. Metalanguage for the sequential READ when the ACCESS MODE is DYNAMIC

The format of READ used for a direct read on a relative file is shown in Figure 17-5. To read a relative file using a key, the relative record number of the required record is placed in the RELATIVE KEY data item (specified in the RELATIVE KEY phrase of the file's SELECT and ASSIGN clause), and then READ is executed. When READ executes, the record with the relative record number equal to the present value of the relative key is read into the file's record buffer (defined in the FD entry). If READ fails to retrieve the record, the INVALID KEY activates, and the statement block following the clause is executed. If READ is successful, NOT INVALID KEY (if present) activates, and the next-record pointer is left pointing to the next valid record in the file.

```

READ FileName RECORD [INTO DestItem$i ]
    [INVALIDKEY StatementBlock ]
    [NOT INVALIDKEY StatementBlock ]
[END-READ]

```

Figure 17-5. Metalanguage for the direct READ

WRITE Verb

The format for writing sequentially to a direct access file is the same as that used for writing to a sequential file. But when you want to write directly to a relative file, a key must be used, and this requires the WRITE format shown in Figure 17-6.

```

WRITE RecName [FROM SourceItem$i ]
    [INVALIDKEY StatementBlock]
    [NOT INVALID KEY StatementBlock]
[END-WRITE]

```

Figure 17-6. Metalanguage for writing to a relative file using a key

Writing a record to a relative file using a key requires you to place the record in the record buffer, place the key value in the RELATIVE KEY data item, and then execute the WRITE statement. When WRITE executes, the data in the record buffer is written to the record position with a relative record number equal to the present value of the key.

If WRITE fails, perhaps because a record already exists at that relative record number position, the INVALID KEY clause activates, and the statements following the clause are executed.

REWRITE Verb

The REWRITE verb is used to update a record in situ by overwriting it. The format of REWRITE is given in Figure 17-7. The REWRITE verb is generally used with READ because you can only update a record by bringing it into the record buffer first. Once the record is in the buffer, you can make the changes to the required fields; when the changes have been made, you REWRITE the record to the file.

```

REWRITE RecName [FROM SourceItem$i]
    [INVALIDKEY StatementBlock]
    [NOT INVALIDKEY StatementBlock]
[END-REWRITE]

```

Figure 17-7. Metalanguage for the REWRITE verb

To use REWRITE to update fields in a record, you first place the key value in the RELATIVE KEY data item and do a direct READ. This brings the required record into the record buffer. Next you make the required changes to the data in the record. Then you execute a REWRITE to write the record in the buffer back to the file.

Keep the following in mind:

- If the file has an ACCESS MODE of SEQUENTIAL, then the INVALID KEY clause cannot be specified, and the record to be replaced must have been the subject of a READ or START before the REWRITE is executed.
- For all access modes, the file must be opened for I-0.

DELETE Verb

The syntax for the DELETE verb is given in Figure 17-8. To delete a record, you place the key value in the RELATIVE KEY data item and then execute DELETE. The record in the relative record number position indicated by the RELATIVE KEY data item is marked as deleted (it is not actually deleted). If the DELETE attempt fails, perhaps because there is no record at that position, INVALID KEY activates.

```
DELETE FileName RECORD
    [INVALIDKEY StatementBlock]
    [NOT INVALIDKEY StatementBlock]
[END-DELETE]
```

Figure 17-8. Metalanguage for the DELETE verb

Note the following:

- To use DELETE, the file must have been opened for I-O.
- When ACCESS MODE is SEQUENTIAL, a READ statement must have accessed the record to be deleted (that's how the system knows which record to delete).

START Verb

For relative files, the START verb is only used to control the position of the next-record pointer. Where the START verb appears in a program, it is usually followed by a sequential READ or WRITE because START does not get data from or put data into the file. It merely positions the next-record pointer.

To use the START verb to position the next-record pointer at a particular record (so that subsequent sequential accesses will use that record position), you place the key value of the record at the desired position into the RELATIVE KEY data item and then execute a START . . KEY IS EQUAL TO statement.

To use the START verb to position the next-record pointer at the first active record in the file, you move zeros to the RELATIVE KEY data item and then execute a START . . KEY IS GREATER THAN statement. You can't move the number 1 to the RELATIVE KEY data item, because there may be no active record in the first record position.

The metalanguage for the START verb is given in Figure 17-9. When START executes, it has the following interpretation: position the next-record pointer such that the relative record number of the record pointed to is EQUAL TO or GREATER THAN or NOT LESS THAN or GREATER THAN OR EQUAL TO the current value of the RELATIVE KEY data item.

```
START FileName KEY {
    [ISEQUAL TO
    IS=
    ISGREATER THAN
    IS>
    ISNOT LESS THAN
    ISNOT <
    ISGREATER THAN OR EQUAL TO
    IS>=
    } RelKey
    [INVALIDKEY StatementBlock]
    [NOT INVALID KEY StatementBlock]
[END-START]
```

Figure 17-9. Metalanguage for the START verb

Organization of Indexed Files

Unlike relative files, which only allow a single, numeric key, an indexed file may have up to 255 alphanumeric keys. The key on which the data records are actually ordered is called the *primary key*. The other keys are called *alternate keys*. Although a relative file allows you to access records sequentially or directly by key, an indexed file lets you access the records directly or sequentially using any of its keys. For instance, suppose an indexed file supporting a video rental system has VideoId as its primary key and VideoTitle and SupplierId as its alternate keys. You can read a record from the file using any of the keys, and you can also read through the file in VideoId sequence, VideoTitle sequence, or SupplierId sequence. This versatility is what makes indexed files so useful.

How is this flexibility achieved? How can it be possible to read through the file sequentially in different sequences?

The data records in an indexed file are sequenced in ascending primary-key order. Over the data records, the file system builds an index. This arrangement is shown schematically in Figure 17-10.

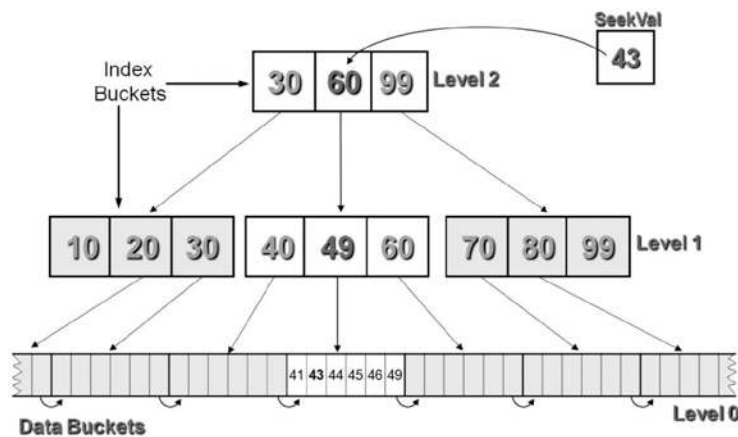


Figure 17-10. Primary-key index: seeking a record with a key value of 43

A number of terms relating to Figure 17-10 need clarification. A *bucket* is the smallest number of characters of disk storage that can be read or written in one I/O operation. It is the equivalent of a block on a PC disk—the smallest segment of disk space that can be addressed. *Index depth* is the number of levels of index above level 0, which is the data bucket (or base bucket) level (in Figure 17-10, the index depth is 2).

When direct access is required, the file system uses the index to find, read, insert, update, or delete the required record. Figure 17-11 shows how the index is used to locate the record with a key value of 43. The file system starts at the first level of index (one I/O operation is required to bring the records in this bucket into memory). In the index buckets, each index record contains a pointer to the highest key value in the next-level buckets. Using the condition $\text{SeekVal} \leq \text{IndexKeyVal}$, a bucket is retrieved from the next level of index (another I/O operation is required to bring the records in this bucket into memory). Again the condition is applied, and the bucket at level 0 (the data buckets) is retrieved (another final I/O is required to bring the records in this bucket into memory). Once the actual data records are in memory, the file system searches them sequentially until the required record is found.

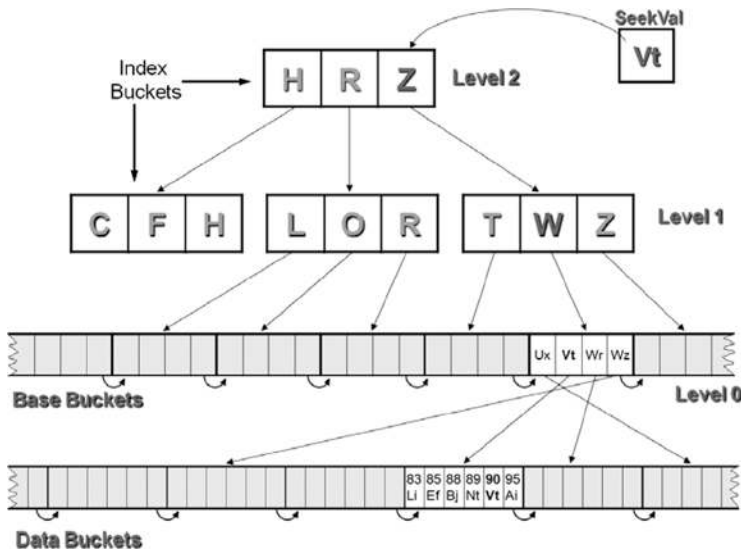


Figure 17-11. Alternate-key index: seeking a record with a key value of *Vt*

In addition to allowing direct access to records on the primary key or any of the 254 alternate keys, indexed files may also be processed sequentially. When you process an indexed file sequentially, you can read the records in ascending order on the primary key or on any of the alternate keys.

Because the data records are held in ascending primary-key sequence, it is easy to see how the file may be accessed sequentially on the primary key. It is not quite so obvious how you achieve sequential access on the alternate keys. For this, you need to examine the alternate index schematic in Figure 17-11.

For each of the alternate keys specified in an indexed file, an alternate index is built. However, unlike the primary-key index, which contains the data buckets at the lowest level of the index, the lowest level of an alternate index is made up of base records that contain only the alternate-key value and a pointer to where the actual record is. These base records are organized in ascending alternate-key order; by reading through these base records in sequence, you achieve sequential access using the alternate key. This arrangement is shown schematically in Figure 17-11.

Figure 17-11 shows how the index is used to locate the record with a key value of *Vt*. As with the primary key, each level of index points to the next level until level 0 is reached. Each of the base buckets at level 0 contains records that consist of the alternate-key value and a pointer to the data bucket where the record with that key value is to be found. In Figure 17-11, for example, the *Vt* record in the base buckets points to a bucket that actually contains the record. Note that the records in this bucket are in ascending primary key order.

Processing Indexed Files

Just as with relative files, this section introduces indexed files by showing you some simple examples. When you have a feel for how it all works, you learn about the required clauses, verbs, and concepts more formally.

Let's start with a simple program that reads an indexed file both sequentially and directly on a number of keys. Then you see how to create an indexed file from a sequential file. In the third example, you learn how to use indexed files in combination: you use an indexed file of film directors and an indexed file containing film details together to display all the films directed by a particular director. In the final example, you apply a set of transactions to the film file and cover the issue of *referential integrity* that crops up when a new film record is inserted.

Reading an Indexed File

Listing 17-4 displays the contents of an indexed file in the key sequence chosen by the user and then displays one record directly using the key chosen by the user.

Listing 17-4. Reading an indexed file sequentially and then directly using any key

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing17-4.
AUTHOR. Michael Coughlan.
*Reads the file sequentially and then directly on any key

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
    SELECT FilmFile ASSIGN TO "Listing17-4Film.DAT"
        ORGANIZATION IS INDEXED
        ACCESS MODE IS DYNAMIC
        RECORD KEY IS FilmId
        ALTERNATE RECORD KEY IS FilmTitle
            WITH DUPLICATES
        ALTERNATE RECORD KEY IS DirectorId
            WITH DUPLICATES
        FILE STATUS IS FilmStatus.

DATA DIVISION.
FILE SECTION.
FD FilmFile.
01 FilmRec.
    88 EndOfFilms          VALUE HIGH-VALUES.
    02 FilmId              PIC 9(7).
    02 FilmTitle           PIC X(40).
    02 DirectorId         PIC 999.

WORKING-STORAGE SECTION.
01 FilmStatus             PIC XX.
    88 FilmOK VALUE ZEROS.

01 RequiredSequence      PIC 9.
    88 FilmIdSequence     VALUE 1.
    88 FilmTitleSequence  VALUE 2.
    88 DirectorIdSequence VALUE 3.

PROCEDURE DIVISION.
Begin.
    OPEN INPUT FilmFile
    DISPLAY "*** Get Records Sequentially ***"
    DISPLAY "Enter key : 1 = FilmId, 2 = FilmTitle, 3 = DirectorId - "
        WITH NO ADVANCING.
    ACCEPT RequiredSequence.

    EVALUATE TRUE
        WHEN FilmIdSequence      PERFORM DisplayFilmData
```

```

    WHEN FilmTitleSequence    MOVE SPACES TO FilmTitle
                              START FilmFile KEY IS GREATER THAN FilmTitle
                              INVALID KEY DISPLAY "FilmStatus = " FilmStatus
                              END-START
                              PERFORM DisplayFilmData
    WHEN DirectorIdSequence  MOVE ZEROS TO DirectorId
                              START FilmFile KEY IS GREATER THAN DirectorId
                              INVALID KEY DISPLAY "FilmStatus = " FilmStatus
                              END-START
                              PERFORM DisplayFilmData

END-EVALUATE

DISPLAY SPACES
DISPLAY "*** Get Records Directly ***"
DISPLAY "Enter key : 1 = FilmId, 2 = FilmTitle, 3 = DirectorId - "
    WITH NO ADVANCING.
ACCEPT RequiredSequence.
EVALUATE TRUE
    WHEN FilmIdSequence      PERFORM GetFilmByFilmId
    WHEN FilmTitleSequence   PERFORM GetFilmByFilmTitle
    WHEN DirectorIdSequence  PERFORM GetFilmByDirectorId
END-EVALUATE

CLOSE FilmFile
STOP RUN.

```

```

DisplayFilmData.
    READ FilmFile NEXT RECORD
    AT END SET EndOfFilms TO TRUE
END-READ
PERFORM UNTIL EndOfFilms
    DISPLAY FilmId SPACE FilmTitle SPACE DirectorId
    READ FilmFile NEXT RECORD
    AT END SET EndOfFilms TO TRUE
END-READ
END-PERFORM.

```

```

GetFilmByFilmId.
    DISPLAY "Enter the FilmId - " WITH NO ADVANCING
    ACCEPT FilmId
    READ FilmFile
    KEY IS FilmId
    INVALID KEY DISPLAY "Film not found - " FilmStatus
    NOT INVALID KEY DISPLAY FilmId SPACE FilmTitle SPACE DirectorId
END-READ.

```

```

GetFilmByFilmTitle.
    DISPLAY "Enter the FilmTitle - " WITH NO ADVANCING
    ACCEPT FilmTitle

```



```

READ FilmFile
  KEY IS FilmTitle
  INVALID KEY DISPLAY "Film not found - " FilmStatus
  NOT INVALID KEY DISPLAY FilmId SPACE FilmTitle SPACE DirectorId
END-READ.

```

```
GetFilmByDirectorId.
```

```

DISPLAY "Enter the Director Id - " WITH NO ADVANCING
ACCEPT DirectorId
READ FilmFile
  KEY IS DirectorId
  INVALID KEY DISPLAY "Film not found - " FilmStatus
  NOT INVALID KEY DISPLAY FilmId SPACE FilmTitle SPACE DirectorId
END-READ.

```

Listing 17-4 Output

```

*** Get Records Sequentially ***
Enter key : 1 = FilmId, 2 = FilmTitle, 3 = DirectorId - 2
8713669 Alien 023
8805288 Cape Fear 005
8805806 Carlito's Way 015
8805156 Carrie 015
8805245 Catch Me If You Can 005
8805334 Desperado 002
8805385 First Knight 003
8805474 Ghost 003
8805253 Heavenly Creatures 009
8805504 Jackie Brown 002
8805121 Jaws 005
8805091 Lord of the Rings:Fellowship of the Ring 009
8805075 Lord of the Rings:Return of the King 009
8805164 Lord of the Rings:The Two Towers 009
8805261 Master and Commander 012
8805105 Mission Impossible 015
8805296 Overboard 004
8805415 Pulp Fiction 002
8805229 Saving Private Ryan 005
8805326 The Color Purple 005
8812438 The Untouchables 015

*** Get Records Directly ***
Enter key : 1 = FilmId, 2 = FilmTitle, 3 = DirectorId - 1
Enter the FilmId - 8805415
8805415 Pulp Fiction 002

```

There is quite a bit to talk about in this program. The first thing to note is the new entries in the SELECT and ASSIGN clause. Because an indexed file has a primary key and, perhaps, some alternate keys, you must have entries in SELECT and ASSIGN for each key, and you must distinguish the primary key from the alternate keys. One very important thing to remember is that whereas the key defined in the RELATIVE KEY entry of a relative file *cannot be* a field in the relative file's record description, the keys defined for an indexed file *must be* fields in the record defined for the file.

Another item of interest is the WITH DUPLICATES phrase, which is specified with the ALTERNATE KEY clause in the SELECT and ASSIGN clause. In a relative file, the key must be unique; and in an indexed file, the primary key defined in the RECORD KEY clause must be unique, but the alternate keys may have duplicates if they use the WITH DUPLICATES phrase. For instance, in this program, the same DirectorId appears for many films. If the WITH DUPLICATES phrase is omitted, the alternate key has to be unique.

The program starts by asking the user what key to use when displaying the contents of the file sequentially. This raises an interesting question. If you examine the code in the paragraph `DisplayFilmData`, you see that the `READ` format used is the one for reading a file sequentially. So the question is, how does the system know to read through the file in `FilmId` order on one occasion, in `FilmTitle` order on another occasion, and in `DirectorId` order on yet another occasion? The answer is that the system relies on a concept called the *key of reference*. The key of reference refers to the key that is used to process an indexed file sequentially. A particular key is established as the key of reference by using that key with `START` or a direct `READ`. You can see this in the program. If `FilmTitleSequence` is selected, `START` is used with the `FilmTitle` key to both establish `FilmTitle` as the key of reference and position the next-record pointer at the first record. Similarly, if `DirectorIdSequence` is selected, `START` is used to establish `DirectorId` as the key of reference and to position the next-record pointer at the first record in the file. What about `FilmIdSequence`, though? Why doesn't that `WHEN` branch have a `START` verb? I could have used `START` with that branch, too, but I wanted to make the point that when the file is opened, the primary key is the default key of reference and the next-record pointer is pointing at the first record in the file.

When the program has displayed the contents of the file in the required sequence, the user is asked which key they wish to use for a direct `READ`. Then that key is used to read the required record from the file. If you examine the `READ` operation in any of the paragraphs that read the record from the file, you see that this format of `READ` is different from that used for relative files. For relative files, `READ` does not require a `KEY IS` phrase because there is only one key; but because indexed files use many keys, you have to say which key you are using to read the record.

One final issue needs to be discussed. The paragraph `GetFilmByDirectorId` returns only one record, but the same director occurs many times in the file. How can you show the other films made by this director? The answer lies once more in the key of reference. When a direct `READ` is made, the key used is established as the key of reference, and the next-record pointer is pointing at the next record in the file. You can display all the films made by a particular director by doing a direct `READ` followed by sequential `READs`. You stop reading the records when the `Director Id` changes. This procedure is shown in the revised version of `GetFilmByDirectorId` in Example 17-2.

Example 17-2. Revision of `GetFilmByDirectorId` to Show All of a Director's Films

```
GetFilmByDirectorId.
  DISPLAY "Enter the Director Id - " WITH NO ADVANCING
  ACCEPT DirectorId
  READ FilmFile
    KEY IS DirectorId
    INVALID KEY DISPLAY "Film not found - " FilmStatus
    NOT INVALID KEY DISPLAY FilmId SPACE FilmTitle SPACE DirectorId
      PERFORM GetOtherFilmsByThisDirector
  END-READ.

GetOtherFilmsByThisDirector.
  MOVE DirectorId TO PrevDirectorId
  READ FilmFile NEXT RECORD
    AT END SET EndOffilms TO TRUE
  END-READ
  PERFORM UNTIL DirectorId NOT EQUAL TO PrevDirectorId
    OR EndOffilms
    DISPLAY FilmId SPACE FilmTitle SPACE DirectorId
    READ FilmFile NEXT RECORD
      AT END SET EndOffilms TO TRUE
  END-READ
  END-PERFORM.
```

Creating an Indexed File from a Sequential File

In Listing 17-5, an indexed file is created from a sequential file. Sequential files are useful because you can create them with an ordinary editor. There are tools available that can convert a sequential file into an indexed file, but this program does the job itself.

Listing 17-5. Creating an Indexed File from a Sequential File

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing17-5.
AUTHOR. Michael Coughlan.
*Creating an Indexed File from a Sequential File

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
    SELECT FilmFile ASSIGN TO "Listing17-5Film.DAT"
        ORGANIZATION IS INDEXED
        ACCESS MODE IS DYNAMIC
        RECORD KEY IS FilmId
        ALTERNATE RECORD KEY IS FilmTitle
            WITH DUPLICATES
        ALTERNATE RECORD KEY IS DirectorId
            WITH DUPLICATES
        FILE STATUS IS FilmStatus.

    SELECT SeqFilmFile ASSIGN TO "Listing17-5Film.SEQ"
        ORGANIZATION IS LINE SEQUENTIAL.

DATA DIVISION.
FILE SECTION.
FD FilmFile.
01 FilmRec.
    02 FilmId          PIC 9(7).
    02 FilmTitle       PIC X(40).
    02 DirectorId      PIC 999.

FD SeqFilmFile.
01 SeqFilmRec          PIC X(50).
   88 EndOfFilmFile    VALUE HIGH-VALUES.

WORKING-STORAGE SECTION.
01 FilmStatus          PIC XX.
   88 FilmOK           VALUE ZEROS.

PROCEDURE DIVISION.
Begin.
    OPEN INPUT SeqFilmFile
    OPEN OUTPUT FilmFile

    READ SeqFilmFile
    AT END SET EndOfFilmFile TO TRUE
END-READ

```

```

PERFORM UNTIL EndOfFilmFile
  WRITE FilmRec FROM SeqFilmRec
    INVALID KEY DISPLAY "Error writing to film file"
  END-WRITE
  READ SeqFilmFile
    AT END SET EndOfFilmFile TO TRUE
  END-READ
END-PERFORM
CLOSE SeqFilmFile, FilmFile
STOP RUN.

```

The first issue to bring to your attention is the statement `WRITE FilmRec FROM SeqFilmRec`. When you consider this statement, you may wonder why there is no `KEY IS` phrase as there is with the direct `READ`. The reason is that records are always written to an indexed file based on the value in the primary key, so no `KEY IS` phrase is required.

You may also wonder why I don't put the key value into the primary-key data item before the `WRITE` is executed. The answer is that I do put the key value into the primary-key data item—but I do it in a different way. `WRITE FilmRec FROM SeqFilmRec` has the same effect as

```

MOVE SeqFilmRec TO FilmRec
WRITE FilmRec
  INVALID KEY DISPLAY "Error writing to film file"
END-WRITE

```

Using Indexed Files in Combination

Listing 17-6 uses an indexed file of film directors and an indexed file containing film details in combination to display all the films directed by a particular director. The program accepts the name of a director from the user and then displays all the films made by that director. For each film, the director ID, the surname of the director, the film ID, and the title of the film are displayed.

Listing 17-6. Using Indexed Files in Combination

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing17-6.
AUTHOR. Michael Coughlan.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
  SELECT FilmFile ASSIGN TO "Listing17-6Film.DAT"
    ORGANIZATION IS INDEXED
    ACCESS MODE IS DYNAMIC
    RECORD KEY IS FilmId-FF
    ALTERNATE RECORD KEY IS FilmTitle-FF
      WITH DUPLICATES
    ALTERNATE RECORD KEY IS DirectorId-FF
      WITH DUPLICATES
    FILE STATUS IS FilmStatus.

  SELECT DirectorFile ASSIGN TO "Listing17-6Dir.DAT"
    ORGANIZATION IS INDEXED
    ACCESS MODE IS DYNAMIC

```

```

RECORD KEY IS DirectorId-DF
ALTERNATE RECORD KEY IS DirectorSurname-DF
FILE STATUS IS DirectorStatus.

```

```
DATA DIVISION.
```

```
FILE SECTION.
```

```
FD FilmFile.
```

```
01 FilmRec-FF.
```

```

    88 EndOfFilms      VALUE HIGH-VALUES.
    02 FilmId-FF       PIC 9(7).
    02 FilmTitle-FF    PIC X(40).
    02 DirectorId-FF   PIC 999.

```

```
FD DirectorFile.
```

```
01 DirectorRec-DF.
```

```

    88 EndOfDirectors VALUE HIGH-VALUES.
    02 DirectorId-DF   PIC 999.
    02 DirectorSurname-DF PIC X(20).

```

```
WORKING-STORAGE SECTION.
```

```
01 AllStatusFlags VALUE ZEROS.
```

```

    02 FilmStatus      PIC XX.
    88 FilmOk          VALUE "02", "00".

```

```
    02 DirectorStatus PIC XX.
```

```
01 DirectorName      PIC X(20).
```

```
PROCEDURE DIVISION.
```

```
Begin.
```

```

    OPEN INPUT FilmFile
    OPEN INPUT DirectorFile
    DISPLAY "Please enter the director surname :- "
        WITH NO ADVANCING
    ACCEPT DirectorSurname-DF
    READ DirectorFile
        KEY IS DirectorSurname-DF
        INVALID KEY DISPLAY "-DF ERROR Status = " DirectorStatus
        NOT INVALID KEY PERFORM GetFilmsForDirector
    END-READ

    CLOSE FilmFile
    CLOSE DirectorFile
    STOP RUN.

```

```
GetFilmsForDirector.
```

```

    MOVE DirectorId-DF TO DirectorId-FF
    READ FilmFile
        KEY IS DirectorId-FF

```

```

INVALID KEY DISPLAY "-FF ERROR Status = " FilmStatus
END-READ
IF FilmOk
  PERFORM UNTIL DirectorId-DF NOT Equal TO DirectorId-FF OR EndOfFilms
    DISPLAY DirectorId-DF SPACE DirectorSurname-DF SPACE
      FilmId-FF SPACE FilmTitle-FF
    READ FilmFile NEXT RECORD
    AT END SET EndOfFilms TO TRUE
  END-READ
END-PERFORM
END-IF.

```

Listing 17-6 Output

```

Please enter the director surname :- Spielberg
005 Spielberg           8805121 Jaws
005 Spielberg           8805229 Saving Private Ryan
005 Spielberg           8805245 Catch Me If You Can
005 Spielberg           8805326 The Color Purple

```

This program uses two indexed files in combination. Used this way, indexed files are similar to a database where each file is a table, the records in the file are the table rows, and the fields in the records are the table columns.

The program starts by getting the name of the director from the user. This name is used as the key value for a direct READ on the director file. When the record is retrieved, DirectorId-DF is used to get all the director's film titles.

One item of interest in the program is the file status for FilmFile. Note that one of two codes is specified to indicate the operation was successful. Normally, "00" indicates that the operation was successful; but in this case, the code "02" indicates success and also carries extra information. A code of "02" may be returned for indexed files only and is returned in these cases:

- When after a READ operation, the next record has the same key value as the key used for the READ
- When a WRITE or a REWRITE creates a duplicate key value for an alternate key that has the WITH DUPLICATES phrase

If you want to detect when you have processed all the films directed by a particular director without having to compare keys, you can use the returned "02" code as shown in Example 17-3.

Example 17-3. Using the "02" File Status to Create a More Succinct Loop

```

01 AllStatusFlags VALUE ZEROS.
02 FilmStatus      PIC XX.
08 AnotherFilmForThisDirector VALUE "02".

: : : : : : : : : : : : : : : :

GetFilmsForDirector.
MOVE DirectorId-DF TO DirectorId-FF
READ FilmFile
KEY IS DirectorId-FF
INVALID KEY DISPLAY "-FF ERROR Status = " FilmStatus

```

```

NOT INVALID KEY DISPLAY DirectorId-DF SPACE DirectorSurname-DF SPACE
                                FilmId-FF      SPACE FilmTitle-FF
END-READ
PERFORM UNTIL NOT AnotherFilmForThisDirector
    READ FilmFile NEXT RECORD
    AT END SET EndOfFilms TO TRUE
END-READ
DISPLAY DirectorId-DF SPACE DirectorSurname-DF SPACE
        FilmId-FF      SPACE FilmTitle-FF
END-PERFORM.

```

Applying Transactions to an Indexed File

Listing 17-7 applies a set of transactions (deletions, insertions, and updates) to the film file. The result of applying the transactions is shown in Figure 17-12. Applying the insertions to the film file is complicated by the issue of referential integrity. It should not be valid to insert a new film record when there is no record in the directors file for the director of the film. In a relational database system, referential integrity is automatically enforced by the database; but in COBOL, you have to do it yourself. The failure of programs to enforce referential integrity in COBOL legacy systems is one of the problems of legacy data. If you try to load such legacy data into a relational database that does enforce referential integrity, uniqueness, and other standards, the database system will probably crash.

Listing 17-7. Applying Transactions to an Indexed File

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing17-7.
AUTHOR. Michael Coughlan.
*Applies transactions to the Indexed FilmFile and enforces referential integrity
*with the Indexed Directors File

```

```

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
    SELECT FilmFile ASSIGN TO "Listing17-7Films.DAT"
        ORGANIZATION IS INDEXED
        ACCESS MODE IS DYNAMIC
        RECORD KEY IS FilmId-FF
        ALTERNATE RECORD KEY IS FilmTitle-FF
            WITH DUPLICATES
        ALTERNATE RECORD KEY IS DirectorId-FF
            WITH DUPLICATES
        FILE STATUS IS FilmStatus.

    SELECT DirectorsFile ASSIGN TO "Listing17-7Dir.DAT"
        ORGANIZATION IS INDEXED
        ACCESS MODE IS DYNAMIC
        RECORD KEY IS DirectorId-DF
        ALTERNATE RECORD KEY IS DirectorSurname-DF
        FILE STATUS IS DirectorStatus.

    SELECT TransFile ASSIGN TO "Listing17-7Trans.dat"
        ORGANIZATION IS LINE SEQUENTIAL.

```

DATA DIVISION.

FILE SECTION.

FD FilmFile.

01 FilmRec-FF.

```

88 EndOfFilms      VALUE HIGH-VALUES.
02 FilmId-FF       PIC 9(7).
02 FilmTitle-FF    PIC X(40).
02 DirectorId-FF   PIC 9(3).

```

FD DirectorsFile.

01 DirectorsRec-DF.

```

88 EndOfDirectors  VALUE HIGH-VALUES.
02 DirectorId-DF   PIC 9(3).
02 DirectorSurname-DF PIC X(20).

```

FD TransFile.

01 DeletionRec-TF.

```

88 EndOfTrans      VALUE HIGH-VALUES.
02 TypeId-TF       PIC X.
88 DoDeletion      VALUE "D".
88 DoInsertion     VALUE "I".
88 DoUpdate        VALUE "U".
02 FilmId-TF       PIC 9(7).

```

01 InsertionRec-TF.

```

02 FILLER          PIC 9.
02 InsertionBody-TF.
03 FILLER          PIC X(47).
03 DirectorId-TF  PIC 9(3).

```

01 UpdateRec-TF.

```

02 FILLER          PIC X(8).
02 FilmTitle-TF   PIC X(40).

```

WORKING-STORAGE SECTION.

01 AllStatusFlags VALUE ZEROS.

```

02 FilmStatus      PIC XX.
88 FilmOK VALUE ZEROS.
02 DirectorStatus  PIC XX.
88 MatchingDirectorFound VALUE ZEROS.

```

PROCEDURE DIVISION.

Begin.

```

OPEN I-O FilmFile
OPEN INPUT DirectorsFile
OPEN INPUT TransFile
DISPLAY "*** Film file before updates ***"
PERFORM DisplayFilmFileContents
DISPLAY SPACES
READ TransFile
    AT END SET EndOfTrans TO TRUE
END-READ

```



```

PERFORM UpdateFilmFile UNTIL EndofTrans
DISPLAY SPACES
DISPLAY "*** Film file after updates ***"
PERFORM DisplayFilmFileContents
CLOSE FilmFile, DirectorsFile, TransFile
STOP RUN.

```

DisplayFilmFileContents.

```

MOVE ZEROS TO FilmId-FF
START FilmFile KEY IS GREATER THAN FilmId-FF
  INVALID KEY DISPLAY "Error1 - FilmStatus = " FilmStatus
END-START
READ FilmFile NEXT RECORD
  AT END SET EndOfFilms TO TRUE
END-READ
PERFORM UNTIL EndOfFilms
  DISPLAY FilmId-FF SPACE DirectorId-FF SPACE FilmTitle-FF
  READ FilmFile NEXT RECORD
    AT END SET EndOfFilms TO TRUE
  END-READ
END-PERFORM.

```

UpdateFilmFile.

```

EVALUATE TRUE
  WHEN DoDeletion PERFORM DeleteFilmRec
  WHEN DoInsertion PERFORM InsertFilmRec
  WHEN DoUpdate PERFORM UpdateFilmRec
END-EVALUATE
READ TransFile
  AT END SET EndOfTrans TO TRUE
END-READ.

```

DeleteFilmRec.

```

MOVE FilmId-TF TO FilmId-FF
DELETE FilmFile RECORD
  INVALID KEY DISPLAY FilmId-FF " - Delete Error. No such record"
END-DELETE.

```

InsertFilmRec.

*To preserve Referential Integrity check director exists for this Film

```

MOVE DirectorId-TF TO DirectorId-DF
START DirectorsFile
  KEY IS EQUAL TO DirectorId-DF
  INVALID KEY DISPLAY FilmId-FF " - Insert Error. No matching entry for director - "

```

DirectorId-TF

```

END-START

IF MatchingDirectorFound
  MOVE InsertionBody-TF TO FilmRec-FF
  WRITE FilmRec-FF
    INVALID KEY DISPLAY FilmId-FF " - Insert Error. That FilmId already exists."
  END-WRITE
END-IF.

```

UpdateFilmRec.

```

MOVE FilmId-TF TO FilmId-FF
READ FilmFile RECORD
  KEY IS FilmId-FF
  INVALID KEY DISPLAY FilmId-FF " - Update error. No such record exists"
END-READ
IF FilmOk
  MOVE FilmTitle-TF TO FilmTitle-FF
  REWRITE FilmRec-FF
  INVALID KEY DISPLAY "Unexpected Error1. FilmStatus - " FilmStatus
END-REWRITE
END-IF.

```

Listing 17-7 Output

```

*** Film file before updates ***
8713669 023 Alien
8805075 009 Lord of the Rings:Return of the King
8805091 009 Lord of the Rings:Fellowship of the Ring
8805105 015 Mission Impossible
8805121 005 Jaws
8805156 015 Carrie
8805164 009 Lord of the Rings:The Two Towers
8805229 005 Saving Private Ryan
8805245 005 Catch Me If You Can
8805253 009 Heavenly Creatures
8805261 012 Master and Commander
8805288 033 Cape Fear
8805296 004 Overboard
8805326 005 The Color Purple
8805334 002 Desperado
8805385 003 First Knight
8805415 002 Pulp Fiction
8805474 003 Ghost
8805504 002 Jackie Brown
8805806 015 Carlito's Way
8812438 015 The Untouchables
8822334 023 Blade Runner

*** Transactions ***
D8805334 +++valid delete
D8844444 ---invalid delete
I8833333Raiders of the Lost Ark - valid insert 005
I8805111 invalid Insert no matching dir code 008
I8805245 invalid Insert rec already exists 005
U8805326Color Purple, The +++ valid update
U8811111 --- invalid update
U8812438Untouchables, The +++ valid update

8844444 - Delete Error. No such record
8833333 - Insert Error. No matching entry for director - 008
8805245 - Insert Error. That FilmId already exists.
8811111 - Update error. No such record exists

*** Film file after updates ***
8713669 023 Alien
8805075 009 Lord of the Rings:Return of the King
8805091 009 Lord of the Rings:Fellowship of the Ring
8805105 015 Mission Impossible
8805121 005 Jaws
8805156 015 Carrie
8805164 009 Lord of the Rings:The Two Towers
8805229 005 Saving Private Ryan
8805245 005 Catch Me If You Can
8805253 009 Heavenly Creatures
8805261 012 Master and Commander
8805288 033 Cape Fear
8805296 004 Overboard
8805326 005 Color Purple, The +++ valid update
8805385 003 First Knight
8805415 002 Pulp Fiction
8805474 003 Ghost
8805504 002 Jackie Brown
8805806 015 Carlito's Way
8812438 015 Untouchables, The +++ valid update
8822334 023 Blade Runner
8833333 005 Raiders of the Lost Ark - valid insert

*** Directors File ***
002Tarantino
003Zucker
004Marshall
005Spielberg
009Jackson
012Weir
015De Palma
023Scott
033Scorsese

```

Figure 17-12. Output from Listing 17-7

There is not much to talk about here that I have not already discussed in relation to relative files, but let's touch once more on the issue of referential integrity. When an insertion record has to be applied to `FilmFile`, you must make sure the director of that film has an entry in `DirectorsFile`. You do this in `InsertFilmRec` by using `START` with `DirectorsFile` and the director ID from `TransFile` to make sure there is a director with that ID in `DirectorsFile`. If there is a director with that ID, you try to apply the insertion.

Indexed Files: Syntax and Semantics

This section formally introduces the specific verb formats, clauses, and concepts required for indexed files.

Indexed Files: SELECT and ASSIGN Clause

The metalanguage for the `SELECT` and `ASSIGN` clause for indexed files is shown in Figure 17-13.

```

SELECT [OPTIONAL] FileName
    ASSIGN TO FileSpec
    [ORGANIZATION IS] INDEXED
    [ ACCESS MODE IS { SEQUENTIAL
                     { RANDOM
                     { DYNAMIC } } ]
    [RECORD KEY IS UniqueRecKey]
    [ALTERNATE RECORD KEY IS AltKey [WITH DUPLICATES]]
    [FILE STATUS IS FileStatus]

```

Figure 17-13. Metalanguage for `SELECT` and `ASSIGN` specific to indexed files

Consider the following:

- The key defined for a relative file by the `RELATIVE KEY` phrase in the `SELECT` and `ASSIGN` clause *cannot be* a field in the record of the relative file. In total contrast to this, every key (primary and alternates) defined for an indexed file *must be* a field in record of the indexed file.
- Every indexed file must have a primary key and may have up to 254 alternate keys.
- The primary key must be unique for each record and must be a numeric or alphanumeric data item. The primary key is identified by the `RECORD KEY IS` phrase in the `SELECT` and `ASSIGN` clause.
- Each alternate key must be numeric or alphanumeric and may be unique or may have duplicate values. The alternate keys are identified by the `ALTERNATE RECORD KEY IS` phrase in the `SELECT` and `ASSIGN` clause.
- If an alternate key can have duplicate values, then the `WITH DUPLICATES` phrase must be used. If `WITH DUPLICATES` is not used and you attempt to write a record that contains an alternate-key value that is already present in another record in the file, `WRITE` will fail, and a file status "22" (record already exists) will be returned.

The Key of Reference

When you define an indexed file with `ACCESS MODE IS SEQUENTIAL`, the file is always processed in ascending primary-key order. But if the file is defined with `ACCESS MODE IS DYNAMIC` and is processed sequentially, the file system must be able to tell which of the keys to use as the basis for processing the file. Because the format of the sequential `READ` does not have a key phrase, the file system refers to a special item called the *key of reference* to discover which key to use for processing the file. Before reading a file defined as `ACCESS MODE IS DYNAMIC` sequentially, you must establish one of the file's keys as the key of reference. You do so by using the key in a `START` or a direct `READ`. When the file is opened, the primary key is by default the key of reference, and the next-record pointer is pointing at the first record.

Indexed File Verbs

Indexed files use the same verbs for file manipulation as relative files, but in some cases there are syntactic or semantic differences. This section examines only those verbs that differ in syntax or semantics from those used with relative files.

The READ Verb

When an indexed file is defined with `ACCESS MODE IS SEQUENTIAL`, the `READ` format is the same as for sequential files. But when the file is defined with `ACCESS MODE IS DYNAMIC`, sequential processing of the file is complicated by the presence of a number of indexes. The order in which the data records are read depends on which index is being processed sequentially, and the index used is established by the key of reference.

For indexed files, the format of the `READ` used to read sequentially is the same as for relative files. But in the case of the direct `READ`, the format requires a `KEY IS` phrase to specify the key on which the file is to be read. The metalanguage for this format of `READ` is given in Figure 17-14.

```

READ FileName RECORD [ INTO DestItem ]
    [ KEY IS KeyName ]
    [ INVALIDKEY StatementBlock ]
    [ NOT INVALIDKEY StatementBlock ]
[ END-READ ]

```

Figure 17-14. *READ format used to read an indexed file directly*

To read a record directly from an indexed file, a key value must be placed in the `KeyName` data item (the `KeyName` data item is the area of storage identified as the primary key or one of the alternate keys in the `SELECT` and `ASSIGN` clause). When `READ` executes, the record with a key value equal to the present value of `KeyName` is read into the file buffer.

After the record has been read, the next-record pointer points to the next logical record in the file. If the key of reference is the primary key, then this record is an actual data record; but if the key of reference is one of the alternate keys, the pointer points to the next alternate index base record.

If duplicates are allowed, only the first record in a group with duplicates can be read directly. The rest of the duplicates must be read sequentially using the `READ NEXT RECORD` format.

Here are some things to remember:

- If the record does not exist, the `INVALID KEY` clause activates, and the statement block following the clause is executed.
- If the `KEY IS` clause is omitted, the key used is the primary key.
- When `READ` is executed, the key mentioned in the `KEY IS` phrase is established as the key of reference.

- If there is no KEY IS phrase, the primary key is established as the key of reference.
- The file must have an ACCESS MODE of DYNAMIC or RANDOM and must be opened for I-O or INPUT.

The WRITE, REWRITE and DELETE Verbs

The syntax and semantics of the WRITE, REWRITE, and DELETE verbs is the same as for relative files, except that

- Direct access for all these verbs is based on the primary key only.
- Although REWRITE may not change the value of the primary key, it may change the value of any of the alternate keys.

The START Verb

The syntax for the START verb is the same as for relative files, except that instead of the format START FileName KEY Condition RelKey, the format is as is shown in Figure 17-15. The key of comparison is any of the keys specified in the indexed file's SELECT and ASSIGN clause.

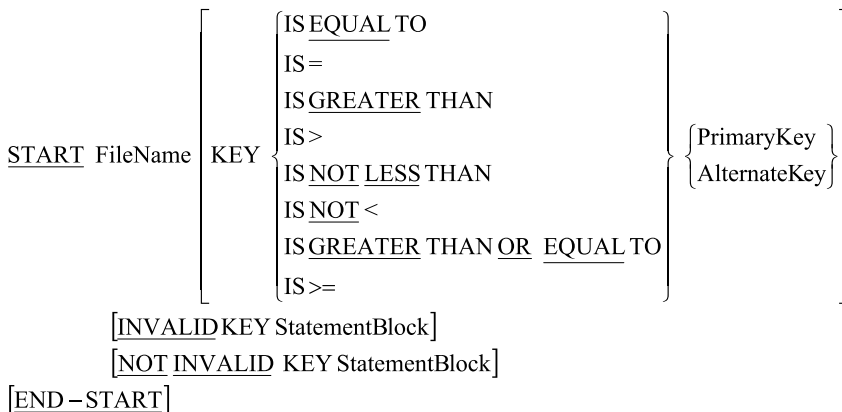


Figure 17-15. Metalanguage for the START verb

Just as with relative files, the START verb may be used to control the position of the next-record pointer. In addition, with indexed files, the START verb may be used to establish a particular key as the key of reference.

The primary key or one of the alternate keys is the key of comparison. To establish a particular key as the key of reference and position the next-record pointer at a particular record, you first move the key value to the key-of-comparison data item. Then you execute the statement START . . KEY IS EQUAL TO . . if you want to position the next-record pointer at the record with a key equal to the value in the key of comparison, or START . . KEY IS GREATER THAN . . if you want to position the next-record pointer at the succeeding record.

Remember these things:

- The file must be opened for **INPUT** or **I-O** when START is executed.
- Execution of the START statement does not change the contents of the record area (that is, START does not read the record—it merely positions the next-record pointer and establishes the key of reference).
- When START is executed, the next-record pointer is set to the first logical record in the file whose key satisfies the condition. If no record satisfies the condition, the INVALID KEY clause is activated.

Comparison of COBOL File Organizations

Now that you have examined all the COBOL file organizations, you may wonder which is the best one to use. The answer is that it depends. This section examines the advantages and disadvantages of each organization; from this information, you should be able to figure out which organization to use in a given situation.

First some terminology. The *hit rate* refers to the number of records in the file that are impacted when you process a file. For instance, if only 100 records are affected by an insert, a delete, or an update operation in a file of 100,000 records, the hit rate is low. But if 90,000 records are affected, the hit rate is high.

Sequential File Organization

The records in a sequential file are held serially, one after another, on disk, tape, or other media. This organization has both advantages and disadvantages.

Disadvantages of Sequential File Organization

Sequential files have the following disadvantages:

- *They are slow when the hit rate is low.* To read a particular record, you have to read all the preceding records. To update records, you have to read all the records in the file and write them to a new file. This is a lot of work if all you are doing is changing a few of the records in the file.
- *They are complicated to change.* Changes to sequential files are batched together in a transaction file to minimize the low-hit-rate problem, but this makes updating sequential files much more complicated than updating direct access files. The complications arise from having to match the records in the transaction file with those in the master file (that is, the file to be updated).
- *They take up double the storage when they are updated.* The records in sequential files cannot be updated in situ; instead, a new file must be created that consists of all the records in the old file plus the insertions and minus the deletions. Of course, this storage problem may be transient, because once the new file has been created, you can delete the old file.

Advantages of Sequential File Organization

Sequential file organization also has a number of advantages:

- *When the hit rate is high, it is the fastest file organization* because the record position does not have to be calculated and no indexes have to be traversed. Because the records are stored contiguously, this organization takes advantage of the fact that the file system doesn't access records on a per-record basis but instead scoops up a block or bucket at a time. When a block contains a number of records, the number of disk accesses required to process the file is greatly reduced.
- *It is the most storage efficient of all the file organizations.* No indexes are required, the space from deleted records is recovered, and only the storage actually required to hold the records is allocated to the file.
- *It is the simplest file organization.* Records are held serially, so you read them one after another.

- *It allows the space from deleted records to be recovered.* To delete records from a sequential file, you create a new file that does not contain the deleted records. Once you delete the old file, all the storage previously used by the deleted records is recovered and can be used for storing something else.
- *Sequential files may be stored and processed on serial media such as magnetic tape.* These media are cheap, removable, and voluminous.

Relative File Organization

You can think of the records in a relative file as a one-dimensional table stored on disk. The file system can calculate where each record is on the disk because it knows the start location for the file, and it knows the amount of storage required to store each record. The record location is calculated as $\text{RecordLocation} = \text{BaseLocation} + (\text{SizePerRecord} * (\text{RelativeRecordNumber} - 1))$.

Disadvantages of Relative File Organization

Relative file organization has a number of disadvantages:

- *It wastes storage if the file is only partially populated with records.* The file is allocated enough disk storage to hold records from 1 to the highest relative record number used, even if only a few records have been written to the file. For instance, if the first record written to the file has a relative record number of 100,000, room for that many records is allocated to the file.
- *It cannot recover the space from deleted records.* When a record is deleted in a relative file, it is marked as deleted, but the space that was occupied by the record is still allocated to the file. This means if a relative file takes up 1.5MB of disk space when full, it still occupies 1.5MB when 99% of the records have been deleted.
- *It allows only a single, numeric key.* The single key is limiting because often you need to access a file on more than one key. For instance, in a file of student records, you might want to access the records on student ID, student name, course code, or module code. The mention of using student name, course code, or module code highlights another drawback with relative files: you frequently need to access a file using an alphanumeric key.
- *The relative file key must map on to the range of the relative record numbers for the file.* The facts that the key must be in the range between 1 and the highest key value and that the file system allocates space for all the records between 1 and the highest relative record number used impose severe constraints on the key. For instance, even though `StudentId` is numeric, you can't use it as a key because the file system allocates space for records between 1 and the highest `StudentId` written to the file. If the highest `StudentId` written to the file is 9976683, the file system will allocate space for 9,976,683 records. Universities rarely have this many students, so most of the file will be wasted space.

Sometimes you can get around the limitations of the relative key by using a transformation function to map the actual key onto the range of relative record numbers. There are a number of possible transformation or *hashing* functions. These transformations include *truncation* (using only some of the digits in the key as the relative record number), *folding* (breaking the key into two or more parts and summing the parts), *digit manipulation* (manipulating some of the digits in the key to produce a relative record number), and *modulus division* (using the remainder of a division operation as the relative record number). Some sophisticated transformation functions may even allow alphanumeric keys.

- *Relative files must be stored and processed on direct access media.* Because relative files are direct access files, they must be processed on direct access media such as a hard disk. They cannot be processed on magnetic tape or other cheap serial media; and if stored on tape, they must be loaded onto a hard disk before they can be used.

Advantages of Relative File Organization

Although relative file organization has many disadvantages, it also has the following advantages:

- *It is the fastest direct access organization.* Only a few simple calculations have to be done to locate a particular record.
- *Records in a relative file have very little storage overhead.* Unlike indexed files, which must store the indexes as well as the data, relative files have only a small storage overhead for each record (such as the record-deletion indicator).
- *Records in a relative file can be read sequentially.* In addition to allowing direct access, relative files allow sequential access to the records in the file.

Indexed File Organization

As shown in the Figure 17-10 earlier, the records in an indexed file are arranged in ascending primary-key order in a series of chained buckets/blocks. In addition to the actual data records, the primary key has a number of index records. For each alternate key specified for the file, there is a similar arrangement; but instead of data records at the final level, there are records arranged in ascending alternate-key order that consist only of the key and a pointer to where the actual record may be found. As shown earlier in Figure 17-11, in addition to the records at the base level, there are a number of alternate-key index records.

Disadvantages of Indexed File Organization

Indexed file organization has many disadvantages:

- *It is the slowest direct access organization,* because indexed files achieve direct access by traversing a number of levels of index. Indexed files must have a primary-key index and an index for each alternate key. Each level of index implies an I/O operation on the hard disk. For instance, three I/O operations are required to read the record shown earlier in Figure 17-10: two for the index records and one for data record).
- *It especially slow when writing or deleting records* because then the primary-key index and the alternate-key indexes may need to be rebuilt.
- *It is not very storage efficient,* because indexed files must store the index records, the alternate index records, the data records, and the alternate data records.
- *Space from deleted records is only partially recovered* until the indexes are rebuilt (which has to be done periodically).
- *Indexed files may only be processed on direct access media,* because they are direct access files. They cannot be processed on magnetic tape.

Advantages of Indexed File Organization

As you have seen, indexed files have many disadvantages, but these are far outweighed by their advantages:

- They can use multiple, alphanumeric keys.
- They can have duplicate alternate keys.
- They can be read sequentially on any of their keys.
- They can partially recover space from deleted records.
- They can have multiple alphanumeric keys, and only the primary key must be unique.

Although indexed files have their disadvantages, the versatility afforded by having multiple, alphanumeric keys and being able to process the file both directly and sequentially on any of its keys overrides all their disadvantages. As a result, indexed files are the most widely used direct access file organization.

Summary

This chapter introduced COBOL's direct access file organizations: indexed and relative files. You learned about the arrangement of records in each of these file organizations, along with new concepts such as file status, the next-record pointer, and key of reference. You explored the syntactic and semantic changes that allow the existing file-processing verbs to process direct access files, and you were introduced to new COBOL file-processing verbs such as DELETE, REWRITE, and START. In the final section of the chapter, you saw the advantages and disadvantages of each of the COBOL file organizations.

The next chapter discusses the COBOL Report Writer. The Report Writer allows you to write programs that produce reports using declarative rather than procedural/imperative techniques. In imperative programming, you tell the computer how to do what you want done. In declarative programming, you tell the computer what you would like done, and the computer works out how to do it.

The Report Writer also uses a kind of specialized exception handling called *declaratives*. You can also use declaratives with files. When you specify the declaratives for a file, an exception that would normally activate the AT END or INVALID KEY clause instead executes the code you have written in the DECLARATIVE SECTION to deal with the problem.

By way of introduction, the answer to the exercise at the end of this chapter uses the Report Writer to print a small report. Because you don't know how to use the Report Writer yet, you have to do the exercise the hard way. There is nothing like the pain of coding a report program to make you appreciate the benefits of the Report Writer!

PROGRAMMING EXERCISE

Time for a little exercise. Whip out your 2B pencil and see if you can come up with a solution to this problem.

Introduction

Acme Automobile Parts Limited sells motorcycle and automobile spare parts. Recently, the company purchased a computer and retained your firm to write the programs required. Your supervisor has asked you to write the program detailed next.

General Description

The program is required to perform file maintenance on the vehicle master file using a transaction file of validated amendment records. The transaction file has been sorted on ascending date (YYYYMMDD). If an error is encountered when attempting to apply transactions to the vehicle master file, then the transaction record must be written to an error file (Listing17-8-Err.DAT). When a vehicle record is deleted, the spare parts stocked for that vehicle are no longer required and so must be printed to a redundant stock report (Listing17-8-Stk.RPT).

There are two types of records in the transaction file, and they are distinguished from one another by the codes "I" (insert vehicle record) and "D" (delete vehicle record) in the first character position of the record.

Vehicle Master File

The vehicle master file (Listing17-8-VMF.DAT) is a relative file. VehicleNumber is used for the relative record number. Each record has following description:

Field	Type	Length	Value
VehicleNumber	9	4	1-9999
VehicleDescription	X	25	-
ManufacturerName	X	20	-

Stock Master File

The stock master file (Listing17-8-SMF.DAT) is an indexed file. It is required so that you can report all the stock records that are affected when a vehicle is deleted from the vehicle master file. Each record in the stock master file has the following record description:

Field	Key Type	Type	Length	Value
PartNumber	Primary	9	7	1-9999999
VehicleNumber	Alt with duplicates	9	4	1-9999
PartDescription	-	X	25	-

Transaction File

The transaction file (AcmeTrans.DAT) is validated file, sequenced on ascending DateOfEntry. Records in the file have the following description:

Record Type	Field	Type	Length	Value
InsertVehicleRecord	TypeCode	X	1	I
	DateOfEntry	9	8	YYYYMMDD
	VehicleNumber	9	4	1-9999
	VehicleDescription	X	25	-
DeleteVehicleRecord	TypeCode	X	1	D
	DateOfEntry	9	8	YYYYMMDD
	VehicleNumber	9	4	1-9999

Maintenance Procedure

Type Code	Action
I	If a record with this VehicleNumber already exists in either the stock or vehicle master file, then write the transaction record to the error file. Otherwise, insert the record.
D	If the record does not exist in the vehicle master file, then write the transaction record to the error file. If there is no error, then read all the stock records with the same VehicleNumber as the record to be deleted and write the details to the redundant stock report. Rewrite the VehicleNumber field in each of these stock records with zeros. Delete the vehicle master file record.

The Redundant Stock Report

Headings should be printed at the top of each page. See the print specification in Figure 17-16 for further details.

```

12345678901234567890123456789012345678901234567890123456789012345678901
01
02
03          REDUNDANT STOCK REPORT
04          -----
05
06 PART NUMBER      PART DESCRIPTION      VEHICLE NO.      MANUFACTURER NAME
07
08 XXXXXXXX      XXXXXXXXXXXXXXXXXXXXXXXX      XXXX      XXXXXXXXXXXXXXXXXXXX
09
10 XXXXXXXX      XXXXXXXXXXXXXXXXXXXXXXXX      XXXX      XXXXXXXXXXXXXXXXXXXX
11
12 XXXXXXXX      XXXXXXXXXXXXXXXXXXXXXXXX      XXXX      XXXXXXXXXXXXXXXXXXXX
13
14 XXXXXXXX      XXXXXXXXXXXXXXXXXXXXXXXX      XXXX      XXXXXXXXXXXXXXXXXXXX
15
16 XXXXXXXX      XXXXXXXXXXXXXXXXXXXXXXXX      XXXX      XXXXXXXXXXXXXXXXXXXX
17
18 XXXXXXXX      XXXXXXXXXXXXXXXXXXXXXXXX      XXXX      XXXXXXXXXXXXXXXXXXXX
19
20 XXXXXXXX      XXXXXXXXXXXXXXXXXXXXXXXX      XXXX      XXXXXXXXXXXXXXXXXXXX
21
22 XXXXXXXX      XXXXXXXXXXXXXXXXXXXXXXXX      XXXX      XXXXXXXXXXXXXXXXXXXX
23
24 XXXXXXXX      XXXXXXXXXXXXXXXXXXXXXXXX      XXXX      XXXXXXXXXXXXXXXXXXXX
25
26

```

Figure 17-16. Print specification. Line numbers and column numbers added

PROGRAMMING EXERCISE: ANSWER

IDENTIFICATION DIVISION.

PROGRAM-ID. Listing17-8.

AUTHOR. MICHAEL COUGHLAN.

*Applies Insertions and Deletions in TransFile to the VehicleFile.

*For Insertions - If a vehicle already exists in either the Stock or

*Vehicle file, the transaction record is written to the Error File otherwise inserted

*For Deletions - If the vehicle does not exist in the Vehicle File the transaction

*record is written to the Error File otherwise the Vehicle record is deleted

*If the vehicle record is deleted all the Stock records with the same VehicleNumber

*as the deleted record are written to the Redundant Stock Report and the VehicleNumber

*field in each of these Stock records is overwritten with zeros.

ENVIRONMENT DIVISION.

INPUT-OUTPUT SECTION.

FILE-CONTROL.

```
SELECT StockFile ASSIGN TO "Listing17-8-SMF.DAT"
    ORGANIZATION IS INDEXED
    ACCESS MODE IS DYNAMIC
    RECORD KEY IS PartNumSF
    ALTERNATE RECORD KEY IS VehicleNumSF
        WITH DUPLICATES
    FILE STATUS IS StockErrStatus.
```

```
SELECT VehicleFile ASSIGN TO "Listing17-8-VMF.DAT"
    ORGANIZATION IS RELATIVE
    ACCESS MODE IS DYNAMIC
    RELATIVE KEY IS VehicleNumKey
    FILE STATUS IS VehicleErrStatus.
```

```
SELECT TransFile ASSIGN TO "Listing17-8-TRANS.DAT"
    ORGANIZATION IS LINE SEQUENTIAL.
```

```
SELECT ErrorFile ASSIGN TO "Listing17-8-ERR.DAT"
    ORGANIZATION IS LINE SEQUENTIAL.
```

```
SELECT RedundantStockRpt ASSIGN TO "Listing17-8-STK.RPT".
```

DATA DIVISION.

FILE SECTION.

FD StockFile.

01 StockRecSF.

02 PartNumSF PIC 9(7).

02 VehicleNumSF PIC 9(4).

02 PartDescSF PIC X(25).

```

FD VehicleFile.
01 VehicleRecVF.
    02 VehicleNumVF          PIC 9(4).
    02 VehicleDescVF        PIC X(25).
    02 ManfNameVF           PIC X(20).

FD TransFile.
01 TransRecTF.
    02 TransTypeTF          PIC X.
        88 InsertionRec      VALUE "I".
        88 DeletionRec       VALUE "D".
    02 DateTF               PIC X(8).
    02 VehicleNumTF         PIC 9(4).
    02 VehicleDescTF        PIC X(25).
    02 ManfNameTF           PIC X(20).

FD RedundantStockRpt REPORT IS StockReport.

FD ErrorFile.
01 ErrorRec                 PIC X(56).

WORKING-STORAGE SECTION.
01 ErrorStatusCodes.
    02 StockErrStatus        PIC X(2).
        88 StockFileOpOK     VALUE "00", "02".
        88 StockRecExistis   VALUE "22".
        88 NoStockRec        VALUE "23".
    02 VehicleErrStatus      PIC X(2).
        88 VehicleFileOpOK   VALUE "00".
        88 VehicleRecExists  VALUE "22".
        88 NoVehicleRec      VALUE "23".

01 FileVariables.
    02 VehicleNumKey         PIC 9(4).
    02 PrevVehicleNum        PIC 9(4).

01 ConditionNames.
    02 FILLER                PIC X.
        88 EndOfStockFile    VALUE HIGH-VALUES.
        88 NotEndOfStockFile VALUE LOW-VALUES.
    02 FILLER                PIC X.
        88 EndOfTransFile    VALUE HIGH-VALUES.

REPORT SECTION.
RD StockReport
PAGE LIMIT IS 66
HEADING 1
FIRST DETAIL 6
LAST DETAIL 50
FOOTING 55.

```

```

01 TYPE IS PAGE HEADING.
02 LINE 2.
03 COLUMN 31          PIC X(24) VALUE
   "REDUNDANT STOCK REPORT".
02 LINE 3.
03 COLUMN 30          PIC X(26) VALUE ALL "-".

02 LINE 6.
03 COLUMN 2           PIC X(36) VALUE
   "PART NUMBER      PART DESCRIPTION".
03 COLUMN 45          PIC X(35) VALUE
   "VEHICLE NO.      MANUFACTURER  NAME".

01 DetailLine TYPE IS DETAIL.
02 LINE IS PLUS 2.
03 COLUMN 3           PIC 9(7) SOURCE PartNumSF .
03 COLUMN 17          PIC X(25) SOURCE PartDescSF.
03 COLUMN 48          PIC 9(4) SOURCE VehicleNumSF.
03 COLUMN 60          PIC X(20) SOURCE ManfNameVF.

```

PROCEDURE DIVISION.

Begin.

```

OPEN INPUT  TransFile.
OPEN I-O    StockFile
            VehicleFile.
OPEN OUTPUT ErrorFile
            RedundantStockRpt.

```

INITIATE StockReport

```

READ TransFile
  AT END SET EndOfTransFile TO TRUE
END-READ
PERFORM UNTIL EndOfTransFile
  MOVE VehicleNumTF TO VehicleNumKey
                    VehicleNumSF

  EVALUATE  TRUE
    WHEN InsertionRec PERFORM CheckStockFile
    WHEN DeletionRec  PERFORM DeleteVehicleRec
    WHEN OTHER        DISPLAY "NOT INSERT OR DELETE"
  END-EVALUATE
  READ TransFile
  AT END SET EndOfTransFile TO TRUE
END-READ
END-PERFORM

```

TERMINATE StockReport

```

CLOSE   ErrorFile
        RedundantStockRpt
        TransFile
        StockFile
        VehicleFile

```

```
STOP RUN.
```

```
CheckStockFile.
```

```

READ StockFile KEY IS VehicleNumSF
    INVALID KEY CONTINUE
END-READ
IF StockFileOpOK
    PERFORM WriteErrorLine
ELSE IF NoStockRec
    PERFORM InsertVehicleRec
ELSE
    DISPLAY "Unexpected Read Error on Stockfile"
    DISPLAY "Stockfile status = " StockErrStatus
END-IF
END-IF.

```

```
InsertVehicleRec.
```

```

MOVE ManfNameTF TO ManfNameVF
MOVE VehicleDescTF TO VehicleDescVF
MOVE VehicleNumTF TO VehicleNumVF
WRITE VehicleRecVF
    INVALID KEY CONTINUE
END-WRITE
IF VehicleRecExists PERFORM WriteErrorLine
ELSE IF NOT VehicleFileOpOK
    DISPLAY "Unexpected Write Error on VehicleFile."
    DISPLAY "Vehicle file status = " VehicleErrStatus
END-IF
END-IF.

```

```
DeleteVehicleRec.
```

```

READ VehicleFile
    INVALID KEY CONTINUE
END-READ
IF NoVehicleRec PERFORM WriteErrorLine
ELSE IF VehicleFileOpOK
    DELETE VehicleFile RECORD
        INVALID KEY
        DISPLAY "Unexpected Delete Error on VehicleFile"
        DISPLAY "Vehicle file status = " VehicleErrStatus
    END-DELETE
    PERFORM UpdateStockFile
ELSE
    DISPLAY "DeleteProblem = " VehicleErrStatus
END-IF
END-IF.

```

WriteErrorLine.

```
    MOVE TransRecTF TO ErrorRec
    WRITE ErrorRec.
```

UpdateStockFile.

```
    MOVE VehicleNumSF TO PrevVehicleNum
    READ StockFile KEY IS VehicleNumSF
        INVALID KEY CONTINUE
    END-READ
    IF StockFileOpOK
        SET NotEndOfStockFile TO TRUE
        PERFORM PrintStockRpt
            UNTIL VehicleNumSF NOT EQUAL TO PrevVehicleNum
                OR EndOfStockFile
    END-IF.
```

PrintStockRpt.

```
    GENERATE DetailLine
    MOVE ZEROS TO VehicleNumSF
    REWRITE StockRecSF
        INVALID KEY DISPLAY "ERROR ON REWRITE"
    END-REWRITE
    READ StockFile NEXT RECORD
        AT END SET EndOfStockFile TO TRUE
    END-READ.
```



The COBOL Report Writer

This chapter introduces the COBOL Report Writer. In a series of increasingly complex programs, you learn how to use the Report Writer to create control-break-based report programs. By examining these programs, you are gradually introduced to the new verbs, clauses, sections and concepts of the Report Writer. You see how to use the RD entry in the REPORT SECTION to specify control-break items and define the basic layout of the page. The chapter explores report groups and how to create report groups linked to the control-break items specified in the report's RD entry. You learn how to use the SUM clause for subtotalling and rolling forward. The final program introduces declaratives and how to use them to extend the capabilities of the Report Writer. Once you've seen the capabilities of the Report Writer through the example programs, the chapter explores the verbs, clauses, and concepts of the Report Writer more formally.

Declaratives can be used to extend the capabilities of the Report Writer, but you can also use them to define exception-handling procedures for files. The final section explains how to create declaratives for file error handling.

Report Writer

Producing reports is an important aspect of business programming. Nowadays, reports may consist of rows and columns of figures and be supported by summary information in the form of a variety of charts and graphs. In the past, reports consisted solely of printed figures. You've probably seen such reports in old films, where a management person is poring over page after page of green-lined, fan-fold computer printout.

Although producing reports is important, unfortunately the report programs produced using standard COBOL print files (see Chapter 8) are often tedious to code. Report programs are long, achieving correct placement of horizontal and vertical print items is laborious, and the programs frequently consist of repetitions of the tasks and techniques (such as control-break processing) used in other report programs. In recognition of the importance of reports in the business domain, and to simplify the task of writing report programs, COBOL provides the Report Writer.

Like indexed files, the COBOL Report Writer used to be one of the jewels in COBOL's crown. But today, just as relational databases have eroded the importance of indexed files, so off-the-shelf packages such as Crystal Reports with its array of charts and graphs have put COBOL's Report Writer in the shade. Nevertheless, although summary information in the form of charts and graphs is very useful, there is still a need for printed reports; and you can learn a lot from a close acquaintance with the Report Writer.

I start by showing you an example of a report produced by the Report Writer. Then, through a series of increasingly complex report programs, you learn how to create the program that produced that report. The final example program takes the complexity one stage further.

Example Report: Solace Solar Solutions

This report shows the sales made by agents selling solar power products in each of the 50 American states. You see the program specification and the report, and then I follow up with a discussion that highlights the report's features. After discussing the report, I show you the PROCEDURE DIVISION code that produced the report.

Problem Specification

Solace Solar Solutions is a company that sells solar power products through its sales agents all over the United States. Sales agents are paid a base salary (which is different from state to state) and a commission of 8% on the value of the products they sell.

The monthly report shows the value of the individual sales and the total sales made by each Solace sales agent. The total sales made for the state and the base salary for the state are also shown. The report is printed on ascending sales agent number within ascending state name.

The report is based on a sequential sales file, which contains details of each sale made in the country. The sales file is ordered on ascending sales agent number within ascending state number. Each record of the sales file has the following description:

Field	Type	Length	Value
StateNum	9	2	1-50
SalesAgentNum	9	3	1-999
ValueOfSale	9	7	0.50-99999.99

Example Report

The first page of the example report is shown in Example 18-1. For ease of reference, I have attached line numbers to the report.

Example 18-1. Solace Solar Solutions Example Report: First Page

```

01                Solace Solar Solutions
02      Sales Agent - Sales and Salary Report Monthly Report
03
04      State      Agent      Value
05      Name      Number     Of Sales
06      Alabama   38          $9,325.14
07                      $11,839.19
08                      $19,102.61
09                      Sales for sales agent 38 = $40,266.94
10
11
12      Alabama   73          $4,503.71
13                      $11,659.87
14                      $19,540.19
15                      Sales for sales agent 73 = $35,703.77
16
17                      Total sales for Alabama      $75,970.71
18                      Base salary for Alabama      $1,149.00
19      -----
20
21

```

```

22  Alaska          55          $18,981.84
23                      $3,065.97
24                      $10,686.92
25                      Sales for sales agent 55 = $32,734.73
26
27
28  Alaska          89          $11,187.72
29                      $14,145.82
30                      Sales for sales agent 89 = $25,333.54
31
32
33  Alaska          104         $18,005.42
34                      $17,614.20
35                      Sales for sales agent 104 = $35,619.62
36
37                      Total sales for Alaska          $93,687.89
38                      Base salary for Alaska          $1,536.00
39  -----
40
41
42  Arizona          23          $4,237.72
43
44
45
46
47
48
49  Programmer - Michael Coughlan                Page : 1

```

Report Writer Tasks

To get a feel for what the Report Writer can do, let's examine in some detail what it has to do to produce this report:

- Print the report heading lines (lines 01–02). These are printed, once only, at the beginning of the report.
- Print the subject heading lines (page headings). These are printed at the top of each page—on lines 04–05 on the first page and lines 01–02 on subsequent pages.
- Print a footer at the bottom of each page (showing the name of the programmer and a page number: line 49). To print the page number, the Report Writer must keep a page count.
- Keep a line count, and change the page when the count is greater than 42 (unless the next thing to print is a sales agent total line, a state total line, a base salary line, or the final total line).
- Print the details of a sales agent's sales (for example, as shown for sales agent 38 on lines 06–08). Because the sales file only contains a state number, the Report Writer must get the state name from a lookup table.
- Suppress the sales agent number and state name after their first occurrence (but restore them if there is a change of page, sales agent, or state name: see lines 06, 12, 22, 28, 33, 42).
- When the sales agent number changes, print the total sales accumulated for the sales agent (lines 15, 25, 35)

- When the state number changes, print the total sales accumulated for the state (lines 17, 37).
- When the state number changes, get the base salary for the state from a lookup table, and print it (lines 18, 38).
- When the state number changes, print a line of hyphens to separate this state from the next (lines 19, 39).

Accumulate all the sales values, and print them as a final total at the end of the report (not shown on the example page).

Report Writer PROCEDURE DIVISION

If you had to create the Solace Solar Solutions sales report using the approach shown in Chapter 8 (that is, using a control-break program and the WRITE verb), you would probably write a program that had a PROCEDURE DIVISION with more than 100 lines of code. It is interesting to discover that the Report Writer can do all this work in just the 10 COBOL statements shown in Example 18-2.

Example 18-2. PROCEDURE DIVISION That Produces the Sales Report

```
PROCEDURE DIVISION.
Begin.
  OPEN INPUT SalesFile.
  OPEN OUTPUT PrintFile.
  READ SalesFile
    AT END SET EndOfFile TO TRUE
  END-READ.
  INITIATE SolaceSalesReport.
  PERFORM PrintSalaryReport
    UNTIL EndOfFile.
  TERMINATE SolaceSalesReport.
  CLOSE SalesFile, PrintFile.
  STOP RUN.

PrintSalaryReport.
  GENERATE DetailLine.
  READ SalesFile
    AT END SET EndOfFile TO TRUE
  END-READ.
```

So Much Work, So Little Code

How can so much work be done in so little PROCEDURE DIVISION code? How does the Report Writer know that page headings or page footers are required? If you wrote a program to print this report using WRITE statements, you would need a control-break program with a PERFORM UNTIL StateNum NOT EQUAL TO PrevStateNum loop to process each state and an inner loop PERFORM UNTIL SalesAgentNum NOT EQUAL TO PrevSalesAgentNum to process the sales for each sales agent. Without those loops, how does the Report Writer know it is time to print the sales agent totals or the state totals, and how does it accumulate those totals in the first place?

To achieve so much in so little PROCEDURE DIVISION code, the Report Writer uses a declarative approach to programming rather than the imperative (procedural) approach familiar to most programmers. In imperative programming, you tell the computer how to do what you want done. In declarative programming, you tell the computer what you would like done, and the computer works out how to do it. When you use the Report Writer, you

declare *what* to print when a page heading, page footer, sales agent total, state total, or final total is required, and the Report Writer works out *when* to print these items. In keeping with the adage that “there is no such thing as a free lunch,” the PROCEDURE DIVISION of a Report Writer program is short because most of the work is done in the (greatly expanded) DATA DIVISION.

How the Report Writer Works

The Report Writer works by recognizing that many reports take (more or less) the same shape. There may be headings at the beginning of the report and footers at the end. There may be headings at the top of each page and footers at the bottom. Headings or footers may need to be printed whenever there is a control break (that is, when the value in a specified field changes, such as when the sales agent number or state number changes in Example 18-1). In addition, the detail lines that display the information summarized in control-break totals also need to be printed.

The Report Writer calls these different report items *report groups*. Reports are organized around report groups. The Report Writer recognizes the seven types of report group shown in Example 18-3; the indentation shows their relative importance/order of execution.

Example 18-3. Report Group Types

REPORT HEADING or RH group

- printed once at the beginning of the report

PAGE HEADING or PH group

- printed at the top of each page

CONTROL HEADING or CH group

- printed at the beginning of each control break

DETAIL or DE group

- printed each time the GENERATE statement is executed

CONTROL FOOTING or CF group

- printed at the end of each control break

PAGE FOOTING or PF group

- printed at the bottom of each page

REPORT FOOTING or RF group

- printed once at the end of the report.

For each report, there must be a Report Description (RD) entry in the REPORT SECTION of the DATA DIVISION that fully describes the report. The report groups that describe the report are defined as records in the RD entries. Most groups are defined once for each report, but control groups are defined for each control-break item. For instance, in the example program, control footings are defined on SalesAgentNum, StateNum, and FINAL. FINAL is a special control group that is invoked before or after the normal control groups (before if CONTROL HEADING FINAL is used, and after if CONTROL FOOTING FINAL is used).

Ordinary control groups are defined on a control-break data item. The Report Writer monitors the contents of the designated data item, and when the value changes, a control break is automatically initiated. When the control break is initiated, the CONTROL FOOTING group of the breaking item (if there is one) and the CONTROL HEADING group of the next item are printed.

Writing a report program consists of a number of tedious tasks such as keeping track of the line count to ensure that page headings or footers are printed when required, or simply moving data values into their corresponding items in the print line. In addition, when you write a report according to a program specification, you often have to adhere to the report layout specified in a print layout form such as that shown in Figure 18-1. When you have to adhere to such a form, it can be tricky to get the vertical and horizontal placement of printed items correct. Counting characters to figure out what size to make each of the fields that define a print line is tedious and time consuming.

Modifying the Specification

This first example program creates a report program that does the following:

- Prints a report heading
- Prints a heading and a footer on each page
- For each sale record, prints the state name (obtained from a table), the sales agent number, and the value of the sale
- Prints the total value of the sales made by each sales agent
- Prints a line of hyphens at the end of each state to separate the states from one another

The first page of the report produced by this program is shown in Example 18-4 (line numbers have been added). The program that produces the report is shown in Listing 18-1.

Example 18-4. Simplified Version of the Report Showing Only Sales Agent Totals

```

01                Solace Solar Solutions
02      Sales Agent - Sales and Salary Report Monthly Report
03
04      State      Agent      Value
05      Name       Number     Of Sales
06      Alabama   38        $9,325.14
07      Alabama   38        $11,839.19
08      Alabama   38        $19,102.61
09                Sales for sales agent 38 = $40,266.94
10
11
12      Alabama   73        $4,503.71
13      Alabama   73        $11,659.87
14      Alabama   73        $19,540.19
15                Sales for sales agent 73 = $35,703.77
16      -----
17
18
19      Alaska    55        $18,981.84
20      Alaska    55        $3,065.97
21      Alaska    55        $10,686.92
22                Sales for sales agent 55 = $32,734.73
23
24
25      Alaska    89        $11,187.72
26      Alaska    89        $14,145.82
27                Sales for sales agent 89 = $25,333.54
28
29
30      Alaska    104       $18,005.42
31      Alaska    104       $17,614.20
32                Sales for sales agent 104 = $35,619.62
33      -----
34
35

```

```

36  Arizona          23          $4,237.72
37  Arizona          23          $13,315.00
38          Sales for sales agent 23  =  $17,552.72
39
40
41  Arizona          90          $2,078.93
42  Arizona          90          $17,228.88
43  Arizona          90          $8,929.96
44          Sales for sales agent 90  =  $28,237.77

```

```

45  -----

```

```

46
47
48

```

```

49  Programmer - Michael Coughlan

```

```

Page : 1

```

Listing 18-1. Simplified Report Program

IDENTIFICATION DIVISION.

PROGRAM-ID. Listing18-1.

AUTHOR. Michael Coughlan.

ENVIRONMENT DIVISION.

INPUT-OUTPUT SECTION.

FILE-CONTROL.

```

    SELECT SalesFile ASSIGN TO "Listing18-1-Sales.DAT"
       ORGANIZATION IS LINE SEQUENTIAL.

```

```

    SELECT PrintFile ASSIGN TO "Listing18-1.Rpt".

```

DATA DIVISION.

FILE SECTION.

FD SalesFile.

01 SalesRecord.

```

    88 EndOfFile VALUE HIGH-VALUES.

```

```

    02 StateNum PIC 99.

```

```

    02 SalesAgentNum PIC 999.

```

```

    02 ValueOfSale PIC 9(5)V99.

```

FD PrintFile

```

    REPORT IS SolaceSalesReport.

```

WORKING-STORAGE SECTION.

01 StateNameTable.

```

    02 StateNameValues.

```

```

        03 FILLER PIC X(14) VALUE "Alabama".

```

```

        03 FILLER PIC X(14) VALUE "Alaska".

```

```

        03 FILLER PIC X(14) VALUE "Arizona".

```

```

        03 FILLER PIC X(14) VALUE "Arkansas".

```

```

        03 FILLER PIC X(14) VALUE "California".

```

```

        03 FILLER PIC X(14) VALUE "Colorado".

```

```

        03 FILLER PIC X(14) VALUE "Connecticut".

```

```

        03 FILLER PIC X(14) VALUE "Delaware".

```

```

        03 FILLER PIC X(14) VALUE "Florida".

```

```

        03 FILLER PIC X(14) VALUE "Georgia".

```



```

03 FILLER PIC X(14) VALUE "Hawaii".
03 FILLER PIC X(14) VALUE "Idaho".
03 FILLER PIC X(14) VALUE "Illinois".
03 FILLER PIC X(14) VALUE "Indiana".
03 FILLER PIC X(14) VALUE "Iowa".
03 FILLER PIC X(14) VALUE "Kansas".
03 FILLER PIC X(14) VALUE "Kentucky".
03 FILLER PIC X(14) VALUE "Louisiana".
03 FILLER PIC X(14) VALUE "Maine".
03 FILLER PIC X(14) VALUE "Maryland".
03 FILLER PIC X(14) VALUE "Massachusetts".
03 FILLER PIC X(14) VALUE "Michigan".
03 FILLER PIC X(14) VALUE "Minnesota".
03 FILLER PIC X(14) VALUE "Mississippi".
03 FILLER PIC X(14) VALUE "Missouri".
03 FILLER PIC X(14) VALUE "Montana".
03 FILLER PIC X(14) VALUE "Nebraska".
03 FILLER PIC X(14) VALUE "Nevada".
03 FILLER PIC X(14) VALUE "New Hampshire".
03 FILLER PIC X(14) VALUE "New Jersey".
03 FILLER PIC X(14) VALUE "New Mexico".
03 FILLER PIC X(14) VALUE "New York".
03 FILLER PIC X(14) VALUE "North Carolina".
03 FILLER PIC X(14) VALUE "North Dakota".
03 FILLER PIC X(14) VALUE "Ohio".
03 FILLER PIC X(14) VALUE "Oklahoma".
03 FILLER PIC X(14) VALUE "Oregon".
03 FILLER PIC X(14) VALUE "Pennsylvania".
03 FILLER PIC X(14) VALUE "Rhode Island".
03 FILLER PIC X(14) VALUE "South Carolina".
03 FILLER PIC X(14) VALUE "South Dakota".
03 FILLER PIC X(14) VALUE "Tennessee".
03 FILLER PIC X(14) VALUE "Texas".
03 FILLER PIC X(14) VALUE "Utah".
03 FILLER PIC X(14) VALUE "Vermont".
03 FILLER PIC X(14) VALUE "Virginia".
03 FILLER PIC X(14) VALUE "Washington".
03 FILLER PIC X(14) VALUE "West Virginia".
03 FILLER PIC X(14) VALUE "Wisconsin".
03 FILLER PIC X(14) VALUE "Wyoming".
02 FILLER REDEFINES StateNameValues.
    03 State OCCURS 50 TIMES.
        04 StateName PIC X(14).

```

REPORT SECTION.

```

RD SolaceSalesReport
   CONTROLS ARE StateNum
                SalesAgentNum
PAGE LIMIT IS 54
FIRST DETAIL 3
LAST DETAIL 46
FOOTING 48.

```

```

01 TYPE IS REPORT HEADING NEXT GROUP PLUS 1.
  02 LINE 1.
    03 COLUMN 20      PIC X(32)
                       VALUE "Solace Solar Solutions".

  02 LINE 2.
    03 COLUMN 6       PIC X(51)
                       VALUE "Sales Agent - Sales and Salary Report Monthly Report".

01 TYPE IS PAGE HEADING.
  02 LINE IS PLUS 1.
    03 COLUMN 2       PIC X(5) VALUE "State".
    03 COLUMN 16      PIC X(5) VALUE "Agent".
    03 COLUMN 32      PIC X(8) VALUE "Value".

  02 LINE IS PLUS 1.
    03 COLUMN 2       PIC X(4) VALUE "Name".
    03 COLUMN 16      PIC X(6) VALUE "Number".
    03 COLUMN 31      PIC X(8) VALUE "Of Sales".

01 DetailLine TYPE IS DETAIL.
  02 LINE IS PLUS 1.
    03 COLUMN 1       PIC X(14)
                       SOURCE StateName(StateNum).

    03 COLUMN 17      PIC ZZ9
                       SOURCE SalesAgentNum.

    03 COLUMN 30      PIC $$$,$$$.$99 SOURCE ValueOfSale.

01 SalesAgentGrp
  TYPE IS CONTROL FOOTING SalesAgentNum NEXT GROUP PLUS 2.
  02 LINE IS PLUS 1.
    03 COLUMN 15      PIC X(21) VALUE "Sales for sales agent".
    03 COLUMN 37      PIC ZZ9 SOURCE SalesAgentNum.
    03 COLUMN 43      PIC X VALUE "=".
    03 TotalAgentSales COLUMN 45 PIC $$$,$$$.$99 SUM ValueOfSale.

01 StateGrp TYPE IS CONTROL FOOTING StateNum NEXT GROUP PLUS 2.
  02 LINE IS PLUS 1.
    03 COLUMN 1       PIC X(58) VALUE ALL "-".

01 TYPE IS PAGE FOOTING.
  02 LINE IS 49.
    03 COLUMN 1       PIC X(29) VALUE "Programmer - Michael Coughlan".
    03 COLUMN 55      PIC X(6) VALUE "Page :".
    03 COLUMN 62      PIC ZZ9 SOURCE PAGE-COUNTER.

PROCEDURE DIVISION.
Begin.
  OPEN INPUT SalesFile.
  OPEN OUTPUT PrintFile.
  READ SalesFile
    AT END SET EndOfFile TO TRUE
  END-READ.

```

```

INITIATE SolaceSalesReport.
PERFORM PrintSalaryReport
        UNTIL EndOfFile.
TERMINATE SolaceSalesReport.
CLOSE SalesFile, PrintFile.
STOP RUN.

```

```

PrintSalaryReport.
GENERATE DetailLine.
READ SalesFile
        AT END SET EndOfFile TO TRUE
END-READ.

```

The first thing to note is that the PROCEDURE DIVISION for this program is the same as for the program that produced the report in Example 18-1. This is your first indication that most of the work is being done in the DATA DIVISION. As I add complexity to the program in the succeeding examples, eventually I have to make some changes to the PROCEDURE DIVISION code.

The second thing to note is that just like an ordinary print file, a Report Writer file must have a SELECT and ASSIGN clause in the ENVIRONMENT DIVISION and an FD entry in the DATA DIVISION. But look at the FD entry. Instead of a record description, you have a REPORT IS SolaceSalesReport entry. This entry tells you that the Report Writer is being used and that this particular report is called SolaceSalesReport. This entry links the PrintFile with the report described in the REPORT SECTION. That is the next thing to note; when you use the Report Writer, you describe the report in the REPORT SECTION.

The first entry in the REPORT SECTION is the RD entry, which is followed by the name of the report. This is the same name you use in the REPORT IS entry in the FD entry of the PrintFile. The RD entry has a number of clauses. The first is the CONTROLS ARE clause, which allows you to identify the control-break item(s) that the Report Writer must monitor in order to detect a control break. These entries usually identify fields in an input file, but they don't have to. The remaining RD clauses specify information about the page, such as the size of the page, the first line where a detail line may be printed, and the line after which the footer may be printed.

The remaining entries identify the required report groups. Each report group is a record and must start with a 01 level number. As noted in Example 18-3, there are seven possible types of report groups, and the first entry in the report group must specify the type of the group. Listing 18-1 has the following report groups:

- A REPORT HEADING group that specifies what is to be printed at the start of the report.
- A PAGE HEADING group that specifies what is to be printed at the top of each page.
- A DETAIL group that specifies what is to be printed for each sales record.
- CONTROL FOOTING groups for the SalesAgentNum control-break item and the StateNum control-break item. These groups specify what is printed when a control break occurs on SalesAgentNum or StateNum.
- A PAGE FOOTING group that specifies what is to be printed at the bottom of each page.

Report Groups

Let's look at some of the entries in these report groups in more detail. The REPORT HEADING group is of interest because it demonstrates absolute position using the LINE clause. It also demonstrates the COLUMN clause, which you use to specify the horizontal placement of the material to be printed. The final item of interest in this group is the NEXT GROUP PLUS clause, which specifies that the next group will start one line down from this group. Although, as you see with the PAGE HEADING group, you can specify vertical placement using a relative reference rather than an absolute line number, that is not always sufficient for all your positioning needs. Sometimes you require a combination of the NEXT GROUP PLUS and the LINE IS PLUS clauses.

You might think that the PAGE HEADING group would also use absolute positioning, but in this example, the page headings are not printed on the same line on every page. On the first page, they are printed after the report heading lines; but on the other pages, they are printed on the first line. For this reason, LINE IS PLUS relative positioning is used for this group. Because the other groups, except the PAGE FOOTING group, are also printed on different lines on the page, they also use LINE IS PLUS relative positioning.

The main clause of interest in the DETAIL report group is the SOURCE clause. This clause specifies that the data for this print item is to come from some source data item. This is how the Report Writer gets values for the state name (from the table), the sales agent number, and the value of the sale.

SalesAgentGrp is a CONTROL FOOTING group. It is printed whenever there is a control break on SalesAgentNum. When you create a CONTROL group, you have to associate the group with a control item mentioned in the RD . .CONTROLS ARE phrase. This is how the Report Write associates a particular control-break item with a CONTROL HEADING or FOOTING group. At the moment, this group only prints a line of hyphens; but the next program uses it to accumulate and print the total sales agent sales.

The final group to consider is the PAGE FOOTING group. The item of interest in this group is PAGE-COUNTER, which is identified as the source of the page number printed in this footer. PAGE-COUNTER is a special Report Writer register that automatically keeps a count of the pages printed.

PROCEDURE DIVISION Notes

Now that you have seen the role played by the DATA DIVISION entries in producing the report, you need to know how the report is driven from the PROCEDURE DIVISION. The Report Writer introduces three new verbs: INITIATE, GENERATE, and TERMINATE.

When the INITIATE verb is executed, all the heading groups, such as REPORT HEADING and the first PAGE HEADING, are produced. All the system registers, such as PAGE-COUNTER, are set to their starting values.

When the TERMINATE verb is executed, all the relevant FOOTING groups, such as REPORT FOOTING and the last PAGE FOOTING, are produced.

The report is driven by the GENERATE verb. GENERATE is normally associated either with the DETAIL group (as it is in this example) or with the report name. When GENERATE is associated with a DETAIL group, each time the GENERATE statement is executed, the DETAIL group is printed. Obviously this makes sense only if each time GENERATE executes, the DETAIL group is fed new data. In this program, the new data is provided by reading the sales file.

Adding Features to the Report Program

Let's add some features to the Solace Sales Report program. Let's change the program so that the report now shows the total sales for the sales agent, total sales for the state, and a final total for the country. The report should also show the base salary paid to sales agents in each state. To do this, the state table has to be modified to include the salary information. One final thing needs to change. If you look at the report in Example 18-4, you see that each line that prints a sales value also prints the state name and the sales agent number. This looks unsightly. The state name and the sales agent number should be suppressed after their first occurrence. Instead of this

04	State	Agent	Value	
05	Name	Number	Of Sales	
06	Alabama	38	\$9,325.14	
07	Alabama	38	\$11,839.19	
08	Alabama	38	\$19,102.61	
09		Sales for sales agent 38	=	\$40,266.94

the report should print this:

04	State	Agent	Value	
05	Name	Number	Of Sales	
06	Alabama	38	\$9,325.14	
07			\$11,839.19	
08			\$19,102.61	
09		Sales for sales agent 38	=	\$40,266.94

You probably have realized by now that these specification changes are satisfied by the report shown in Example 18-1. Listing 18-2 is the program that produced that report.

Listing 18-2. Program to Create a Report with Sales Totals

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing18-2.
AUTHOR. Michael Coughlan.

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT SalesFile ASSIGN TO "Listing18-2-Sales.DAT"
        ORGANIZATION IS LINE SEQUENTIAL.

    SELECT PrintFile ASSIGN TO "Listing18-2.Rpt".

DATA DIVISION.
FILE SECTION.
FD SalesFile.
01 SalesRecord.
    88 EndOfFile VALUE HIGH-VALUES.
    02 StateNum PIC 99.
    02 SalesAgentNum PIC 999.
    02 ValueOfSale PIC 9(5)V99.

FD PrintFile
REPORT IS SolaceSalesReport.

WORKING-STORAGE SECTION.
01 StateNameTable.
    02 StateNameValues.
        03 FILLER PIC X(18) VALUE "1149Alabama".
        03 FILLER PIC X(18) VALUE "1536Alaska".
        03 FILLER PIC X(18) VALUE "1284Arizona".
        03 FILLER PIC X(18) VALUE "1064Arkansas".
        03 FILLER PIC X(18) VALUE "1459California".
        03 FILLER PIC X(18) VALUE "1508Colorado".
        03 FILLER PIC X(18) VALUE "1742Connecticut".
        03 FILLER PIC X(18) VALUE "1450Delaware".
        03 FILLER PIC X(18) VALUE "1328Florida".
        03 FILLER PIC X(18) VALUE "1257Georgia".
```

```

03 FILLER PIC X(18) VALUE "1444Hawaii".
03 FILLER PIC X(18) VALUE "1126Idaho".
03 FILLER PIC X(18) VALUE "1439Illinois".
03 FILLER PIC X(18) VALUE "1203Indiana".
03 FILLER PIC X(18) VALUE "1267Iowa".
03 FILLER PIC X(18) VALUE "1295Kansas".
03 FILLER PIC X(18) VALUE "1126Kentucky".
03 FILLER PIC X(18) VALUE "1155Louisiana".
03 FILLER PIC X(18) VALUE "1269Maine".
03 FILLER PIC X(18) VALUE "1839Maryland".
03 FILLER PIC X(18) VALUE "1698Massachusetts".
03 FILLER PIC X(18) VALUE "1257Michigan".
03 FILLER PIC X(18) VALUE "1479Minnesota".
03 FILLER PIC X(18) VALUE "0999Mississippi".
03 FILLER PIC X(18) VALUE "1236Missouri".
03 FILLER PIC X(18) VALUE "1192Montana".
03 FILLER PIC X(18) VALUE "1261Nebraska".
03 FILLER PIC X(18) VALUE "1379Nevada".
03 FILLER PIC X(18) VALUE "1571New Hampshire".
03 FILLER PIC X(18) VALUE "1743New Jersey".
03 FILLER PIC X(18) VALUE "1148New Mexico".
03 FILLER PIC X(18) VALUE "1547New York".
03 FILLER PIC X(18) VALUE "1237North Carolina".
03 FILLER PIC X(18) VALUE "1290North Dakota".
03 FILLER PIC X(18) VALUE "1256Ohio".
03 FILLER PIC X(18) VALUE "1155Oklahoma".
03 FILLER PIC X(18) VALUE "1309Oregon".
03 FILLER PIC X(18) VALUE "1352Pennsylvania".
03 FILLER PIC X(18) VALUE "1435Rhode Island".
03 FILLER PIC X(18) VALUE "1172South Carolina".
03 FILLER PIC X(18) VALUE "1206South Dakota".
03 FILLER PIC X(18) VALUE "1186Tennessee".
03 FILLER PIC X(18) VALUE "1244Texas".
03 FILLER PIC X(18) VALUE "1157Utah".
03 FILLER PIC X(18) VALUE "1374Vermont".
03 FILLER PIC X(18) VALUE "1607Virginia".
03 FILLER PIC X(18) VALUE "1487Washington".
03 FILLER PIC X(18) VALUE "1062West Virginia".
03 FILLER PIC X(18) VALUE "1393Wisconsin".
03 FILLER PIC X(18) VALUE "1393Wyoming".
02 FILLER REDEFINES StateNameValues.
    03 State OCCURS 50 TIMES.
        04 BaseSalary PIC 9(4).
        04 StateName PIC X(14).

```

```

REPORT SECTION..
RD SolaceSalesReport
  CONTROLS ARE FINAL
    StateNum
    SalesAgentNum

```

PAGE LIMIT IS 54
 FIRST DETAIL 3
 LAST DETAIL 42
 FOOTING 48.

01 TYPE IS REPORT HEADING NEXT GROUP PLUS 1.

02 LINE 1.

03 COLUMN 20 PIC X(32)
 VALUE "Solace Solar Solutions".

02 LINE 2.

03 COLUMN 6 PIC X(51)
 VALUE "Sales Agent - Sales and Salary Report Monthly Report".

01 TYPE IS PAGE HEADING.

02 LINE IS PLUS 1.

03 COLUMN 2 PIC X(5) VALUE "State".
 03 COLUMN 16 PIC X(5) VALUE "Agent".
 03 COLUMN 32 PIC X(8) VALUE "Value".

02 LINE IS PLUS 1.

03 COLUMN 2 PIC X(4) VALUE "Name".
 03 COLUMN 16 PIC X(6) VALUE "Number".
 03 COLUMN 31 PIC X(8) VALUE "Of Sales".

01 DetailLine TYPE IS DETAIL.

02 LINE IS PLUS 1.

03 COLUMN 1 PIC X(14)
 SOURCE StateName(StateNum) **GROUP INDICATE.**
 03 COLUMN 17 PIC ZZ9
 SOURCE SalesAgentNum **GROUP INDICATE.**
 03 COLUMN 30 PIC \$\$\$,\$\$\$.\$99 SOURCE ValueOfSale.

01 SalesAgentGrp

TYPE IS CONTROL FOOTING SalesAgentNum NEXT GROUP PLUS 2.

02 LINE IS PLUS 1.

03 COLUMN 15 PIC X(21) VALUE "Sales for sales agent".
 03 COLUMN 37 PIC ZZ9 SOURCE SalesAgentNum.
 03 COLUMN 43 PIC X VALUE "=".
 03 TotalAgentSales COLUMN 45 PIC \$\$\$,\$\$\$,\$\$\$.\$99 SUM ValueOfSale.

01 StateGrp TYPE IS CONTROL FOOTING StateNum NEXT GROUP PLUS 2.

02 LINE IS PLUS 2.

03 COLUMN 15 PIC X(15) VALUE "Total sales for".
03 COLUMN 31 PIC X(14) SOURCE StateName(StateNum).
03 TotalStateSales COLUMN 45 PIC \$\$\$,\$\$\$,\$\$\$.\$99 SUM TotalAgentSales.

02 LINE IS PLUS 1.

03 COLUMN 15 PIC X(15) VALUE "Base salary for".
03 COLUMN 31 PIC X(14) SOURCE StateName(StateNum).
03 COLUMN 48 PIC \$\$\$,\$\$\$.\$99 SOURCE BaseSalary(StateNum).

```
02 LINE IS PLUS 1.
03 COLUMN 1 PIC X(58) VALUE ALL "-".
```

01 TotalSalesGrp TYPE IS CONTROL FOOTING FINAL.

```
02 LINE IS PLUS 2.
03 COLUMN 15 PIC X(11)
VALUE "Total sales".
03 COLUMN 46 PIC X VALUE "=".
03 COLUMN 48 PIC $$$,$$$,$$$.$99 SUM TotalStateSales.
```

```
01 TYPE IS PAGE FOOTING.
02 LINE IS 49.
03 COLUMN 1 PIC X(29) VALUE "Programmer - Michael Coughlan".
03 COLUMN 55 PIC X(6) VALUE "Page :".
03 COLUMN 62 PIC ZZ9 SOURCE PAGE-COUNTER.
```

PROCEDURE DIVISION.

Begin.

```
OPEN INPUT SalesFile.
OPEN OUTPUT PrintFile.
READ SalesFile
  AT END SET EndOfFile TO TRUE
END-READ.
INITIATE SolaceSalesReport.
PERFORM PrintSalaryReport
  UNTIL EndOfFile.
TERMINATE SolaceSalesReport.
CLOSE SalesFile, PrintFile.
STOP RUN.
```

PrintSalaryReport.

```
GENERATE DetailLine.
READ SalesFile
  AT END SET EndOfFile TO TRUE
END-READ.
```

Let's look at the changes. The major differences between Listing 18-1 and Listing 18-2 are shown in bold. The PROCEDURE DIVISION has not changed. But there is a new control group: in order to print the final total for the country, a CONTROL FOOTING group is required. This control group is controlled by a special control item called FINAL. Note that now the CONTROLS ARE phrase in the report's RD contains the word FINAL. The FINAL control-break item activates when the report is terminated. You should also take note of the *order* of the control-break items in the CONTROLS ARE phrase. FINAL is the major control break, StateNum is next in importance, and SalesAgentNum is the least important. A break on a major control item causes a break on all the subordinate control items.

If you examine the report in Example 18-5, you'll see that now StateName and SalesAgentNum are suppressed after their first occurrence. This is done by specifying the GROUP INDICATE clause for the data item.

Another change to the program was required to accumulate and print the total sales for the sales agent. The Report Writer has three ways of incrementing totals: subtotalling, rolling forward, and crossfooting. All these methods use the SUM clause but target different types of data item. *Subtotalling* targets data items in the FILE SECTION or the WORKING-STORAGE SECTION. *Rolling forward* targets data items in a subordinate CONTROL FOOTING group. *Crossfooting* targets data items in the same group. This example uses subtotalling and rolling forward.

Subtotaling is used in `SalesAgentGrp` to sum the sales made by the agent. A `SUM` clause is used that targets the `ValueOfSale` data item so that every time a `GENERATE` statement is executed, the current value of `ValueOfSale` is added to a sum counter. When the control break occurs, the `CONTROL FOOTING` group activates, and the value accumulated in the sum counter is printed.

There is something else here that you note. As you have no doubt noticed, in the `REPORT SECTION` you don't have to follow a level number with a data-item name or even the word `FILLER`. This saves a lot of unnecessary work. But you can include a name if you want to. In the `SalesAgentGrp`, I have included the name `TotalAgentSales`. The reason for naming this item is shown in the `StateGrp CONTROL FOOTING` group, where it is used as the target of the `SUM` clause. Every time there is a control break on `SalesAgentNum`, the current value of `TotalAgentSales` is added to the sum counter in `StateGrp`. When there is a control break on `StateNum`, the accumulated value of the sum counter is printed. This is an example of rolling forward.

Rolling forward is also used with `TotalStateSales` in `StateGrp`. `TotalStateSales` is used as the target of the `SUM` clause in `TotalSalesGrp` to sum each state total into a final total. When the `TERMINATE` statement is executed, the final total is printed.

Adding More Features to the Report Program

In the specification at the start of this section, I mentioned that Solace sales agents are paid a base salary and a commission of 8% on the value of the products they sell. In Listing 18-3, each time the total sales for an agent are printed, the commission they have earned and their total salary (base salary + commission) should also be printed. The first page of the report produced by Listing 18-3 is shown in Example 18-5.

Listing 18-3. Adding the Sales Agent Commission and Salary to the Report

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing18-3.
AUTHOR. Michael Coughlan.

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT SalesFile ASSIGN TO "Listing18-3-Sales.DAT"
        ORGANIZATION IS LINE SEQUENTIAL.

    SELECT PrintFile ASSIGN TO "Listing18-3.Rpt".

DATA DIVISION.
FILE SECTION.
FD SalesFile.
01 SalesRecord.
    88 EndOfFile VALUE HIGH-VALUES.
    02 StateNum PIC 99.
    02 SalesAgentNum PIC 999.
    02 ValueOfSale PIC 9(5)V99.

FD PrintFile
REPORT IS SolaceSalesReport.
```

WORKING-STORAGE SECTION.

01 StateNameTable.

0 02 StateNameValues.

```

03 FILLER PIC X(18) VALUE "1149Alabama".
03 FILLER PIC X(18) VALUE "1536Alaska".
03 FILLER PIC X(18) VALUE "1284Arizona".
03 FILLER PIC X(18) VALUE "1064Arkansas".
03 FILLER PIC X(18) VALUE "1459California".
03 FILLER PIC X(18) VALUE "1508Colorado".
03 FILLER PIC X(18) VALUE "1742Connecticut".
03 FILLER PIC X(18) VALUE "1450Delaware".
03 FILLER PIC X(18) VALUE "1328Florida".
03 FILLER PIC X(18) VALUE "1257Georgia".
03 FILLER PIC X(18) VALUE "1444Hawaii".
03 FILLER PIC X(18) VALUE "1126Idaho".
03 FILLER PIC X(18) VALUE "1439Illinois".
03 FILLER PIC X(18) VALUE "1203Indiana".
03 FILLER PIC X(18) VALUE "1267Iowa".
03 FILLER PIC X(18) VALUE "1295Kansas".
03 FILLER PIC X(18) VALUE "1126Kentucky".
03 FILLER PIC X(18) VALUE "1155Louisiana".
03 FILLER PIC X(18) VALUE "1269Maine".
03 FILLER PIC X(18) VALUE "1839Maryland".
03 FILLER PIC X(18) VALUE "1698Massachusetts".
03 FILLER PIC X(18) VALUE "1257Michigan".
03 FILLER PIC X(18) VALUE "1479Minnesota".
03 FILLER PIC X(18) VALUE "0999Mississippi".
03 FILLER PIC X(18) VALUE "1236Missouri".
03 FILLER PIC X(18) VALUE "1192Montana".
03 FILLER PIC X(18) VALUE "1261Nebraska".
03 FILLER PIC X(18) VALUE "1379Nevada".
03 FILLER PIC X(18) VALUE "1571New Hampshire".
03 FILLER PIC X(18) VALUE "1743New Jersey".
03 FILLER PIC X(18) VALUE "1148New Mexico".
03 FILLER PIC X(18) VALUE "1547New York".
03 FILLER PIC X(18) VALUE "1237North Carolina".
03 FILLER PIC X(18) VALUE "1290North Dakota".
03 FILLER PIC X(18) VALUE "1256Ohio".
03 FILLER PIC X(18) VALUE "1155Oklahoma".
03 FILLER PIC X(18) VALUE "1309Oregon".
03 FILLER PIC X(18) VALUE "1352Pennsylvania".
03 FILLER PIC X(18) VALUE "1435Rhode Island".
03 FILLER PIC X(18) VALUE "1172South Carolina".
03 FILLER PIC X(18) VALUE "1206South Dakota".
03 FILLER PIC X(18) VALUE "1186Tennessee".
03 FILLER PIC X(18) VALUE "1244Texas".
03 FILLER PIC X(18) VALUE "1157Utah".
03 FILLER PIC X(18) VALUE "1374Vermont".
03 FILLER PIC X(18) VALUE "1607Virginia".
03 FILLER PIC X(18) VALUE "1487Washington".
03 FILLER PIC X(18) VALUE "1062West Virginia".

```

```

03 FILLER PIC X(18) VALUE "1393Wisconsin".
03 FILLER PIC X(18) VALUE "1393Wyoming".
02 FILLER REDEFINES StateNameValues.
03 State OCCURS 50 TIMES.
04 BaseSalary PIC 9(4).
04 StateName PIC X(14).

```

01 MiscVariables.

```

02 SalesCommission PIC 9(5)V99.
02 Percentage PIC V99 VALUE .08.
02 FullSalary PIC 9(6)V99.
02 ActualStateNum PIC 99.

```

REPORT SECTION.

```

RD SolaceSalesReport
  CONTROLS ARE FINAL
    StateNum
    SalesAgentNum
  PAGE LIMIT IS 66
  HEADING 1
  FIRST DETAIL 6
  LAST DETAIL 54
  FOOTING 56.

```

01 TYPE IS PAGE HEADING.

```

02 LINE 1.
03 COLUMN 20 PIC X(32)
  VALUE "Solace Solar Solutions".

```

02 LINE 2.

```

03 COLUMN 6 PIC X(51)
  VALUE "Sales Agent - Sales and Salary Report Monthly Report".

```

02 LINE 4.

```

03 COLUMN 2 PIC X(5) VALUE "State".
03 COLUMN 16 PIC X(5) VALUE "Agent".
03 COLUMN 32 PIC X(8) VALUE "Value".

```

02 LINE 5.

```

03 COLUMN 2 PIC X(4) VALUE "Name".
03 COLUMN 16 PIC X(6) VALUE "Number".
03 COLUMN 31 PIC X(8) VALUE "Of Sales".

```

01 DetailLine TYPE IS DETAIL.

02 LINE IS PLUS 1.

```

03 COLUMN 1 PIC X(14)
  SOURCE StateName(StateNum) GROUP INDICATE.
03 COLUMN 17 PIC 999
  SOURCE SalesAgentNum GROUP INDICATE.
03 COLUMN 30 PIC $$$,$$.99 SOURCE ValueOfSale.

```

```

01 SalesAgentGrp
  TYPE IS CONTROL FOOTING SalesAgentNum NEXT GROUP PLUS 2.
02 LINE IS PLUS 1.
  03 COLUMN 15 PIC X(21) VALUE "Sales for sales agent".
  03 COLUMN 37 PIC 999 SOURCE SalesAgentNum.
  03 COLUMN 43 PIC X VALUE "=" .
  03 TotalAgentSales COLUMN 45 PIC $$$$, $$$.99 SUM ValueOfSale.

02 LINE IS PLUS 1.
  03 COLUMN 15 PIC X(19) VALUE "Sales commission is".
  03 COLUMN 43 PIC X VALUE "=" .
  03 COLUMN 45 PIC $$$$, $$$.99 SOURCE SalesCommission.

02 LINE IS PLUS 1.
  03 COLUMN 15 PIC X(22) VALUE "Sales agent salary is".
  03 COLUMN 43 PIC X VALUE "=" .
  03 COLUMN 45 PIC $$$$, $$$.99 SOURCE FullSalary.

01 StateGrp TYPE IS CONTROL FOOTING StateNum NEXT GROUP PLUS 2.
02 LINE IS PLUS 2.
  03 COLUMN 15 PIC X(15) VALUE "Total sales for".
  03 COLUMN 31 PIC X(14) SOURCE StateName(StateNum).
  03 TotalStateSales COLUMN 45 PIC $$$$, $$$.99 SUM TotalAgentSales.

02 LINE IS PLUS 1.
  03 COLUMN 15 PIC X(15) VALUE "Base salary for".
  03 COLUMN 31 PIC X(14) SOURCE StateName(StateNum).
  03 COLUMN 48 PIC $$, $$$.99 SOURCE BaseSalary(StateNum).

02 LINE IS PLUS 1.
  03 COLUMN 15 PIC X(26)
  VALUE "Actual state number is -".
  03 COLUMN 42 PIC Z9 SOURCE ActualStateNum.

02 LINE IS PLUS 1.
  03 COLUMN 15 PIC X(26)
  VALUE "Supplied state number is -".
  03 COLUMN 42 PIC Z9 SOURCE StateNum.

02 LINE IS PLUS 1.
  03 COLUMN 1 PIC X(58) VALUE ALL "-".

01 TotalSalesGrp TYPE IS CONTROL FOOTING FINAL.
02 LINE IS PLUS 4.
  03 COLUMN 15 PIC X(11)
  VALUE "Total sales".
  03 COLUMN 46 PIC X VALUE "=" .
  03 COLUMN 48 PIC $$$$, $$$.99 SUM TotalStateSales.

```

```

01 TYPE IS PAGE FOOTING.
  02 LINE IS 58.
    03 COLUMN 1      PIC X(29) VALUE "Programmer - Michael Coughlan".
    03 COLUMN 55     PIC X(6) VALUE "Page :".
    03 COLUMN 62     PIC ZZ9 SOURCE PAGE-COUNTER.

```

PROCEDURE DIVISION.

DECLARATIVES.

Calc SECTION.

USE BEFORE REPORTING SalesAgentGrp.

Calculate-Salary.

MULTIPLY TotalAgentSales BY Percentage

GIVING SalesCommission ROUNDED

ADD SalesCommission, BaseSalary(StateNum)

GIVING FullSalary.

END DECLARATIVES.

Main SECTION.

Begin.

```

OPEN INPUT SalesFile
OPEN OUTPUT PrintFile
READ SalesFile
  AT END SET EndOfFile TO TRUE
END-READ
INITIATE SolaceSalesReport
PERFORM PrintSalaryReport
  UNTIL EndOfFile
TERMINATE SolaceSalesReport
CLOSE SalesFile, PrintFile
STOP RUN.

```

PrintSalaryReport.

```

GENERATE DetailLine
READ SalesFile
  AT END SET EndOfFile TO TRUE
END-READ
MOVE StateNum TO ActualStateNum.

```

Example 18-5. Report Showing Commission Earned and Total Salary

Solace Solar Solutions
Sales Agent - Sales and Salary Report Monthly Report

State Name	Agent Number	Value Of Sales	
Alabama	038	\$9,325.14	
		\$11,839.19	
		\$19,102.61	
	Sales for sales agent 038	=	\$40,266.94
	Sales commission is	=	\$3,221.36
	Sales agent salary is	=	\$4,370.36

Alabama	073	\$4,503.71	
		\$11,659.87	
		\$19,540.19	
	Sales for sales agent 073	=	\$35,703.77
	Sales commission is	=	\$2,856.30
	Sales agent salary is	=	\$4,005.30
	Total sales for Alabama		\$75,970.71
	Base salary for Alabama		\$1,149.00
	Actual state number is	-	2
	Supplied state number is	-	1

Alaska	055	\$18,981.84	
		\$3,065.97	
		\$10,686.92	
	Sales for sales agent 055	=	\$32,734.73
	Sales commission is	=	\$2,618.78
	Sales agent salary is	=	\$4,154.78

Alaska	089	\$11,187.72	
		\$14,145.82	
	Sales for sales agent 089	=	\$25,333.54
	Sales commission is	=	\$2,026.68
	Sales agent salary is	=	\$3,562.68

Alaska	104	\$18,005.42	
		\$17,614.20	
	Sales for sales agent 104	=	\$35,619.62
	Sales commission is	=	\$2,849.57
	Sales agent salary is	=	\$4,385.57
	Total sales for Alaska		\$93,687.89
	Base salary for Alaska		\$1,536.00
	Actual state number is	-	3
	Supplied state number is	-	2

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The major differences between Listing 18-2 and Listing 18-3 are shown in bold. To print the agent commission and total salary, I have added a number of entries to SalesAgentGrp. Note, though, that the sources of these items are data items declared outside the REPORT SECTION. The reason is that these items require calculations beyond what the Report Writer can handle automatically. To calculate these items, you must use declaratives. I discuss declaratives presently; but for now, I want to discuss another issue.

Look at the StateGrp CONTROL FOOTING and in particular at these lines:

```
03 COLUMN 31    PIC X(14) SOURCE StateName(StateNum).
03 COLUMN 48    PIC $$$,$$.99 SOURCE BaseSalary(StateNum).
```

Notice anything strange? This footer is printed when there is a control break on `StateNum`—in other words, when the value of `StateNum` changes. This means `StateNum` in the previous lines should refer to the next state and not the one for which the totals have just been accumulated. And yet, if you examine the report, you see that the correct state name and base salary are printed. How can this be? Remember this:

In a `CONTROL FOOTING` or in the `DECLARATIVES SECTION`, when a control data item is referenced, the value supplied is the previous value and not the value that has just caused the control break.

To emphasize this point, I have printed the actual state number value (the one in the record buffer) and the state number supplied by the Report Writer. To get the actual state number, each time a record is read, the `StateNum` in the record is moved to the `ActualStateNum` in the `WORKING-STORAGE SECTION`. This data item is used as a `SOURCE` when the `CONTROL FOOTING` is printed.

Report Writer Declaratives

The Report Writer is a wonderful tool if the structure of the required report fits the way the Report Writer does things. But sometimes the structure or requirements of a report are such that the standard Report Writer alone is not sufficient. In these cases, you can use declaratives to extend the functionality of the Report Writer.

The `USE BEFORE REPORTING` phrase allows code specified in the declaratives to be executed just before the report group mentioned in the `USE BEFORE REPORTING` phrase is printed. The code in the declaratives extends the functionality of the Report Writer by performing tasks or calculations that the Report Writer cannot do automatically or by selectively stopping a report group from being printed (using the `SUPPRESS PRINTING` command).

In Listing 18-3, declaratives are used to calculate `SalesCommission` and `FullSalary` before `SalesAgentGrp` is printed.

Report Writer Syntax and Semantics

I have shown you a number of example programs that use the Report Writer. That informal introduction should have given you a good idea of the new verbs and declarations required when you write a Report Writer program. This section deals with the syntax and semantics of Report Writer elements.

ENVIRONMENT DIVISION Entries

Just like ordinary reports, the reports generated by the Report Writer are written to an external device—usually a report file. The `ENVIRONMENT DIVISION` entries for a report file are the same as those for an ordinary file. The same `SELECT` and `ASSIGN` clauses apply. You can either omit the `ORGANIZATION` phrase as in the example programs, in which case the default of `ORGANIZATION IS SEQUENTIAL` applies, or you can specify `ORGANIZATION IS SEQUENTIAL` explicitly, as in the following example:

```
FILE-CONTROL.
  SELECT SalesFile ASSIGN TO "Listing18-4-Sales.DAT"
    ORGANIZATION IS LINE SEQUENTIAL.

  SELECT PrintFile ASSIGN TO "Listing18-4.Rpt"
    ORGANIZATION IS SEQUENTIAL.
```

FILE SECTION Entries

The entries in the ENVIRONMENT DIVISION are the same as those for ordinary print files. But in the FILE SECTION, the normal file description is replaced by the REPORT IS phrase, which points to the RD in the REPORT SECTION. The metalanguage for the phrase is

$$\left\{ \begin{array}{l} \text{REPORT IS} \\ \text{REPORTS ARE} \end{array} \right\} \{ \textit{ReportName} \} \dots$$

where ReportName must be the same as the ReportName used in the RD entry. You can see this in Listing 18-3, where the REPORT IS SolaceSalesReport phrase links the PrintFile with the RD in the REPORT SECTION.

Note that before the report can be used, it must be opened for output. For instance, in Listing 18-3, the PrintFile is opened for output before the SolaceSalesReport is generated.

Report Description (RD) Entries

The RD entry in the REPORT SECTION defines the report. There must be a separate RD entry for each report you want to print. The RD entry names the report, specifies the format of the printed page, and identifies the control-break items.

Each RD entry is followed by one or more 01 level-number entries. Each 01 level-number entry identifies a report group and consists of a hierarchical structure similar to a COBOL record. Each report group is a unit consisting of one or more print lines and cannot be split across pages. The metalanguage for the RD is given in Figure 18-2.

RD *ReportName*

[IS GLOBAL]

$$\left[\left\{ \begin{array}{l} \text{CONTROL IS} \\ \text{CONTROLS ARE} \end{array} \right\} \left\{ \{ \textit{ControlName}\$i \} \dots \right\} \right. \\ \left. \left\{ \text{FINAL} [\textit{ControlName}\$i] \dots \right\} \right]$$

$$\left[\text{PAGE} \left[\begin{array}{l} \text{LIMIT IS} \\ \text{LIMITS ARE} \end{array} \right] \textit{PageSize}\#l \left[\begin{array}{l} \text{LINE} \\ \text{LINES} \end{array} \right] \right]$$

$$\left[\begin{array}{l} \left[\text{HEADING} \textit{HeadingLine}\#l \right] \\ \left[\text{FIRST DETAIL} \textit{FirstDetailLine}\#l \right] \\ \left[\text{LAST DETAIL} \textit{LastDetailLine}\#l \right] \\ \left[\text{FOOTING} \textit{HeadingLine}\#l \right] \end{array} \right]$$

Figure 18-2. Metalanguage for the Report Description (RD) entry

Keep the following points in mind:

- ReportName can appear in only one RD entry.
- When more than one report is declared in the REPORT SECTION, ReportName may be used to qualify the LINE-COUNTER and PAGE-COUNTER report registers.
- ControlName\$i must not be a data item defined in the REPORT SECTION.
- Each occurrence of ControlName\$i must identify a different data item.

- ControlName\$#i must not have a variable-length table subordinate to it.
- ControlName\$#i and FINAL specify the levels of the control-break hierarchy, where FINAL (if specified) is the highest, the first ControlName\$#i is the next highest, and so on.
- When the value in any ControlName\$#i changes, a control break occurs. The level of the control break depends on the position of the ControlName\$#i in the control-break hierarchy.
- HeadingLine#l must be greater than or equal to 1.
- The following must hold: HeadingLine#l <= FirstDetailLine#l <= LastDetailLine#l <= FootingLine#l <= PageSize#l
- The line numbers used in a REPORT HEADING or PAGE HEADING group must be greater than or equal to HeadingLine#l and less than FirstDetailLine#l. But when a REPORT HEADING appears on a page by itself, any line number between HeadingLine#l and PageSize#l may be used.
- The line numbers used in a DETAIL or CONTROL HEADING group must be in the range FirstDetailLine#l to LastDetailLine#l, inclusive.
- The line numbers used in CONTROL FOOTING groups must be in the range FirstDetailLine#l to FootingLine#l, inclusive.
- The line numbers used in a REPORT FOOTING or PAGE FOOTING group must be greater than FootingLine#l and less than or equal to PageSize#l. But when a REPORT FOOTING appears on a page by itself, any line number between HeadingLine#l and PageSize#l may be used.
- All the report groups must be defined so that they can be presented on one page. The Report Writer never splits a multiline group across page boundaries.

Report Group Entries

The RD entry specifies the name of the report, identifies the control items, and lays down the basics of how the page is to be formatted. After the RD entry, you specify the report groups to be used in the report. Each report group is represented by a report-group record. As with all record descriptions in COBOL, a report-group record starts with level number 01. The subordinate items in the record describe the report lines and columns in the report group.

Each report group starts with a level 01 report group definition. The metalanguage for the report group definition is given in Figure 18-3.

01 *ReportGroupName*

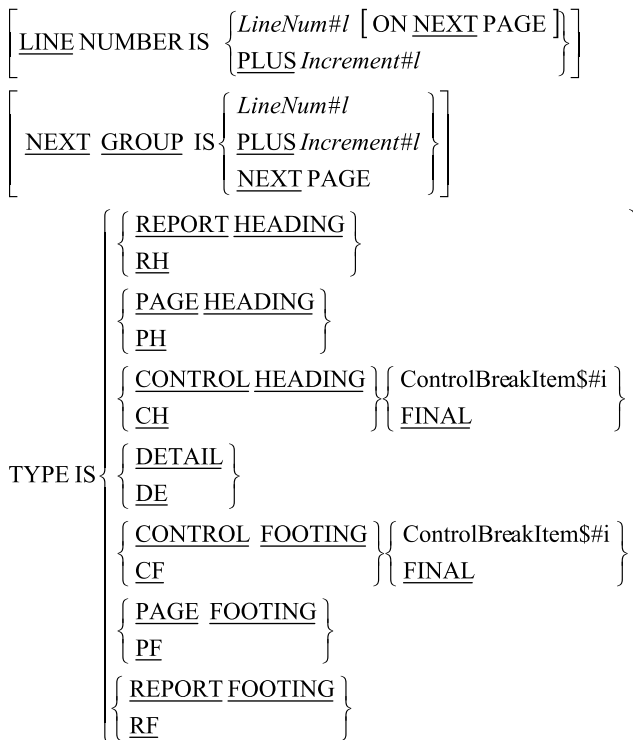


Figure 18-3. Metalanguage for the report group definition

RD Entry

When you create an RD entry, keep in mind that *ReportGroupName* is required only when the group

- Is a **DETAIL** group referenced by a **GENERATE** statement or the **UPON** phrase of a **SUM** clause
- Is referenced in a **USE BEFORE REPORTING** sentence in the declaratives
- Is required to qualify the reference to a **SUM** counter

LINE NUMBER Clause

When you use the **LINE NUMBER** clause, keep the following in mind:

- The **LINE NUMBER** clause is used to specify the vertical positioning of print lines. Lines can be printed on
 - A specified line (absolute)
 - A specified line on the next page (absolute)
 - The current line number plus some increment (relative)
- The **LINE NUMBER** clause specifies where each line is to be printed, so no item that contains a **LINE NUMBER** clause may contain a subordinate item that also contains a **LINE NUMBER** clause (subordinate items specify the column items).

- Where absolute `LINE NUMBER` clauses are specified, all absolute clauses must precede all relative clauses, and the line numbers specified in the successive absolute clauses must be in ascending order.
- The first `LINE NUMBER` clause specified in a `PAGE FOOTING` group must be absolute.
- The `NEXT PAGE` clause can appear only once in a given report group description, and it must be in the first `LINE NUMBER` clause in the report group.
- The `NEXT PAGE` clause cannot appear in any `HEADING` group.

NEXT GROUP Clause

When you use the `NEXT GROUP` clause, keep the following things in mind:

- The `NEXT GROUP` clause is used to specify the vertical positioning of the start of the next group. This clause can be used to specify that the next report group should be printed on
 - A specified line (absolute)
 - The current line number plus some increment (relative)
 - The next page
- The `NEXT PAGE` option in the `NEXT GROUP` clause must not be specified in a page footer.
- The `NEXT GROUP` clause must not be specified in a `REPORT FOOTING` or `PAGE HEADING` group.
- When used in a `DETAIL` group, the `NEXT GROUP` clause refers to the next `DETAIL` group to be printed.

The TYPE Clause

The `TYPE` clause specifies the type of the report group. The type of the report group governs when and where it is printed in the report (for instance, a `REPORT HEADING` group is printed only once: at the beginning of the report).

When you use the `TYPE` clause, keep the following things in mind:

- Most groups are defined once for each report, but control groups (other than `CONTROL . . FINAL` groups) are defined for each control-break item.
- In `REPORT FOOTING`, and `CONTROL FOOTING` groups, `SOURCE` and `USE` clauses must not reference any data item that contains a control-break item or is subordinate to a control-break item.
- `PAGE HEADING` and `FOOTING` groups must not reference a control-break item or any item subordinate to a control-break item.
- `DETAIL` report groups are processed when they are referenced in a `GENERATE` statement. All other groups are processed automatically by the Report Writer. There can be more than one `DETAIL` group.
- The `REPORT HEADING`, `PAGE HEADING`, `CONTROL HEADING FINAL`, `CONTROL FOOTING FINAL`, `PAGE FOOTING`, and `REPORT FOOTING` report groups can each appear only once in the description of a report.

Report Group Lines

The subordinate items in a report-group record describe the report lines and columns in the report group. There are two formats for defining items subordinate to the report-group record. The first is usually used to define the lines of the report group, and the second defines and positions the elementary print items.

Defining the Print Lines

Print lines in a report group are usually defined using the metalanguage given in Figure 18-4. This format is used to specify the vertical placement of a print line, and it is always followed by subordinate items that specify the columns where the data items are to be printed.

02 - 48 [*ReportLineName*]

$$\left[\underline{\text{LINE NUMBER}} \text{ IS } \left\{ \begin{array}{l} \textit{LineNum\#l} \text{ [ON } \underline{\text{NEXT}} \text{ PAGE]} \\ \underline{\text{PLUS}} \textit{ Increment\#l} \end{array} \right\} \right]$$

Figure 18-4. Metalanguage for vertical print line positioning

As shown in the metalanguage, the level number is from 2 to 48, inclusive. If *ReportLineName* is used, its only purpose is to qualify a SUM counter reference.

Defining the Elementary Print Items

The elementary print items in the print line of a report group are described using the metalanguage shown in Figure 18-5. As you can see, the normal data-description clauses such as PIC, USAGE, SIGN, JUSTIFIED, BLANK WHEN ZERO, and VALUE may be applied when describing an elementary print item. The Report Writer provides a number of additional clauses that may also be used with these items.

02 - 49 *SumCounterName*

$$\left\{ \begin{array}{l} \underline{\text{PICTURE}} \\ \underline{\text{PIC}} \end{array} \right\} \text{ IS } \textit{PictureString}$$

$$\left[\left[\underline{\text{USAGE}} \text{ IS } \right] \underline{\text{DISPLAY}} \right]$$

$$\left[\underline{\text{SIGN}} \text{ IS } \left\{ \begin{array}{l} \underline{\text{LEADING}} \\ \underline{\text{TRAILING}} \end{array} \right\} \underline{\text{SEPARATE CHARACTER}} \right]$$

$$\left[\left\{ \begin{array}{l} \underline{\text{JUSTIFIED}} \\ \underline{\text{JUST}} \end{array} \right\} \underline{\text{RIGHT}} \right]$$

$$\left[\underline{\text{BLANK WHEN}} \{ \underline{\text{ZERO}} \} \right]$$

$$\left[\underline{\text{COLUMN NUMBER}} \text{ IS } \textit{ColNum\#l} \right]$$

$$\left[\underline{\text{GROUP INDICATE}} \right]$$

$$\left[\underline{\text{LINE NUMBER}} \text{ IS } \left\{ \begin{array}{l} \textit{LineNum\#l} \text{ [ON } \underline{\text{NEXT}} \text{ PAGE]} \\ \underline{\text{PLUS}} \textit{ Increment\#l} \end{array} \right\} \right]$$

$$\left\{ \begin{array}{l} \underline{\text{SOURCE}} \text{ IS } \textit{SourceName\#i} \\ \underline{\text{VALUE}} \text{ IS } \textit{Value\#i} \\ \{ \underline{\text{SUM}} \{ \textit{SumName\#i} \} \left[\underline{\text{UPON}} \{ \textit{DetailReportGroupName\#i} \} \dots \} \dots \} \right. \\ \left. \left[\underline{\text{RESET ON}} \left\{ \begin{array}{l} \textit{ControlBreakItem\#i} \\ \underline{\text{FINAL}} \end{array} \right\} \right] \right\}$$

Figure 18-5. Metalanguage to define elementary report items

SumCounterName can only be referenced if the entry uses the SUM clause to define a sum counter.

The COLUMN NUMBER Clause

When you use the COLUMN NUMBER clause, keep the following things in mind:

- COLUMN NUMBER specifies the position of a print item on the print line. When this clause is used, it must be subordinate to an item that contains a LINE NUMBER clause.
- In a given print line, the ColNum#ls should be in ascending sequence.
- ColNum#l specifies the column number of the leftmost character position of the print item.

The GROUP INDICATE Clause

The GROUP INDICATE clause can only appear in a DETAIL report group. It is used to specify that a print item should be printed only on the first occurrence of its report group after a control break or page advance. For instance, in Listing 18-3, the state name and sales agent number are suppressed after their first occurrence. As a reminder, I have repeated the DETAIL group declaration here:

```
01 DetailLine TYPE IS DETAIL.
  02 LINE IS PLUS 1.
    03 COLUMN 1      PIC X(14)
      SOURCE StateName(StateNum) GROUP INDICATE.
    03 COLUMN 17     PIC 999
      SOURCE SalesAgentNum GROUP INDICATE.
    03 COLUMN 30     PIC $$$,$$$.$99 SOURCE ValueOfSale.
```

The SOURCE Clause

The SOURCE clause is used to identify a data item that contains the value to be used when the print item is printed. For instance, the SOURCE ValueOfSale clause in the previous example specifies that the value of the item to be printed in column 30 is to be found in the data item ValueOfSale.

The SUM Clause

The SUM clause is used both to establish a sum counter and to name the data items to be summed. A SUM clause can appear only in the description of a CONTROL FOOTING report group. Statements in the PROCEDURE DIVISION can be used to alter the contents of the sum counters.

You can do three forms of summing in the Report Writer:

- Subtotaling
- Rolling forward
- Crossfooting

Subtotaling

When the SUM clause is used with a data item declared in the FILE or WORKING-STORAGE SECTION, then each time a GENERATE is executed, the value to be summed is added to the sum counter. If there is more than one DETAIL group in the report, the SUM. .UPON option allows you to select which sum counter to total. For instance, if the report contains two DETAIL groups—one called DetailLine and the other called AlternateDetailLine—you can use SUM. .UPON to specify that subtotaling is to be done only each time a GENERATE AlternateDetailLine is executed.

Rolling Forward

When the SUM clause is used with a data item representing the sum counter of another CONTROL FOOTING group, then each time the other group is executed, the value of its sum counter is added to the value of the sum counter of the current group.

Listing 18-3 contains good examples of both subtotalling and rolling forward. Example 18-6 provides a reminder of the relevant code. Each time a DETAIL line is GENERATED, the ValueOf Sale is added to the TotalAgentSales sum counter. When a control break occurs on SalesAgentNum, the accumulated sum is printed and is added to the TotalStateSales sum counter. When a control break occurs on StateNum, the sum accumulated in the TotalStateSales sum counter is added to the final total sum counter.

Example 18-6. Subtotalling and Rolling Forward from Listing 18-3

```
01 SalesAgentGrp
   TYPE IS CONTROL FOOTING SalesAgentNum NEXT GROUP PLUS 2.
   :   :   :   :   :   :   :   :   :   :   :   :   :   :   :
   03 TotalAgentSales COLUMN 45 PIC $$$$$,$$$$.99 SUM ValueOfSale.

01 StateGrp TYPE IS CONTROL FOOTING StateNum NEXT GROUP PLUS 2.
02 LINE IS PLUS 2.
   :   :   :   :   :   :   :   :   :   :   :   :   :   :
   03 TotalStateSales COLUMN 45 PIC $$$$$,$$$$.99 SUM TotalAgentSales.

01 TotalSalesGrp TYPE IS CONTROL FOOTING FINAL.
   :   :   :   :   :   :   :   :   :   :   :   :   :   :
   03 COLUMN 48      PIC $$,$$$,$$$$.99 SUM TotalStateSales.
```

Crossfooting

In crossfooting, the sum counters in the same CONTROL FOOTING group can be added together to create another sum counter. In Example 18-7, each time a GENERATE statement is executed, the value of NetWeightOfGoods (in the file record) is added to the NWG sum counter, and the value of WeightOfPackingMaterials (in the file record) is added to WPM (subtotalling). When a control break occurs on OrderNumber, the values of the NWG and WPM sum counters are added together to give the combined total identified as GrossWeight and printed in column 40 (crossfooting).

Example 18-7. Crossfooting to Create the GrossWeight Sum Counter

```
01 ShippingGrp
   TYPE IS CONTROL FOOTING OrderNumber NEXT GROUP PLUS 3.
   : other entries :
   : other entries :
   03 NWG          COLUMN 20 PIC Z,ZZ9   SUM NetWeightOfGoods.
   03 WPM          COLUMN 30 PIC ZZ9     SUM WeightOfPackingMaterials.
   03 GrossWeight COLUMN 40 PIC ZZ,ZZ9  SUM GNW, PMW.
```

The RESET ON Clause

Sum counters are normally reset to zero after a control break on the control-break item associated with the report group. For instance, in Example 18-6, if you wanted SalesAgentGrp to show a rolling total of the sales in the state, you could change SalesAgentGrp as shown in Example 18-8. In this example, TotalAgentSales prints the sales of a particular agent and is reset to zero when the footer group is printed, whereas StateSalesToDate prints a rolling total of sales for the state and is reset to zero only when there is a control break on StateNum.

Example 18-8. Using the RESET ON Clause

```
01 SalesAgentGrp
   TYPE IS CONTROL FOOTING SalesAgentNum NEXT GROUP PLUS 2.
   :   :   :   :   :   :   :   :   :   :   :   :   :   :
   03 TotalAgentSales COLUMN 45 PIC $$$$$,$$.99 SUM ValueOfSale.
   03 StateSalesToDate COLUMN 60 PIC $$$$$,$$.99 SUM ValueOfSale
                                           RESET ON StateNum.
```

Special Report Writer Registers

The Report Writer maintains two special registers for each report declared in the REPORT SECTION: LINE-COUNTER and PAGE-COUNTER.

LINE-COUNTER

LINE-COUNTER is a reserved word that can be used to access a special register that the Report Writer maintains for each report in the REPORT SECTION. The Report Writer uses the LINE-COUNTER register to keep track of where the lines are being printed on the report. It uses this information and the information specified in the PAGE LIMIT clause in the RD entry to decide when a new page is required.

Although the LINE-COUNTER register can be used as a SOURCE item in the report, no statements in the PROCEDURE DIVISION can alter the value in the register.

References to the LINE-COUNTER register can be qualified by referring to the name of the report given in the RD entry.

PAGE-COUNTER

The reserved word PAGE-COUNTER is used to access a special register that the Report Writer maintains for each report in the REPORT SECTION. It keeps track of the number of pages printed in the report. The PAGE-COUNTER register can be used as a SOURCE item in the report, but the value of the PAGE-COUNTER may also be changed by statements in the PROCEDURE DIVISION.

PROCEDURE DIVISION Report Writer Verbs

The Report Writer introduces four new verbs for processing reports:

- INITIATE
- GENERATE
- TERMINATE
- SUPPRESS PRINTING

The first three are normal PROCEDURE DIVISION verbs, but the last one can only be used in the declaratives. I will postpone discussion of that verb until I deal with declaratives.

The INITIATE Verb

An INITIATE statement starts the processing of the ReportName report or reports. The metalanguage for the INITIATE verb is given in Figure 18-6.

INITIATE{ *ReportName*}...

Figure 18-6. Metalanguage for the INITIATE verb

Before INITIATE is executed, the file associated with the *ReportName* must have been opened for OUTPUT or EXTEND. This is illustrated in Listing 18-3 by these statements:

```
SELECT PrintFile ASSIGN TO "Listing18-3.Rpt".
:   :   :   :   :   :   :   :   :
FD PrintFile
  REPORT IS SolaceSalesReport.
:   :   :   :   :   :   :   :   :
RD SolaceSalesReport
:   :   :   :   :   :   :   :   :
OPEN OUTPUT PrintFile
:   :   :   :   :   :   :   :   :
INITIATE SolaceSalesReport
```

The GENERATE Verb

The GENERATE statement drives the production of the report. The metalanguage for GENERATE is given in Figure 18-7.

GENERATE{ *ReportName*}...

Figure 18-7. Metalanguage for the GENERATE verb

The target of a GENERATE statement is either a DETAIL report group or a *ReportName*. When the target is a *ReportName*, the report description must contain the following:

- A CONTROL clause
- Not more than one DETAIL group
- At least one group that is not a PAGE or REPORT group

When all the GENERATE statements for a particular report target the *ReportName*, the report performs summary processing only, and the report produced is called a *summary report*. For instance, to make a summary report using Listing 18-3, all you have to do is change

```
GENERATE DetailLine
```

to

```
GENERATE SolaceSalesReport.
```

If you specify GENERATE SolaceSalesReport, then the DETAIL group is never printed, but the other groups *are* printed.

The TERMINATE Verb

You use a TERMINATE statement to instruct the Report Writer to finish the processing of the specified report. The metalanguage for TERMINATE is given in Figure 18-8.

`TERMINATE`{ *ReportName*}...

Figure 18-8. Metalanguage for the `TERMINATE` verb

When `TERMINATE` is executed, the Report Writer prints the `PAGE` and `REPORT FOOTING` groups, and all the `CONTROL FOOTING` groups are printed as if there had been a control break on the most senior control group.

After the report has been terminated, the file associated with the report must be closed. For instance, in Listing 18-3, the `TERMINATE SolaceSalesReport` statement is followed by the `CLOSE PrintFile` statement.

Declaratives

The main structural elements of a COBOL program are divisions, sections, and paragraphs. This section introduces a new structural element: *declaratives*. When declaratives are used, they are the first element in the `PROCEDURE DIVISION` and start with the word `DECLARATIVES` and end with `END DECLARATIVES`. Declaratives specify `USE` procedures that are executed when certain conditions occur. You write the `USE` procedures in the declaratives in consecutive sections.

When declaratives are used, the remainder of the `PROCEDURE DIVISION` must consist of at least one section. Example 18-9 is a template that shows the structure of declaratives.

Example 18-9. Structure of Declaratives

```
PROCEDURE DIVISION.
DECLARATIVES
SectionName SECTION.
    USE statement
ParagraphName.
    COBOL Statements
END DECLARATIVES.
Main SECTION.
```

Declaratives are used for two main purposes:

- To extend the functionality of the Report Writer
- To handle file operation errors

Using Declaratives with the Report Writer

Declaratives are used to extend the functionality of the Report Writer by performing tasks or calculations that the Report Writer cannot do automatically or by selectively stopping a report group from being printed (using the `SUPPRESS PRINTING` command). When you use declaratives with the Report Writer, the `USE BEFORE REPORTING` phrase lets you specify that a particular section of code is to be executed before the identified report group is printed. The metalanguage for the `USE` statement used with the Report Writer is given in Figure 18-9.

`USE [GLOBAL] BEFORE REPORTING` *ReportGroupName*

Figure 18-9. Metalanguage for the Report Writer version of `USE`

Note the following:

- ReportGroupName must not appear in more than one USE statement.
- The GENERATE, INITIATE, and TERMINATE statements must not appear in the declaratives.
- The value of any control data items must not be altered in the declaratives.
- Statements in the declaratives must not reference procedures outside the declaratives.

Listing 18-3 has a good example of how declaratives may be used to extend the functionality of the Report Writer. They are used to calculate the sales agent SalesCommission and FullSalary before SalesAgentGrp is printed. For convenience, the code is repeated in Example 18-10.

Example 18-10. Declaratives from Listing 18-3

```
PROCEDURE DIVISION.
DECLARATIVES.
Calc SECTION.
    USE BEFORE REPORTING SalesAgentGrp.
Calculate-Salary.
    MULTIPLY TotalAgentSales BY Percentage
        GIVING SalesCommission ROUNDED
    ADD SalesCommission, BaseSalary(StateNum)
        GIVING FullSalary.
END DECLARATIVES.
Main SECTION.
Begin.
    OPEN INPUT SalesFile
    OPEN OUTPUT PrintFile
```

The SUPPRESS PRINTING Statement

The SUPPRESS PRINTING statement is used in a DECLARATIVES section to stop a particular report group from being printed. The report group suppressed is the one mentioned in the USE statement associated with the section containing the SUPPRESS PRINTING statement. The SUPPRESS PRINTING statement must be executed each time you want to stop the report group from being printed.

In Example 18-11, the CONTROL FOOTING data for StateGrp is printed only if the state sales total is above a certain threshold.

Example 18-11. Suppressing the Printing of a Report Group

```
PROCEDURE DIVISION.
DECLARATIVES.
CheckStateSales SECTION.
    USE BEFORE REPORTING StateGrp.
PrintImportantStatesOnly.
    IF TotalStateSales < 100000
        SUPPRESS PRINTING
    END-IF.
END DECLARATIVES.
```

Control-Break Registers

The Report Writer maintains a special control-break register for each control-break item mentioned in the `CONTROLS ARE` phrase in the `RD` entry. When a control-break item is referred to in a control footer or in the declaratives, the Report Writer supplies the value held in the control-break register and not the value in the item itself. If a control break has just occurred, the value in the control-break register is the previous value of the control-break item.

This point is demonstrated in the report produced by Listing 18-3 by printing the actual state number (the one in the record buffer) and the supplied state number (the one in the control-break register) each time `StateGrp` group is printed.

Using Declaratives with Files

You can also use declaratives to handle file operation errors. The metalanguage for the version of `USE` used with files is given in Figure 18-10.

$$\text{USE } [\text{GLOBAL}] \text{ AFTER STANDARD } \left\{ \begin{array}{l} \text{EXCEPTION} \\ \text{ERROR} \end{array} \right\} \text{ PROCEDURE ON}$$

$$\left\{ \begin{array}{l} [\text{FileName}] \dots \\ \text{INPUT} \\ \text{OUTPUT} \\ \text{I-O} \\ \text{EXTEND} \end{array} \right\}$$

Figure 18-10. Metalanguage for the files version of `USE`

When you use this version of the declaratives, you can create code that deals with any I-O error on a particular file or more generalized code that deals with `INPUT`, `OUTPUT`, `I-O`, or `EXTEND` errors on any file. When declaratives exist for a file, the `INVALID KEY` clause and the `AT END` clause are optional.

The program fragment in Example 18-12 shows how you can use declaratives to handle errors on a particular file.

Example 18-12. Declarative Procedures to Handle Unexpected File Errors

```
PROCEDURE DIVISION.
DECLARATIVES.
SupFile SECTION.
    USE AFTER ERROR PROCEDURE ON SupplierFile.
DisplaySupplierFileStatus.
    DISPLAY "Unexpected error on Supplier file. Status = " SupplierStatus
    DISPLAY "The file name used was :- " SupplierFileName
    STOP RUN.

VidFile SECTION.
    USE AFTER ERROR PROCEDURE ON VideoFile.
DisplayVideoFileStatus.
    DISPLAY "Unexpected error on Video file. Status = " VideoStatus
    DISPLAY "The file name used was :- " VidFileName
    STOP RUN.
```

```

END DECLARATIVES.
Main SECTION.
Begin.
  OPEN INPUT SupplierFile
  OPEN INPUT VideoFile
  etc

```

Summary

This chapter introduced you to the COBOL Report Writer. In a series of increasingly complex programs, you learned how to use the Report Writer to create control-break-based reports. You were introduced to a number of new verbs, clauses, sections, and concepts. You saw how to use the RD entry in the REPORT SECTION to specify control-break items and define the basic layout of the report page. You were introduced to the idea of a report group and shown how to create report groups linked to control-break items. You learned how to use the SUM clause for totaling and rolling forward. The final program demonstrated how to extend the capabilities of the Report Writer by using declaratives. You then covered the verbs, clauses, and concepts of the Report Writer. And in the final section, you saw how to use declaratives for error handling in files.

The final chapter introduces OO-COBOL. This book adheres to the ANS 85 COBOL standard, so the ISO 2002 OO-COBOL is somewhat outside its remit. Nevertheless, some of the drawbacks of contained subprograms are remedied by OO-COBOL, and it is from this perspective that I examine the topic. Do not expect a course in object-oriented programming.

PROGRAMMING EXERCISE

And now for a programming exercise that tests your understanding of the last two chapters. For this, you need a really sharp 2B pencil.

Introduction

Two months before the beginning of each semester, Campus Bookshop produces a Purchase Requirements Report. This report details the books that have to be purchased for the coming semester. In the past, this was done manually; but now management has decided to computerize the operation. Accordingly, lecturers' requirements have been captured and the results used to update a purchase requirements file. This is a permanent file that contains details of the lecturers' book requirements for both semesters.

You are required to write a program to produce a Purchase Requirements Report from the publisher, book, and purchase requirements files. The report should be sequenced on ascending publisher name and should only detail the purchase requirements for the semester under scrutiny.

The semester number (1 or 2) should be accepted from the user at the start of the program using a simple ACCEPT and DISPLAY.

File Descriptions

Purchase Requirements File (Indexed)

There is a record for each book title required by a lecturer. Note that a book may be required by more than one lecturer.

Field	KeyType	Type	Length	Value
PR-Number	Primary	9	4	1-9999
Lecturer-Name	Alt with duplicates	X	20	--
Book-Number	Alt with duplicates	9	4	1-9999
Module-Code	--	X	5	--
Copies-Required	--	9	3	1-999
Semester	--	9	1	1/2

Book File (Indexed)

Field	KeyType	Type	Length	Value
Book-Number	Primary	9	4	1-9999
Publisher-Number	Alt with duplicates	9	4	1-9999
Book-Title	--	X	30	--

Publisher File (Indexed)

Field	KeyType	Type	Length	Value
Publisher-Number	Primary	9	4	1-9999
Publisher-Name	Alt with duplicates	X	20	--
Publisher-Address	--	X	40	--

Print Specification

The report must be printed according to the print specification given in Figure 18-11.


```

ORGANIZATION IS INDEXED
FILE STATUS IS FileStatus-PRF
ACCESS MODE IS DYNAMIC
RECORD KEY IS PRNumber-PRF
ALTERNATE RECORD KEY IS LecturerName-PRF
    WITH DUPLICATES
ALTERNATE RECORD KEY IS BookNum-PRF
    WITH DUPLICATES.

```

```

SELECT BookFile ASSIGN TO "Listing18-4-BF.DAT"
    ORGANIZATION IS INDEXED
    FILE STATUS IS FileStatus-BF
    ACCESS MODE IS DYNAMIC
    RECORD KEY IS BookNum-BF
    ALTERNATE RECORD KEY IS PublisherNum-BF
        WITH DUPLICATES.

```

```

SELECT PublisherFile ASSIGN TO "Listing18-4-PF.DAT"
    ORGANIZATION IS INDEXED
    FILE STATUS IS FileStatus-PF
    ACCESS MODE IS DYNAMIC
    RECORD KEY IS PublisherNum-PF
    ALTERNATE RECORD KEY IS PublisherName-PF.

```

```

SELECT ReportFile ASSIGN TO "Listing18-4.RPT".

```

```

DATA DIVISION.

```

```

FILE SECTION.

```

```

FD PurchaseReqFile.

```

```

01 PurchaseRec-PRF.
    88 EndOfPRequirements      VALUE HIGH-VALUES.
    88 NotEndOfPRequirements  VALUE LOW-VALUES.
    02 PRNumber-PRF           PIC 9(4).
    02 LecturerName-PRF      PIC X(20).
    02 BookNum-PRF           PIC 9(4).
    02 ModuleCode-PRF        PIC X(5).
    02 CopiesRequired-PRF    PIC 9(3).
    02 Semester-PRF          PIC 9.

```

```

FD BookFile.

```

```

01 BookRec-BF.
    88 EndOfBooks              VALUE HIGH-VALUES.
    88 NotEndOfBooks           VALUE LOW-VALUES.
    02 BookNum-BF              PIC 9(4).
    02 PublisherNum-BF         PIC 9(4).
    02 BookTitle-BF            PIC X(30).

```

```

FD PublisherFile.

```

```

01 PublisherRec-PF.
    88 EndOfPublishers         VALUE HIGH-VALUES.
    02 PublisherNum-PF         PIC 9(4).

```

```

02 PublisherName-PF      PIC X(20).
02 PublisherAddress-PF   PIC X(40).

```

```

FD ReportFile
  REPORT IS PurchaseRequirementsReport.

```

WORKING-STORAGE SECTION.

```

01 File-Status.
  02 FileStatus-PRF      PIC X(2).
     88 PurchaseRec-PRF-Not-Found VALUE "23".
  02 FileStatus-BF       PIC X(2).
     88 BookRec-Not-Found  VALUE "23".
  02 FileStatus-PF       PIC X(2).

01 Current-Semester      PIC 9.

```

REPORT SECTION.

```

RD PurchaseRequirementsReport
  CONTROLS ARE          FINAL
                        PublisherName-PF
  PAGE LIMIT IS 66
  HEADING 2
  FIRST DETAIL 8
  LAST DETAIL 50
  FOOTING 55.

```

01 TYPE IS REPORT FOOTING.

```

02 LINE 56.
  03 COLUMN 29          PIC X(23)
     VALUE "*** END OF REPORT ***".

```

01 TYPE IS PAGE HEADING.

```

02 LINE 2.
  03 COLUMN 27          PIC X(30)
     VALUE "PURCHASE REQUIREMENTS REPORT".
  03 COLUMN 77          PIC X(6)
     VALUE "PAGE :".
  03 COLUMN 84          PIC Z9 SOURCE PAGE-COUNTER.

```

02 LINE 3.

```

03 COLUMN 26           PIC X(32) VALUE ALL "-".

```

02 LINE 6.

```

03 COLUMN 2            PIC X(24) VALUE "PUBLISHER NAME".
03 COLUMN 33           PIC X(11) VALUE "BOOK TITLE".
03 COLUMN 57           PIC X(3)  VALUE "QTY".
03 COLUMN 65           PIC X(14) VALUE "LECTURER NAME".

```



```

01 PReq-PrintLine TYPE IS DETAIL.
  02 LINE IS PLUS 2.
    03 COLUMN 1          PIC X(20) SOURCE PublisherName-PF
                          GROUP INDICATE.
    03 COLUMN 24         PIC X(30) SOURCE BookTitle-BF.
    03 COLUMN 57         PIC ZZ9  SOURCE CopiesRequired-PRF.
    03 COLUMN 63         PIC X(20) SOURCE LecturerName-PRF.

```

PROCEDURE DIVISION.

BEGIN.

```

  DISPLAY "Enter the semester number (1 or 2) - " WITH NO ADVANCING
  ACCEPT Current-Semester
  OPEN INPUT PurchaseReqFile
  OPEN INPUT BookFile
  OPEN INPUT PublisherFile
  OPEN OUTPUT ReportFile
  INITIATE PurchaseRequirementsReport

```

```

  MOVE SPACES TO PublisherName-PF
  START PublisherFile
    KEY IS GREATER THAN PublisherName-PF
    INVALID KEY DISPLAY "START Pub file status" FileStatus-PF
  END-START
  READ PublisherFile NEXT RECORD
    AT END SET EndOfPublishers TO TRUE
  END-READ
  PERFORM PrintRequirementsReport UNTIL EndOfPublishers

  TERMINATE PurchaseRequirementsReport
  CLOSE  PurchaseReqFile, BookFile,
        PublisherFile, ReportFile
  STOP RUN.

```

PrintRequirementsReport.

```

  SET NotEndOfBooks TO TRUE
  MOVE PublisherNum-PF TO PublisherNum-BF
  READ BookFile
    KEY IS PublisherNum-BF
    INVALID KEY
      DISPLAY SPACES
      DISPLAY "Book File Error. FileStatus = " FileStatus-BF
      DISPLAY "Publisher Number - " PublisherNum-BF
      DISPLAY "Publisher Rec = " PublisherRec-PF
      MOVE ZEROS TO PublisherNum-BF
  END-READ

  PERFORM ProcessPublisher
    UNTIL PublisherNum-PF NOT EQUAL TO PublisherNum-BF
      OR EndOfBooks

```

```
READ PublisherFile NEXT RECORD
  AT END SET EndOfPublishers TO TRUE
END-READ.
```

ProcessPublisher.

```
SET NotEndOfPRequirements TO TRUE
MOVE BookNum-BF TO BookNum-PRF
READ PurchaseReqFile
  KEY IS BookNum-PRF
  INVALID KEY
    DISPLAY SPACES
    DISPLAY "PurchReqFile Error. FileStatus = " FileStatus-PRF
    DISPLAY "Book Num PRF = " BookNum-PRF
    DISPLAY "Book Rec = " BookRec-BF
    MOVE ZEROS TO BookNum-PRF
  END-READ
```

```
PERFORM UNTIL BookNum-BF NOT EQUAL TO BookNum-PRF
  OR EndOfPRequirements
  IF Current-Semester = Semester-PRF THEN
    Generate PReq-PrintLine
  END-IF
  READ PurchaseReqFile NEXT RECORD
  AT END SET EndOfPRequirements TO TRUE
  END-READ
END-PERFORM
```

```
READ BookFile NEXT RECORD
  AT END SET EndOfBooks TO TRUE
END-READ.
```



OO-COBOL

This chapter introduces you to OO-COBOL. This book adheres to the ANS 85 COBOL standard, so ISO 2002 OO-COBOL is somewhat outside its remit. The ANS 85 version of COBOL was designed to bring structured programming to COBOL, but failings in the way contained subprograms were implemented meant this version did not fully live up to its promise. However, the structured programming weaknesses of ANS 85 COBOL are remedied by OO-COBOL, and the chapter examines OO-COBOL from this perspective. In this chapter, you see how OO-COBOL can be used to create informational strength modules that fully realize Parnas's¹ idea of information hiding. I show you some OO-COBOL programs and introduce you to classes and methods, but the chapter does not delve deeply into topics such as inheritance, polymorphism, properties, and interfaces. In other words, do not expect a course in object-oriented programming.

Module Strength and Module Coupling

Prior to the introduction of the ANS 74 version of COBOL, many COBOL systems consisted of huge, monolithic programs containing as many as 100,000 lines of code. It soon became clear that it was difficult, if not impossible, to maintain programs of this size. As a result, the ANS 74 version of COBOL introduced external subprograms that allowed programmers to create modular systems consisting of a number of independently compiled programs bound together into one run-unit. Unfortunately, this did not entirely solve the maintenance crisis. It turned out that some kinds of partitioned programs were as bad, or worse, than the monolithic programs they replaced. Using empirical research done at IBM as the basis for their ideas, Stevens, Myers, and Constantine² addressed this issue by introducing structured programming and the criteria for decomposing a system into modules. In structured programming, a module is defined as any collection of executable program statements that meets all the following criteria:

- It is a closed subroutine.
- It can be called from any other module in the system.
- It has the potential of being independently compiled.

Although structured programming introduced a number of criteria for decomposing a system into modules, the main criteria for judging the quality of a module were module strength and module coupling (see Table 19-1).

¹On the Criteria to Be Used in Decomposing Systems into Modules. *Commun. ACM* 15, no. 12 (December 1972).

²Wayne P. Stevens, Glenford J. Myers, and Larry L. Constantine. "Structured Design," in *Classics in Software Engineering*, ed. Edward N. Yourdon (Upper Saddle River, NJ: Yourdon Press, 1979), 205–232.

Table 19-1. *Module Strength and Module Coupling*³

		Module Coupling	Module Strength/Cohesion
Best	1	No direct coupling	Functional strength
↑	2	Data coupling	and informational strength
Better	3	Stamp coupling	Communicational strength
	4	Control coupling	Procedural strength
Worse	5	External coupling	Classical strength
↓	6	Common coupling	Logical strength
Worst	7	Content coupling	Coincidental strength

Module strength (sometimes called *module cohesion*) is a measure of the association between the elements of a module. Modules whose elements are strongly related to each other are regarded as more desirable than modules whose elements only have a weak or nonexistent connection. For instance, a *functional-strength* module is one in which all the elements combine to perform a single specific function or is one that coordinates subordinate modules such that they perform a single function. Modules such as `ValidateCheckDigit`, `ValidateDate`, `GetStateCode`, and `GetCustomerRecord` are functional-strength modules: they perform one specific task. On the other end of the scale, a *coincidental-strength* module is one in which the elements are only weakly related to one another and are more strongly related to the elements of other modules. Coincidental-strength modules are likely to be created when, for example, management mandates that a monolithic program be partitioned into subprograms, each 100 lines long.

Module coupling is a measure of the degree to which one module is connected to another. Modules that have low coupling are regarded as being more desirable than those that are highly coupled. A module with no direct coupling (the best) does not rely on data from other modules and provides no data to other modules. This data independence means this module is unlikely to be affected by bugs in other modules, and a bug in this module is unlikely to affect other modules.

In terms of module strength, a functional-strength module is often considered to be the best. However, this is not always the case. An informational-strength module has characteristics that may make it even more desirable than a functional-strength module. An informational-strength module has the following characteristics:

- It contains multiple entry points.
- Each entry point performs a single function.
- All the functions are related by a concept, data structure, or resource that is hidden in the module

For instance, in the dictionary module shown in Figure 19-1, the dictionary is held in a table. The `DictionaryModule` has four separate entry points: one that allows words to be added to the dictionary, one that allows the dictionary to be searched for a particular word, one that prints the contents of the dictionary, and a final entry point that allows the definition of a dictionary word to be retrieved. Each entry point has functional strength but shares access to the table.

The advantage of this arrangement is that because knowledge of *how* the dictionary is represented is hidden in the module, you can change it without causing knock-on effects for the modules that use it. In Figure 19-1, the dictionary is held in a table; but if you decide to hold it as a dynamic structure or even an indexed file, the modules that use the dictionary will not be affected. This is the benefit of *information hiding*:⁴ the knowledge of the data structure, concept, or resource is isolated in a single module. It is the idea on which information-strength modules are based.⁵

³Glenford J. Myers, *Composite/Structured Design* (New York: Van Nostrand Reinhold, 1978).

⁴David Parnas, "On the Criteria to Be Used in Decomposing Systems into Modules. *Commun. ACM* 15, no. 12 (December 1972).

⁵Glenford J. Myers, *Reliable Software through Composite Design* (New York: Van Nostrand Reinhold, 1975).

DictionaryModule			
DictionaryTable			
Add word to dictionary	Search dictionary for word	Print dictionary contents	Get word definition

Figure 19-1. Dictionary module with four entry points

Informational-Strength Modules in COBOL

The desirability of being able to create informational-strength modules is self evident. In COBOL, the combination of the IS GLOBAL phrase and contained subprograms seems to allow you create modules of this type. For instance, you could imagine that the dictionary module is an external subprogram that contains the AddWordToDictionary, SearchDictionaryForWord, PrintDictionaryContents, and GetWordDefinition subprograms and in which the dictionary is held in a table made available to all the contained subprograms. Example 19-1 shows the outline of an attempt to create such an external subprogram. This arrangement reflects the structure of the informational-strength module shown in Figure 19-1. Unfortunately, the attempt to create an informational-strength module in this way is prevented by the rule that says a subprogram may only be called by its parent. In other words, the only program that can call AddWordToDictionary, SearchDictionaryForWord, PrintDictionaryContents, and GetWordDefinition is the containing program DictionaryModule. They can't be called by any other program in the run-unit that wants to use the dictionary. This situation is illustrated in Figure 19-2, where the program UseDictionary is not permitted to call the subprograms contained in DictionaryModule. You might think the IS COMMON PROGRAM clause provides a solution to the problem, but unfortunately that clause only allows the sibling subprograms to call one another.

Example 19-1. Attempting to Create an Informational-Strength Module

```
IDENTIFICATION DIVISION.
PROGRAM-ID. DictionaryModule.
WORKING-STORAGE SECTION.
01 DictionaryTable IS GLOBAL.
   02 DictionaryEntry OCCURS 1000 TIMES.
   03 DictionaryWord PIC X(20).
   03 WordDefinition PIC X(1000)

IDENTIFICATION DIVISION.
PROGRAM-ID. AddWordToDictionary IS INITIAL.
PROCEDURE DIVISION USING WordToAdd, WordDefinition.
END PROGRAM AddWordToDictionary.

IDENTIFICATION DIVISION.
PROGRAM-ID. SearchDictionaryForWord IS INITIAL.
PROCEDURE DIVISION USING WordToFind, WordFoundFlag.
END PROGRAM SearchDictionaryForWord.

IDENTIFICATION DIVISION.
PROGRAM-ID. PrintDictionaryContents IS INITIAL.
PROCEDURE DIVISION.
END PROGRAM PrintDictionaryContents.

IDENTIFICATION DIVISION.
PROGRAM-ID. GetWordDefinition IS INITIAL.
PROCEDURE DIVISION USING WordToFind, WordDefinition.
END PROGRAM GetWordDefinition.
END PROGRAM DictionaryModule.
```

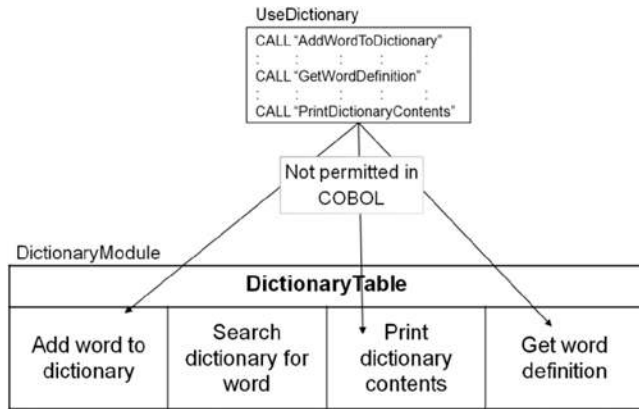


Figure 19-2. COBOL only allows a subprogram to be called by its parent

The only way any kind of informational-strength module can be achieved is for UseDictionary to call the external subprogram DictionaryModule and for DictionaryModule to call the appropriate subprogram, as shown in Figure 19-3. To do this, UseDictionary has to pass a code to DictionaryModule to tell it which of the subprograms to use; and the parameter list passed to DictionaryModule has to be wide enough to accommodate the needs of the contained subprograms. This means even when PrintDictionaryContents is called, you must pass WordToAdd, WordToFind, WordFoundFlag, and WordDefinition as parameters. The problem with this solution is that although you may have created a kind of informational-strength module, the programs UseDictionary and DictionaryModule are now control coupled. The exposure to unnecessary data is not particularly egregious in this example, but it might prove a serious drawback if the contained programs had more significant data needs.

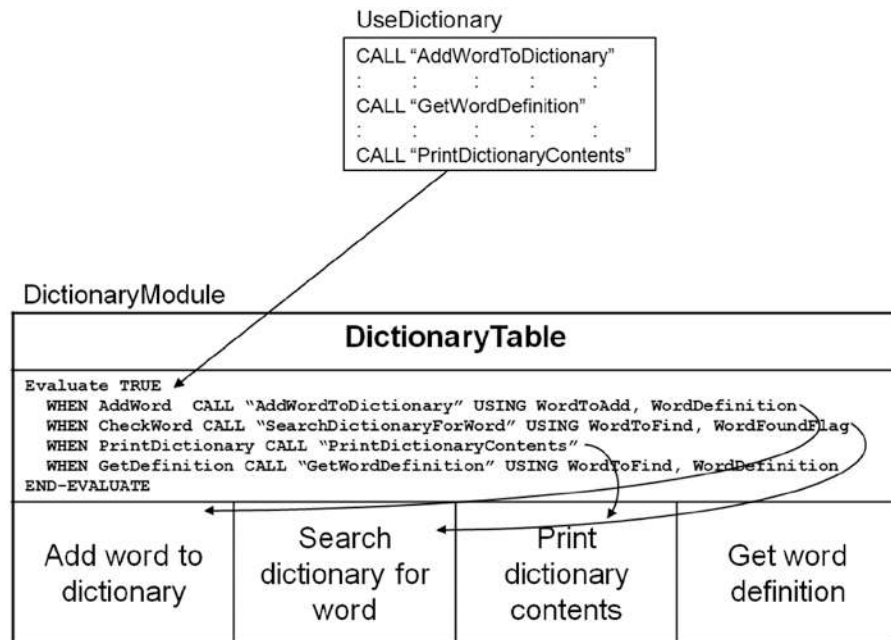


Figure 19-3. Workaround to create an informational-strength module in COBOL

The workaround to the problem of creating an informational-strength module in COBOL is not very satisfactory. Module coupling has been traded for module strength. A kind of informational-strength module has been created, but at the expense of control coupling the `DictionaryModule` and `UseDictionary` programs.

When you come to use `DictionaryModule`, you may discover another limitation: there is only one instance of the dictionary. This means you cannot use the `DictionaryModule` to create specialized dictionaries for acronyms, networking terms, or slang words without running the program multiple times.

OO-COBOL

OO-COBOL provides a solution to many of the problems outlined so far. In OO-COBOL, you can create a *class* in which to hide the implementation details of the dictionary, and you can create *methods* to put words into the dictionary and retrieve word definitions from the dictionary. In addition, a class-based solution goes one step beyond the informational-strength module because it allows you to create instances of the dictionary. This means you can create a dictionary to hold acronyms, a dictionary to hold networking terms, or even a dictionary to hold slang words.

The UseDictionary Program

Listing 19-1 uses OO-COBOL to create a `Dictionary` class and shows how it can be used to create and use multiple instances of dictionaries. Once you have seen an example program and have a feel for how OO is implemented in COBOL, I introduce the topic more formally. I have kept the `Dictionary` class short by only implementing the `AddWordToDictionary` and `PrintDictionaryContents` methods as well as the internal method `SetDictionaryName`.

Listing 19-1. COBOL Program that Uses the Dictionary Class

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Listing19-1.
AUTHOR. Michael Coughlan.
*UseDictionary program

REPOSITORY.
    CLASS DictionaryCls AS "dictionary".

DATA DIVISION.
WORKING-STORAGE SECTION.
01 AcronymDictionary  USAGE OBJECT REFERENCE DictionaryCls.
01 NetworkDictionary  USAGE OBJECT REFERENCE DictionaryCls.
01 SlangDictionary    USAGE OBJECT REFERENCE DictionaryCls.
01 CurrentDictionary  USAGE OBJECT REFERENCE.

01 WordToAdd          PIC X(20).
   88 EndOfInput      VALUE SPACES.

01 WordDefinition     PIC X(1000).

PROCEDURE DIVISION.
Begin.
    INVOKE DictionaryCls "new" USING BY CONTENT "Acronym Dictionary"
                                   RETURNING AcronymDictionary
    INVOKE DictionaryCls "new" USING BY CONTENT "Network Dictionary"
                                   RETURNING NetworkDictionary
```

```

    INVOKE DictionaryCls "new" USING BY CONTENT "Slang Dictionary"
        RETURNING SlangDictionary

    SET CurrentDictionary TO AcronymDictionary
    DISPLAY "Fill the Acronym dictionary"
    PERFORM FillTheDictionary WITH TEST AFTER UNTIL EndOfInput

    SET CurrentDictionary TO NetworkDictionary
    DISPLAY "Fill the Network dictionary"
    PERFORM FillTheDictionary WITH TEST AFTER UNTIL EndOfInput

    SET CurrentDictionary TO SlangDictionary
    DISPLAY "Fill the Slang dictionary"
    PERFORM FillTheDictionary WITH TEST AFTER UNTIL EndOfInput

    DISPLAY SPACES
    INVOKE AcronymDictionary "PrintDictionaryContents"

    DISPLAY SPACES
    INVOKE NetworkDictionary "PrintDictionaryContents"

    DISPLAY SPACES
    INVOKE SlangDictionary "PrintDictionaryContents"

    INVOKE SlangDictionary "finalize" RETURNING SlangDictionary
    INVOKE NetworkDictionary "finalize" RETURNING NetworkDictionary
    INVOKE AcronymDictionary "finalize" RETURNING AcronymDictionary
    STOP RUN.

FillTheDictionary.
    DISPLAY "Enter a word to add (press return to end) - " WITH NO ADVANCING
    ACCEPT WordToAdd

    DISPLAY "Enter the word definition - " WITH NO ADVANCING
    ACCEPT WordDefinition

    INVOKE CurrentDictionary "AddWordToDictionary"
        USING BY CONTENT WordToAdd, WordDefinition.

```

Listing 19-1 uses the dictionary class to create three instances of the dictionary: one to hold acronyms, one for network terms, and the third to hold slang words. The program demonstrates that three instances of the dictionary have been created by filling each with relevant words and then displaying the words in each dictionary.

It is interesting to note how little the language has been changed to accommodate the syntax required to write OO-COBOL programs. In Listing 19-1, the first difference between this and an ordinary COBOL program is the REPOSITORY paragraph. This paragraph lists the classes used in the program. The AS clause specifies the external name for the class.

The second difference is the USAGE OBJECT REFERENCE clause, which is an extension of the USAGE clause that allows you to specify that a data item is capable of holding a reference (handle) to an object. In the program, three data items capable of holding references to dictionary objects are created, and a fourth is created that can hold a reference to any object. I could have made this last a dictionary reference also, but I wanted to show that you can create object-reference data items that are not bound to a particular type of object.

The first thing done in the PROCEDURE DIVISION is to create three instances of the dictionary and assign their references (handles) to the appropriate object-reference data item. This is done by using the INVOKE verb to execute the new method in the dictionary class (or, to describe it in OO-COBOL terms, the INVOKE verb is used to send the new message to the dictionary class.) Because there are three instances of the dictionary, you need to tell each instance its name, so the name of the dictionary is passed to new as a parameter. The new method creates an object instance and places a reference to the instance (the object handle) in the object-reference data item.

At this point, three instances of the dictionary object have been created, and the next step is to fill each dictionary with the appropriate words. I could have done this by repeating the code in the paragraph FillTheDictionary three times and each time targeting a different dictionary (this is what I do to display the contents of each dictionary). But I wanted to create one piece of code to handle all three dictionaries. To do this, instead of referring to a specific dictionary in the FillTheDictionary paragraph, I refer to the CurrentDictionary object reference and then, just before the FillTheDictionary paragraph is performed, move the appropriate dictionary object reference to CurrentDictionary.

When the dictionaries have been filled with words, the contents of the dictionaries are displayed. This is done by sending the PrintDictionaryContents message to the appropriate dictionary object.

Finally, the storage used by the dictionaries is released by sending a finalize message to the appropriate dictionary object. This is often a vital step because if the program ends without destroying the object, the memory allocated to the object is still allocated but the object references that allow you to access the object in memory are lost.

The Dictionary Class

Listing 19-1 showed how to use the dictionary class to create and use dictionary object instances. Listing 19-1-cls (identified as Listing 19-1-cls.cbl in the online sources) shows how to define the dictionary class.

Listing 19-1-cls. The Dictionary Class

```

CLASS-ID. DictionaryCls AS "dictionary"
        INHERITS FROM Base.
AUTHOR. Michael Coughlan.

REPOSITORY.
        CLASS Base AS "base"
        CLASS DictionaryCls AS "dictionary".

FACTORY.
METHOD-ID. New.
LINKAGE SECTION.
01 TestObject-lnk  OBJECT REFERENCE.
01 DictionaryName PIC X(20).

PROCEDURE DIVISION USING DictionaryName RETURNING TestObject-lnk.
Begin.
*Create a new dictionary object by invoke "new" in the base class
        INVOKE SUPER "new" RETURNING TestObject-lnk.

*Set the dictionary name in the dictionary object
        INVOKE TestObject-lnk "SetDictionaryName"
                USING BY CONTENT DictionaryName
        EXIT METHOD.
END METHOD New.
END FACTORY.

```

OBJECT.

WORKING-STORAGE SECTION.

*Items declared here are visible only to methods of this
*instance. They have state memory.

01 DictionaryTable.

02 DictionaryEntry OCCURS 0 TO 1000 TIMES

DEPENDENT ON NumberOfWords

INDEXED BY WordIdx.

03 DictionaryWord PIC X(20).

03 WordDefinition PIC X(1000).

01 NumberOfWords PIC 9(4) VALUE ZERO.

01 DictionaryName PIC X(20).

METHOD-ID. SetDictionaryName.

LINKAGE SECTION.

01 DictionaryNameIn PIC X(20).

PROCEDURE DIVISION USING DictionaryNameIn.

Begin.

MOVE DictionaryNameIn TO DictionaryName

END METHOD SetDictionaryName.

METHOD-ID. AddWordToDictionary.

LINKAGE SECTION.

01 WordIn PIC X(20).

01 DefinitionIn PIC X(1000).

PROCEDURE DIVISION USING WordIn, DefinitionIn.

Begin.

MOVE FUNCTION UPPER-CASE(WordIn) TO WordIn

SET WordIdx TO 1

SEARCH DictionaryEntry

AT END ADD 1 TO NumberOfWords

MOVE WordIn TO DictionaryWord(NumberOfWords)

MOVE DefinitionIn TO WordDefinition(NumberOfWords)

WHEN WordIn = DictionaryWord(WordIdx)

DISPLAY WordIn " is already in the dictionary"

END-SEARCH

EXIT METHOD.

END METHOD AddWordToDictionary.

METHOD-ID. PrintDictionaryContents.

LOCAL-STORAGE SECTION.

PROCEDURE DIVISION.

Begin.

DISPLAY "Words in - " DictionaryName

PERFORM VARYING WordIdx FROM 1 BY 1 UNTIL WordIdx = NumberOfWords

DISPLAY "Word = " DictionaryWord(WordIdx)

```

END-PERFORM
DISPLAY "----- End of dictionary words -----"
EXIT METHOD.
END METHOD PrintDictionaryContents.
END OBJECT.
END CLASS DictionaryCls.

```

The first difference between this class program and a normal COBOL program is that there is no IDENTIFICATION DIVISION. Actually, the IDENTIFICATION DIVISION is now optional. If you are nostalgic, you can still use it. The second difference is that instead of the PROGRAM-ID, you have a CLASS-ID. The CLASS-ID names the class and specifies from what classes it inherits. In this program, the DictionaryCls class inherits from the Base class. The Base class is a system class from which all classes inherit. It corresponds to the class Object in many other OO languages.

The REPOSITORY paragraph allows you to associate internal names with the name of the external file that contains the code for the class. Internally the dictionary class is known as DictionaryCls, but the system knows it as dictionary.

The next item to consider is the FACTORY. The entries from FACTORY to END FACTORY specify the factory object. The main function of the factory object is to create new object instances where initialization is required. If initialization is not required, the new method inherited from the Base class may be used. For instance, if no initialization was required, you could create new acronym dictionary using the statement

```

INVOKE DictionaryCls "new" RETURNING AcronymDictionary

```

In this example, initialization *is* required, so FACTORY contains a new method that overrides the new method inherited from the Base class. What this new method does is to create a new dictionary object. It does this by using the predefined object identifier SUPER to invoke the new method in the Base class. Once a new dictionary object has been created, it is sent the SetDictionaryName message, and this sets the dictionary name into the dictionary instance object by storing it in a data item declared in the instance object. The factory object could not be used for this purpose because there is only one instance of the factory object (created by including the CLASS entries in the REPOSITORY), and the next time you tried to create a new dictionary, the previous name would be overwritten.

You have probably noticed by now that methods in COBOL bear a very strong resemblance to contained subprograms (with some minor differences). Instead of a PROGRAM-ID, you use a METHOD-ID; instead of delimiting the scope with END PROGRAM, you use END METHOD; instead of terminating the method using an EXIT PROGRAM statement, you use EXIT METHOD; and instead of WORKING-STORAGE SECTION, you use LOCAL-STORAGE SECTION.

In Listing 19-1-cls, the next item of interest is the entries that define the instance object. These entries start at OBJECT and end at END OBJECT and specify the data and methods of each dictionary instance. This is where the table that holds the dictionary entries is defined; each dictionary instance has a separate table. Defining the table in the WORKING-STORAGE SECTION of the OBJECT keeps it alive for the life of the instance and makes it available to the methods of the object. It is also where DictionaryName is defined.

SetDictionaryName is an internal method. It is only invoked by the new method in the factory. Its only purpose is to take the dictionary name passed as a parameter and move it to less transient storage. It can't be stored in the method because method storage only persists as long as the method is alive. When the method ends, any data stored in the method is lost.

AddWordToDictionary adds the word and definition passed as parameters to the appropriate place in the table. PrintDictionaryContents displays the words in the dictionary. The list of words is preceded by the name of the dictionary. The name of the dictionary is obtained from DictionaryName in the WORKING-STORAGE SECTION of the OBJECT.

To keep the class short, so that you are not overwhelmed by detail, I did not include the methods SearchDictionaryForWord and GetWordDefinition. These are left as an exercise for you.

A Formal Introduction to OO-COBOL

Now that you have seen an OO-COBOL program and have an idea about how to create such programs, this section introduces some of the elements of OO-COBOL more formally. But keep in mind that this book is not about OO-COBOL or object-oriented programming, so I skim over many of the constructs and only stop to deal more thoroughly with those I consider particularly salient.

When you remember all the new syntax that was required for the Report Writer, you may find it amazing that object orientation has been brought to COBOL with so few additions to the language. There is only one new verb (INVOKE), one new data type (OBJECT REFERENCE), and a few new entries such as these:

- CLASS-ID and END CLASS
- REPOSITORY
- FACTORY and END FACTORY
- METHOD-ID and END METHOD
- OBJECT and END OBJECT
- EXIT METHOD

Objects, Classes, and Methods

Before I begin a discussion about creating objects, classes, and methods in COBOL, I should define some of these terms. An *object* is an encapsulation of data and procedures that operate on that data. In object orientation, the data is known as the object's attributes, and the procedures are known as its methods. For instance, a Stock object might need attributes such a StockId, QtyInStock, ReorderLevel and ReorderQty and might support such methods as GetStockId, AddToStockQty, SubtractFromStockQty, GetStockQty, GetReorderQty, ChangeReorderQty, GetReorderLevel, and ChangeReorderLevel. *Encapsulation* means the structure and implementation of the attributes (data) is completely hidden in the object and the only access to the attributes of an object is through the object's methods. For instance, the only way to change the ReorderLevel of a particular stock item is to invoke that item's ChangeReorderLevel method.

The user of an object can only discover the value of an attribute or change the value of an attribute by making requests to the object. These requests are known as *messages*. Each message invokes a method supported by the object. The messages to which an object responds is known as the *object interface*. Each class actually defines two interfaces: an interface defining the methods supported by the class object (such as the new method) and the interface defining the methods supported by each instance of the class (such as ChangeReorderQty).

A *class* is a template for creating objects. A class contains all the information you need to create objects of a particular type. In OO-COBOL, a class is called an *object factory* because it “manufactures” the object instances. This idea is reinforced by identifying the area of the program where the factory object is defined using the keywords FACTORY and END FACTORY. The factory object may contain its own factory methods and its own factory data. For instance, the Stock class would allow you to create instances of Stock items by sending the new message to the factory object of the Stock class.

In OO-COBOL, a *class definition* is a program that starts with a CLASS-ID and ends with an END CLASS statement. The class program may contain its own ENVIRONMENT, DATA, and PROCEDURE DIVISIONS. When you write a class program, you need to distinguish between three different but related entities:

- The *class* is the source code program defining the class.
- The *factory object* is the class at runtime.
- *Instance objects* are created by the factory object at runtime.

Programming with Objects

OO-COBOL is not a fully object-oriented language. This means objects can be used inside a COBOL program that is not itself object oriented. However, whether the program you want to write is an OO-COBOL class or an ordinary procedural COBOL program that uses OO-COBOL objects, the same rules for using the objects apply.

Your program must have a REPOSITORY paragraph. The REPOSITORY lists all the class that the program is going to use. If the program itself is an OO-COBOL class, the REPOSITORY paragraph also lists its superclass (the class from which it is derived).

Your program must declare one or more data items of type OBJECT REFERENCE. An OBJECT REFERENCE data item holds an object handle. An object handle enables you to send messages to the object. Object references can be moved from one OBJECT REFERENCE data item to another or can be passed as parameters when you INVOKE a method or CALL a subprogram.

Your program must use the INVOKE verb to send messages to the object. Sending a message to an object invokes the named method in the object. A *method* is a piece of code that performs one of the functions of the object. Some methods receive or return parameters, so when you invoke a method you may have to include the parameters as part of the message in the INVOKE statement.

Registering a Class

Before you can use an OO-COBOL class, you must register it by declaring it in the REPOSITORY paragraph. Entries in this paragraph link the internal class name with the name of the external file that contains the code for the class. Registering the class in the REPOSITORY using the CLASS clause creates a data item for each class named, and at runtime this data item holds an object handle to the factory object.

Declaring Object References

When you have declared the class in the REPOSITORY (an action that creates a factory object for the class), you have to declare the data items that will hold the handles of any instance object you may create. To do this, you declare the data items as USAGE OBJECT REFERENCE. For instance, the following data items are declared in Listing 19-1:

```
01 AcronymDictionary  USAGE OBJECT REFERENCE DictionaryCls.
01 NetworkDictionary  USAGE OBJECT REFERENCE DictionaryCls.
01 SlangDictionary    USAGE OBJECT REFERENCE DictionaryCls.
01 CurrentDictionary  USAGE OBJECT REFERENCE.
```

An object reference can be used

- As the target of an INVOKE statement
- As a parameter to a program or method
- With the SET verb to set one object reference to the value of another or to NULL
- In a comparison comparing one object reference for equality with another or to NULL

The object reference for the factory objects is automatically created when you register a class.

An object reference may be typed or untyped. As demonstrated in Listing 19-1, an untyped object reference data item (called a *universal object reference*) can hold an object reference for any object. A typed object reference data item can only hold an object reference of the type specified. For instance, the AcronymDictionary data item can only hold a handle (object reference) to a DictionaryCls object instance.

Sending Messages to Instance Objects

You interrogate, or change, the values of an object's attributes by sending messages to the object instance. You send messages to an object instance using the `INVOKE` verb. When you send a message to an object instance, it causes the method named in the message text to execute. If the method is not found in the object, it is passed up the method inheritance chain until it is recognized and executed. This is how the `new` and `finalize` methods that create and destroy object instances are executed. These methods are part of the system provided Base class inherited by every COBOL class.

As you can see from Figure 19-4, the `INVOKE` verb has a strong similarity to the `CALL` verb and so requires little in the way of explanation. The `ObjectIdentifier` is the data item that holds the object reference. `MessageLiteral` is the name of the method to be invoked. Parameters are passed using the same syntax as the `CALL` verb except that an additional mechanism (`BY VALUE`) has been added. The `RETURNING` phrase allows the invoked method to return a value.

$$\begin{array}{l}
 \underline{\text{INVOKE}} \left\{ \text{ObjectIdentifier} \right\} \left\{ \begin{array}{l} \text{MessageLiteral} \\ \text{MessageIdentifier} \end{array} \right\} \\
 \\
 \left[\begin{array}{l}
 \left[\begin{array}{l}
 \left[\text{BY REFERENCE} \right] \left\{ \begin{array}{l} \text{Identifier} \\ \underline{\text{ADDRESS OF Identifier}} \end{array} \right\} \dots \\
 \text{BY CONTENT} \left\{ \begin{array}{l} \text{Identifier} \\ \text{Literal} \\ \text{Arithmetic Expression} \end{array} \right\} \dots \\
 \text{BY VALUE} \left\{ \begin{array}{l} \text{Identifier} \\ \text{Arithmetic Expression} \end{array} \right\} \dots
 \end{array} \right\} \dots \\
 \left\{ \underline{\text{RETURNING}} \right\} \left\{ \text{Identifier} \right\}
 \end{array} \right]
 \end{array}$$

Figure 19-4. Metalanguage for the `INVOKE` verb

Creating a New Object Instance

Once you have created a data item capable of holding an object reference, you need to create an object instance and store its reference in the data item. You create an object instance by sending a creation message to its factory object (the factory object itself is created when you register it in the `REPOSITORY`). For objects that do not have any initialization parameters, the creation message is `new` (see Example 19-2 and Example 19-3). When the new method executes, it allocates the storage required for the object and returns the object handle.

Example 19-2. Registering a Class, Declaring an Object Reference Data Item, and Creating an Object Instance

```

REPOSITORY.
  CLASS StockCls AS "stockclassprogram"
  :   :   :   :   :   :   :
WORKING-STORAGE SECTION.
  01 StockItem USAGE OBJECT REFERENCE StockCls.
  :   :   :   :   :   :   :
PROCEDURE DIVISION.
  :   :   :   :   :   :   :
  INVOKE StockCls "new" RETURNING StockItem

```

Example 19-3. Registering a Class, Declaring an Object Reference Data Item, and Invoking new with an Initialization Parameter to Create a Dictionary Instance

```

REPOSITORY.
    CLASS DictionaryCls AS "dictionary".
    :   :   :   :   :   :   :   :
WORKING-STORAGE SECTION.
01 AcronymDictionary  USAGE OBJECT REFERENCE DictionaryCls.
    :   :   :   :   :   :   :   :
PROCEDURE DIVISION.
    :   :   :   :   :   :   :   :
    INVOKE DictionaryCls "new" USING BY CONTENT "Acronym Dictionary"
        RETURNING AcronymDictionary

```

Destroying Objects

When you have finished using an object, you must destroy it. This frees the memory it uses. There is no automatic garbage collection in OO-COBOL, so the memory for objects that have been allocated but whose object handles have been lost cannot be recovered. Once an object has been created, it remains in existence until it is destroyed explicitly, even if the data item that holds its object handle is destroyed or the object handle is overwritten.

You destroy an object by sending it the `finalize` message. Like the `new` method, `finalize` is a method provided by the Base class and inherited by all classes. When you `finalize` an object, the method returns a NULL object reference. Example 19-4 shows how to use `INVOKE` with the `finalize` message to destroy an object.

Example 19-4. Using `finalize` to Destroy an Object

```

INVOKE AcronymDictionary "finalize" RETURNING AcronymDictionary

```

Predefined Object Identifiers

I mentioned the NULL object reference in the previous section. NULL is one of three predefined object identifiers. The identifiers and their significance are given in Table 19-2.

Table 19-2. *Predefined Object Identifiers*

Predefined Object Identifier	Meaning
NULL	<p>The predefined object reference NULL contains the null object-reference value that is a unique value guaranteed by the implementer never to reference an object. It represents a value used to indicate that data items defined as USAGE OBJECT REFERENCE do not contain a valid address. NULL must not be specified as a receiving operand, but it can be used in a comparison such as</p> <pre>IF AcronymDictionary = NULL DISPLAY "The acronym dictionary object does not exist" END-IF</pre>
SELF	<p>SELF is a predefined object identifier used in the PROCEDURE DIVISION of a method. SELF refers to the object instance used to invoke the currently executing method. By using SELF you can cause an object to send a message to itself. This is useful if you want a method to invoke one of its siblings. For instance, in Listing 19-1-cl5 you could use SELF to invoke the SetDictionaryName method from one of the other methods using a statement such as</p> <pre>INVOKE SELF "SetDictionaryName" USING BY CONTENT NewDictionaryName</pre> <p>You might want to use SELF because you have placed a piece of code that is used by several different methods in a method on its own and want to use this method like a subroutine.</p>
SUPER	<p>SUPER allows an object to send a message to itself, but the method invoked is a not a method in the class itself but rather a method in one of the superclasses of the class. If SUPER is used from an instance method, the system searches its way up through the instance methods of all the superclasses until it finds a method matching the message.</p> <p>If SUPER is used from a factory method, the system searches for a factory method beginning with the factory object code of the superclass immediately above the class and searches its way up through the factory methods of all the superclasses until it finds a method matching the message.</p> <p>For instance, in Listing 19-1-cl5, the new method in the FACTORY needs to invoke the new method in the base class. This is achieved using the statement</p> <pre>INVOKE SUPER "new" RETURNING TestObject-lnk.</pre>

Writing Your Own Classes

When you write an OO application, you need to create your own classes. A class program has the structure shown in Figure 19-5, and the entries required are outlined in the class template in Example 19-5.

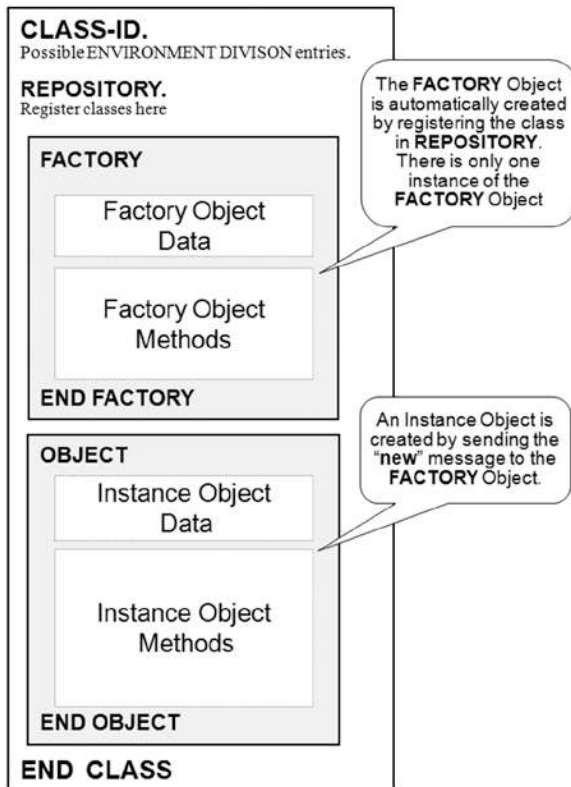


Figure 19-5. Structure of a class program

Example 19-5. A Class Program Template

```

CLASS-ID. Template-cls AS "template"
        inherits from Base.
* Class identification.
ENVIRONMENT DIVISION.
* Optional but when used all normal ENVIRONMENT DIVISION entries are valid
:      :      :      :      :      :      :      :      :
:      :      :      :      :      :      :      :      :

CONFIGURATION SECTION.
* Optional entry but the REPOSITORY is part of the CONFIGURATION SECTION
:      :      :      :      :      :      :      :      :
:      :      :      :      :      :      :      :      :

REPOSITORY.
* The Repository paragraph names the files containing the executables
* for each class.
* The executable for Template-cls is in the file template.
    CLASS BASE AS "base"
    CLASS Template-cls AS "tester".

FACTORY
* Defines the start of the factory object.
ENVIRONMENT DIVISION.
DATA DIVISION.

```

```

* Defines factory object data
WORKING-STORAGE SECTION.
* Defines factory object data
:      :      :      :      :      :      :      :      :
METHOD-ID. new.
* If initialization is required there may be a "new" of factory method.
* This overrides "new" coming from Base.
:      :      :      :      :      :      :      :      :
END METHOD new.
END FACTORY.

OBJECT.
* Start of the code that defines the behaviour of class instances.
WORKING-STORAGE SECTION.
* Defines instance data visible to all methods of the instance.
:      :      :      :      :      :      :      :      :
METHOD-ID. ExampleTemplateMethod.
* Start of instance method "ExampleTemplateMethod "
...
END METHOD ExampleTemplateMethod.
END OBJECT.
* End of code for instance objects.
END CLASS Example.

```

The Issue of Scope

Whenever you write a class program, you have to be aware of the consequences of declaring data items in various parts of the program. When I refer to the *scope* of a data item, I am referring to its lifetime: how long it persists. The scoping issues of data items declared in the class program are summarized in Table 19-3, and Listing 19-2 demonstrates these issues in an example program.

Table 19-3. *Class Program Scoping Issues*

Where Declared	Scope
WORKING-STORAGE SECTION of the FACTORY	A data item declared in the WORKING-STORAGE SECTION of the FACTORY is visible only to factory methods; and because there is only one factory object, there is only one instance of the data item. The item persists as long as the class program is alive.
WORKING-STORAGE SECTION of the OBJECT	A data item declared in the WORKING-STORAGE SECTION of the OBJECT is visible only to object instance methods. There is an instance of the data item for each object, and the data item will persist as long as the instance is alive (has not been finalized).
LOCAL-STORAGE SECTION of any method	A data item declared in the LOCAL-STORAGE SECTION of any method (factory of instance object) visible only to the method, and it persists only as long as the method is alive.

Listing 19-2. Example Program to Demonstrate Scoping Issues

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing19-2.
* AUTHOR. Michael Coughlan.
* Demonstrates the difference between Factory methods & data
* and instance methods & data.
* It is also used to demonstrate the scope of
* data items declared in different parts of the program.

REPOSITORY.
    CLASS Tester-cls AS "tester".

DATA DIVISION.
WORKING-STORAGE SECTION.
01 Test1-obj OBJECT REFERENCE Tester-cls.
01 Test2-obj OBJECT REFERENCE Tester-cls.
01 Test3-obj OBJECT REFERENCE Tester-cls.

PROCEDURE DIVISION.
Begin.
    INVOKE Tester-cls "new" RETURNING Test1-obj
    INVOKE Tester-cls "new" RETURNING Test2-obj
    INVOKE Tester-cls "new" RETURNING Test3-obj

    DISPLAY SPACES
    DISPLAY "----- Test3-obj ViewData -----"
    INVOKE Test3-obj "ViewData"

    DISPLAY SPACES
    DISPLAY "----- Test1-obj ViewData -----"
    INVOKE Test1-obj "ViewData"

    DISPLAY SPACES
    DISPLAY "----- Test3-obj ViewData again -----"
    INVOKE Test3-obj "ViewData"

    DISPLAY SPACES
    DISPLAY "----- Test2-obj ViewData -----"
    INVOKE Test2-obj "ViewData" USING BY CONTENT 5

    INVOKE Test1-obj "finalize" RETURNING Test1-obj
    INVOKE Test2-obj "finalize" RETURNING Test2-obj
    INVOKE Test3-obj "finalize" RETURNING Test3-obj
STOP RUN.

```

Listing 19-2 Output

```
Factory Working-Storage data has state memory - 2
but Factory Method Local-Storage data does not - 2
```

```
Factory Working-Storage data has state memory - 4
but Factory Method Local-Storage data does not - 2
```

```
Factory Working-Storage data has state memory - 6
but Factory Method Local-Storage data does not - 2
```

```
----- Test3-obj ViewData -----
This is instance 3 of 3
Instance Object Data = 30
Instance Method Data = 30
```

```
----- Test1-obj ViewData -----
This is instance 1 of 3
Instance Object Data = 10
Instance Method Data = 10
```

```
----- Test3-obj ViewData again -----
This is instance 3 of 3
Instance Object Data = 60
Instance Method Data = 30
```

```
----- Test2-obj ViewData -----
This is instance 2 of 3
Instance Object Data = 20
Instance Method Data = 20
```

The program starts by creating three instances of the tester class object. It does this by sending the new message to the class. There is a new method in the class factory, so that method is executed. The purpose of the new method is to demonstrate the difference between data items declared in the WORKING-STORAGE SECTION of the factory and items declared in the LOCAL-STORAGE SECTION of a factory method. The output from the program shows that while the WORKING-STORAGE data items remember their values from invocation to invocation, which allows them to be incremented each time new is invoked, the LOCAL-STORAGE items always show the same value.

There is one other thing going on here under the surface. If you look at the ViewData displays in the Listing 19-2 output, note that the first line displayed shows which instance it is and how many instances there are. In order to display this information, you must note the instance when new is invoked. But although the number of instances can be stored in the factory, the particular instance number cannot. It has to be stored with the particular instance. When you examine the class program, you can see how this is done.

The ViewData displays are also used to show that there are separate data items for each instance. The increment value used to show the difference between data items declared in the WORKING-STORAGE of the OBJECT and those declared in LOCAL-STORAGE of the ViewData method is computed as 10 multiplied by the instance number. That is 10 for instance one, 20 for instance two, and 30 for instance three.

The purpose of the ViewData displays is to show that separate instances have been created and that when you invoke an object for the second time, you can see that it has remembered the contents of one variable but not the other. The class program used by Listing 19-2 is given in Listing 19-2-cls.

Listing 19-2-cls. Class Program Used by Listing 19-2

```

CLASS-ID. Tester-cls AS "tester"
        INHERITS FROM Base.
* AUTHOR. Michael Coughlan.
* Demonstrates the difference between Factory methods and data and Instance methods
* and data. Also demonstrates persistence of data items declared in different areas.

REPOSITORY.
        CLASS BASE AS "base"
        CLASS Tester-cls AS "tester".

FACTORY.
WORKING-STORAGE SECTION.
*Items declared here are visible only to factory methods and have state memory
01 InstCounter-fws    PIC 9 VALUE ZEROS.
01 FactoryData-fws   PIC 9 VALUE ZEROS.

METHOD-ID. New.
LOCAL-STORAGE SECTION.
*Items declared here are visible only to this method but do not have state memory.
01 LocalData-mls    PIC 9 VALUE ZEROS.

LINKAGE SECTION.
01 TestObject-lnk  OBJECT REFERENCE.

PROCEDURE DIVISION RETURNING TestObject-lnk.
Begin.
    ADD 2 TO FactoryData-fws LocalData-mls
    DISPLAY "Factory Working-Storage data has state memory - "
           FactoryData-fws
    DISPLAY "but Factory Method Local-Storage data does not - "
           LocalData-mls
    DISPLAY SPACES
    INVOKE SUPER "new" RETURNING TestObject-lnk
    ADD 1 TO InstCounter-fws
    INVOKE TestObject-lnk "InitialiseData"
           USING BY CONTENT InstCounter-fws
    EXIT METHOD.
END METHOD New.

METHOD-ID. GetTotalInstCount.
LINKAGE SECTION.
01 TotalInstCount-lnk    PIC 9.
PROCEDURE DIVISION RETURNING TotalInstCount-lnk.
Begin.

```

```

MOVE InstCounter-fws TO TotalInstCount-lnk.
END METHOD GetTotalInstCount.
END FACTORY.

OBJECT.
WORKING-STORAGE SECTION.
*Items declared here are visible only to methods of this
*instance. They persist for the life of the object instance.
01 ThisInstanceNum-ows          PIC 9 VALUE ZEROS.
01 InstObjectData-ows          PIC 99 VALUE ZEROS.

METHOD-ID. InitialiseData.
LINKAGE SECTION.
01 InstNumIn-lnk                PIC 9.
PROCEDURE DIVISION USING InstNumIn-lnk.
Begin.
    MOVE InstNumIn-lnk TO ThisInstanceNum-ows
    EXIT METHOD.
END METHOD InitialiseData.

METHOD-ID. ViewData.
LOCAL-STORAGE SECTION.
*Items declared here only exist for the life of the method.
*They do not retain their values between invocations.
01 InstMethodData-mls          PIC 99 VALUE ZEROS.
01 TotalInstCount-mls          PIC 9 VALUE ZEROS.
01 Increment-mls                PIC 99 VALUE ZEROS.

PROCEDURE DIVISION.
Begin.
    COMPUTE Increment-mls = 10 * ThisInstanceNum-ows
    ADD Increment-mls TO InstObjectData-ows, InstMethodData-mls
    INVOKE Tester-cls "GetTotalInstCount"
        RETURNING TotalInstCount-mls
    DISPLAY "This is instance " ThisInstanceNum-ows
        " of " TotalInstCount-mls
    DISPLAY "Instance Object Data = " InstObjectData-ows
    DISPLAY "Instance Method Data = " InstMethodData-mls
    EXIT METHOD.
END METHOD ViewData.
END OBJECT.
END CLASS Tester-cls.

```

The first thing to note about Listing 19-2-cls is that I have attached a suffix to each data item to assist your understanding. The suffix meanings are as follows:

- ows indicates a data item in the OBJECT WORKING-STORAGE
- mls indicates a data item in the method LOCAL-STORAGE
- lnk indicates a data item in the LINKAGE-SECTION
- fws indicates a data item in the FACTORY WORKING-STORAGE

The factory contains a new method. This method overrides the new method in the Base class and its purpose is to note the number of the particular object instance created and to keep a count of how many instances have been created. There are two data items in the WORKING-STORAGE SECTION of the FACTORY: `FactoryData-fws` and `InstCounter-fws`. `FactoryData-fws` is used for the purpose of contrast with the `LocalData-mls` data item declared in the new method. As you can see from the output, `FactoryData-fws` remembers its value from invocation to invocation, whereas `LocalData-mls` starts with a value of ZEROS each time the new method is called. `InstCounter-fws` holds the count of the number of instances that have been created. Each time `new` is invoked, this count is incremented. `InstCounter-fws`, however, can't be used to hold the instance number (as soon as the next instance is created, the number is overwritten). Instead, as soon as an instance has been created by the statement

```
INVOKE SUPER "new" RETURNING TestObject-lnk
```

the method `InitialiseData` in the instance just created is invoked and is passed the current value of `InstCounter-fws`. `InitialiseData` then records the number in the instance variable `ThisInstanceNum-ows`.

Two data items have been declared in the WORKING-STORAGE SECTION of the OBJECT: `ThisInstanceNum-ows` and `InstObjectData-ows`. As I have already mentioned, `ThisInstanceNum-ows` is used to hold the instance number. `InstObjectData-ows` is used to show the contrast between items declared in the WORKING-STORAGE of the OBJECT and items declared in the LOCAL-STORAGE of the method.

One last issue needs some explanation. `ViewData` can display the instance number because it is stored in the instance data item `ThisInstanceNum-ows`, but `ViewData` does not know how many instances have been created. That information is stored in the factory in `InstCounter-fws`. The problem is that an instance method cannot see a data item declared in the factory. In order to get access to that information the statement

```
INVOKE Tester-cls "GetTotalInstCount"
      RETURNING TotalInstCount-mls
```

invokes the factory method `GetTotalInstCount`. This method returns the number of instances as a parameter. Pay particular attention to the target of the INVOKE statement. Instead of targeting the instance object, or SELF, or SUPER, the class name is used (registering the class in the REPOSITORY created the factory object.)

Summary

This chapter introduced OO-COBOL from a particular perspective. The ANS 85 version of COBOL was supposed to bring structured programming to COBOL, but although it had many fine features, it was not entirely successful in this respect. This chapter discussed the shortcomings of the ANS 85 version when attempting to create informational-strength modules and showed how OO-COBOL can be used to fulfill the structured programming promise of ANS 85 COBOL. You then saw an OO program that implemented the information hiding techniques of an informational-strength module. Having demonstrated how to create an OO program through an example, I introduced the topic more formally, and you saw the entries required to use a class, invoke a method, and create a class program. The final section discussed the issue of data-item scope and demonstrated the effect of declaring data items in various parts of the class program.

This has been a long journey. I hope that you have enjoyed the trip and have learned something along the way. Although COBOL has its flaws, its many strengths in the area of its chosen domain account for its dominance in the world of enterprise computing.

PROGRAMMING EXERCISE

Well, it's time for the final exercise. If you can locate the stub of your 2B pencil, why not have a go at writing an OO-COBOL program?

The Zodiac Signs Compatibility exercise in Chapter 16 required you to write a program that used a contained subprogram called `IdentifySign` to identify the Zodiac sign for a given birth date. Using the program that you wrote for that exercise as a starting point, write a `Zodiac` class that supplies the following methods, and then rewrite the `Zodiac Sign Compatibility Experiment` program so that it uses that `Zodiac` class:

METHOD-ID. "getSignHouse".

LINKAGE SECTION.

01 InDate.

 02 InDay PIC XX.

 02 InMonth PIC XX.

01 OutZodiacHouse PIC 99.

01 OpStatus PIC 9.

* value of 0 indicates operation was successful

* value of 1 indicates sign is a Cusp Sign

* value of 2 indicates date supplied was invalid

PROCEDURE DIVISION USING InDate, OutZodiacHouse RETURNING OpStatus.

*Accepts a date in form DDMM and returns the Zodiac House value (01-12)

*The twelve houses are Aries, Taurus, Gemini, Cancer, Leo, Virgo,

*Libra, Scorpio, Sagittarius, Capricorn, Aquarius, Pisces

*Method should note if the sign is a cusp sign

END METHOD "getSignHouse".

METHOD-ID. "getSignName".

LINKAGE SECTION.

01 InZodiacHouse PIC 99.

01 OutSignName PIC X(11).

01 OpStatus PIC 9.

* value of 0 indicates operation was successful

* value of 1 indicates InZodiacHouse value not in range 01-12

PROCEDURE DIVISION USING InZodiacHouse, OutSignName RETURNING OpStatus.

*Accepts a Zodiac House value and returns the Zodiac Sign name

*For instance house 3 = Gemini

END METHOD "getSignName".

METHOD-ID. "getSignElement".

LINKAGE SECTION.

01 InZodiacHouse PIC 99.

 88 ValidSignHouse VALUE 01 THRU 12.

01 OutSignElement PIC X(5).

01 OpStatus PIC 9.

 88 InvalidSignHouse VALUE 1.

 88 OperationOk VALUE 0.


```

PROCEDURE DIVISION USING InZodiacHouse, OutSignElement RETURNING OpStatus.
*Accepts a Zodiac House value and returns the element of the sign
*Viz - Fire Earth Air Water.
*Houses 1,5,9 = Fire; 2,6,10 = Earth; 3,7,11 = Air; 4,8,12 = Water
END METHOD "getSignElement".

```

Before you rewrite the Zodiac Sign Compatibility Experiment program, you can test the Zodiac class you have written using the following test program:

```

IDENTIFICATION DIVISION.
PROGRAM-ID. UseZodiac.
AUTHOR. Michael Coughlan.
REPOSITORY.
    CLASS ZodiacFactory AS "zodiac".

DATA DIVISION.
WORKING-STORAGE SECTION.
01 MyZodiac    USAGE OBJECT REFERENCE ZodiacFactory.

01 Date-DDMM   PIC X(4).
    88 EndOfData VALUE SPACES.

01 SignCode    PIC 99.

01 OpStatus1   PIC 9.
    88 CuspSign VALUE 1.

01 OpStatus2   PIC 9.
    88 OperationOK VALUE ZEROS.

01 SignName    PIC X(11).
01 SignElement PIC X(5).

PROCEDURE DIVISION.
Begin.
    INVOKE ZodiacFactory "new" RETURNING MyZodiac
    DISPLAY "Enter the Date DDMM :- " WITH NO ADVANCING
    ACCEPT Date-DDMM

    PERFORM GetAndDisplay UNTIL EndOfdata
    INVOKE MyZodiac "finalize" RETURNING MyZodiac
    DISPLAY "End of Program"
    STOP RUN.

GetAndDisplay.
    INVOKE MyZodiac "getSignHouse" USING BY CONTENT Date-DDMM
                                     BY REFERENCE SignCode
                                     RETURNING OpStatus1

    INVOKE MyZodiac "getSignName"     USING BY CONTENT SignCode
                                     BY REFERENCE SignName
                                     RETURNING OpStatus2

```

```

INVOKE MyZodiac "getSignElement" USING BY CONTENT SignCode
                                BY REFERENCE SignElement
                                RETURNING OpStatus2

DISPLAY "SignCode = " SignCode
DISPLAY "Sign name is " SignName
DISPLAY "Sign Element is " SignElement
IF CuspSign
    DISPLAY "The sign is a cusp"
END-IF
DISPLAY "Enter the Date DDMM :- " WITH NO ADVANCING

ACCEPT Date-DDMM.

```

PROGRAMMING EXERCISE: ANSWER

Listing 19-3. Zodiac Compatibility Program Using the Zodiac Class

```

IDENTIFICATION DIVISION.
PROGRAM-ID. Listing19-3.
* Zodiac Compatibility program
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT BirthsFile ASSIGN TO "Listing19-3-MPDOB.DAT"
        ORGANIZATION IS LINE SEQUENTIAL.

CLASS-CONTROL.
    ZodiacFactory IS CLASS "zodiac".

DATA DIVISION.
FILE SECTION.
FD BirthsFile.
01 BirthsRec.
    88 EndOfFile VALUE HIGH-VALUES.
    02 MaleDOB.
        03 MaleDate          PIC X(4).
        03 FILLER            PIC X(4).
    02 FemaleDOB.
        03 FemaleDate       PIC X(4).
        03 FILLER           PIC X(4).

WORKING-STORAGE SECTION.
01 MyZodiac  USAGE OBJECT REFERENCE.

01 Counts.
    02 CompatiblePairs    PIC 9(7) VALUE ZEROS.
    02 CompatiblePrn     PIC ZZZZ,ZZ9.
    02 CompatiblePercent PIC ZZ9.

```

```

02 IncompatiblePairs PIC 9(7) VALUE ZEROS.
02 IncompatiblePrn   PIC ZZZZ,ZZ9.
02 IncompatiblePercent PIC ZZ9.
02 ValidRecs        PIC 9(8) VALUE ZEROS.
02 ValidRecsPrn     PIC ZZ,ZZZ,ZZ9.
02 TotalRecs        PIC 9(9) VALUE ZEROS.
02 TotalRecsPrn     PIC ZZ,ZZZ,ZZ9.

01 MaleSign         PIC 99.
01 FemaleSign       PIC 99.
01 SumOfSigns       PIC 99.

01 OpStatusM        PIC 9.
   88 ValidMale     VALUE ZEROS.

01 OpStatusF        PIC 9.
   88 ValidFemale   VALUE ZEROS.

PROCEDURE DIVISION.
Begin.
  INVOKE ZodiacFactory "new" RETURNING MyZodiac
  OPEN INPUT BirthsFile.
  READ BirthsFile
    AT END SET EndOfFile TO TRUE
  END-READ
  PERFORM ProcessBirthRecs UNTIL EndOfFile

  COMPUTE ValidRecs = CompatiblePairs + IncompatiblePairs
  COMPUTE CompatiblePercent ROUNDED = CompatiblePairs / ValidRecs * 100
  COMPUTE InCompatiblePercent ROUNDED = InCompatiblePairs / ValidRecs * 100

  PERFORM DisplayResults

  CLOSE BirthsFile.
  STOP RUN.

DisplayResults.
  MOVE CompatiblePairs TO CompatiblePrn
  MOVE IncompatiblePairs TO IncompatiblePrn
  MOVE TotalRecs TO TotalRecsPrn
  MOVE ValidRecs TO ValidRecsPrn

  DISPLAY "Total records = " TotalRecsPrn
  DISPLAY "Valid records = " ValidRecsPrn
  DISPLAY "Compatible pairs = " CompatiblePrn
    " which is " CompatiblePercent "% of total".
  DISPLAY "Incompatible pairs = " IncompatiblePrn
    " which is " InCompatiblePercent "% of total".

```

```

ProcessBirthRecs.
* Get the two sign types and add them together
* If the result is even then they are compatible
ADD 1 TO TotalRecs
INVOKE MyZodiac "getSignHouse" USING BY CONTENT MaleDate
                                   BY REFERENCE MaleSign
                                   RETURNING OpStatusM

INVOKE MyZodiac "getSignHouse" USING BY CONTENT FemaleDate
                                   BY REFERENCE FemaleSign
                                   RETURNING OpStatusF

IF ValidMale AND ValidFemale
  COMPUTE SumOfSigns = MaleSign + FemaleSign
  IF FUNCTION REM(SumOfSigns 2) = ZERO
    ADD 1 TO CompatiblePairs
  ELSE
    ADD 1 TO IncompatiblePairs
  END-IF
END-IF
READ BirthsFile
  AT END SET EndOfFile TO TRUE
END-READ.

```

Listing 19-3-cls. The Zocodiac Class Program

```

CLASS-ID. Zodiac AS "zodiac" INHERITS FROM Base.
* AUTHOR. Michael Coughlan.

REPOSITORY.
  CLASS BASE AS "base"
  CLASS Zodiac AS "zodiac".

* No FACTORY in this program

OBJECT.
WORKING-STORAGE SECTION.
01 ZodiacTable.
  02 ZodiacTableData.
    03 FILLER PIC X(20) VALUE "Aries      103210419".
    03 FILLER PIC X(20) VALUE "Taurus    204200520".
    03 FILLER PIC X(20) VALUE "Gemini    305210620".
    03 FILLER PIC X(20) VALUE "Cancer   406210722".
    03 FILLER PIC X(20) VALUE "Leo      107230822".
    03 FILLER PIC X(20) VALUE "Virgo    208230922".
    03 FILLER PIC X(20) VALUE "Libra    309231022".
    03 FILLER PIC X(20) VALUE "Scorpio  410231121".
    03 FILLER PIC X(20) VALUE "Sagittarius111221221".
    03 FILLER PIC X(20) VALUE "Capricorn 212221231".
    03 FILLER PIC X(20) VALUE "Aquarius  301200218".
    03 FILLER PIC X(20) VALUE "Pisces   402190320".

```

```

02 ZodiacSign REDEFINES ZodiacTableData
    OCCURS 12 TIMES
    INDEXED BY Zidx.
    03 SignName      PIC X(11).
    03 SignElement   PIC 9.
    03 StartDate     PIC X(4).
    03 EndDate       PIC X(4).

01 ElementTable VALUE "Fire EarthAir Water".
    02 Element OCCURS 4 TIMES PIC X(5).

METHOD-ID. getSignHouse.
LOCAL-STORAGE SECTION.
01 WorkDate.
    88 SignIsCusp VALUE "0120", "0121", "0219", "0220",
                        "0320", "0321", "0420", "0421",
                        "0521", "0522", "0621", "0622",
                        "0723", "0724", "0823", "0824",
                        "0923", "0924", "1023", "1024",
                        "1122", "1123", "1221", "1222".
    02 WorkMonth     PIC XX.
    02 WorkDay       PIC XX.

LINKAGE SECTION.
01 InDate.
    02 InDay         PIC XX.
    02 InMonth       PIC XX.

01 House            PIC 99.
01 OpStatus         PIC 9.
    88 CuspSign     VALUE 1.
    88 InvalidDate  VALUE 2.

PROCEDURE DIVISION USING InDate, House RETURNING OpStatus.
    MOVE InDay TO WorkDay
    MOVE InMonth TO WorkMonth
    MOVE 0 TO OpStatus
    SET Zidx TO 1
    SEARCH ZodiacSign
        AT END IF WorkDate >= "0101" AND <= "0119"
            MOVE 11 TO House
        END-IF
    WHEN WorkDate >= StartDate(Zidx) AND <= EndDate(Zidx)
        SET House TO Zidx
    END-SEARCH
    IF SignIsCusp SET CuspSign TO TRUE
    END-IF

EXIT METHOD.
END METHOD getSignHouse.

```

```
METHOD-ID. getSignName.  
LINKAGE SECTION.  
01 House          PIC 99.  
   88 ValidSignHouse  VALUE 01 THRU 12.  
01 OutSignName    PIC X(11).  
  
01 OpStatus       PIC 9.  
   88 InvalidSignHouse VALUE 1.  
   88 OperationOk    VALUE 0.  
  
PROCEDURE DIVISION USING House, OutSignName RETURNING OpStatus.  
  IF NOT ValidSignHouse  
    SET InvalidSignHouse TO TRUE  
  ELSE  
    MOVE SignName(House) TO OutSignName  
    SET OperationOk TO TRUE  
  END-IF  
  EXIT METHOD.  
END METHOD getSignName.  
  
METHOD-ID. getSignElement.  
LINKAGE SECTION.  
01 House          PIC 99.  
   88 ValidSignHouse  VALUE 01 THRU 12.  
01 OutSignElement PIC X(5).  
  
01 OpStatus       PIC 9.  
   88 InvalidSignHouse VALUE 1.  
   88 OperationOk    VALUE 0.  
  
PROCEDURE DIVISION USING House, OutSignElement RETURNING OpStatus.  
  IF NOT ValidSignHouse  
    SET InvalidSignHouse TO TRUE  
  ELSE  
    MOVE Element(SignElement(House)) TO OutSignElement  
    SET OperationOk TO TRUE  
  END-IF  
  EXIT METHOD.  
END METHOD getSignElement.  
END OBJECT.  
  
END CLASS Zodiac.
```

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Beginning COBOL for Programmers



Michael Coughlan

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Beginning COBOL for Programmers

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ISBN-13 (pbk): 978-1-4302-6253-4

ISBN-13 (electronic): 978-1-4302-6254-1

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To my students in grateful thanks for everything you taught me.

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Acknowledgments

Special thanks go to Steve Anglin, who started the whole process of my writing this book, and to Matthew Moodie, Anamika Panchoo, Melissa Maldonado, and Massimo Nardone, the team of editors at Apress whose work was so invaluable in shaping the text. I would especially like to thank Tiffany Taylor for her excellent suggestions and for all her work in eliminating my errors. Any errors that remain are my responsibility, but without her help, there would be many more of them.

I thank my family for all their support. I thank Redmond O'Brien, who acted as a patient sounding board for ideas, and Dermot Shinnars-Kennedy, for our discussions about COBOL. The results of those discussions find many a reflection in this book. Finally, I thank Annette McElligott (HOD) for her support and encouragement in this endeavor.

Thanks also are due to Bill Qualls and Caliber Data Training for granting permission to use their BigDecimal Java example program.

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Preface

It seems strange to be writing a book on COBOL so many years after its death was first predicted. Indeed, COBOL has had such a low profile in recent years that you might be forgiven for thinking that it had all but disappeared. The nature of our industry is such that the new and exciting always gets more airplay than the secure, the accurate, and the reliable. But while Java, C#, Ruby, Python, and Objective C have dominated our consciousness in recent times, in the background billions of lines of COBOL code have quietly gone about supporting the mission-critical applications that make the world work.

Now, after many years, awareness is increasing about COBOL and the huge body of legacy COBOL code. COBOL is mentioned more and more in magazines, in trade journals, and in newspapers. Indeed, you may be reading this book because you have noticed this activity and have become curious about COBOL. You may have wondered why this supposedly dying language is attracting attention recently. The reason is simple. There is a legacy crisis just around the corner, and stakeholders are trying to do something about it.

The problem is, so many attempts to rewrite COBOL legacy systems or replace them with off-the-shelf solutions have ended in failure that custodians of legacy systems are now wary of these approaches to modernization. Migrating the COBOL codebase to take advantage of less-expensive hardware and software is now seen as a more viable, safer, and cheaper alternative to replacement. But keeping, and even growing, the COBOL codebase requires COBOL programmers—and the COBOL workforce is aging and nearing retirement. In an effort to avert the workforce crisis, legacy system stakeholders have implemented initiatives to increase the number of new COBOL programmers entering the marketplace. COBOL implementers such as IBM and Micro Focus have introduced initiatives to encourage colleges and universities around the world to teach COBOL as part of their curriculum, training companies and in-house training groups are once more starting to provide instruction in COBOL, and employers have begun to offer a number of entry-level COBOL positions.

Over the last few years, the demand for programmers has far exceeded the supply. However, as the number of students graduating from computer science courses recovers from the year 2000 downturn, the job market is likely to become more and more competitive. In such a competitive environment, and at a time when the demand for COBOL programmers is increasing, you may find it profitable to have a résumé that includes a knowledge of COBOL.

Who This Book Is For

This book is aimed at programmers familiar with other languages who are curious about COBOL or are working with COBOL legacy systems or who wish to take advantage of COBOL job opportunities. To get the most from this book, you must have some knowledge of programming. It is not an introductory programming text.

How You Should Read This Book

If you are using this book to learn to program in COBOL, rather than just dipping into it to find out how a particular construct or verb works, then you should read the book in the chapter order provided. Many chapters foreshadow or preview material that is dealt with more completely in succeeding chapters. If you read the chapters out of order, you may find the discussion confusing. However, if you wish, you may skip the first chapter, because it deals with such matters as the history of COBOL, the importance for COBOL, and the characteristics of COBOL and COBOL applications. Even if you do skip Chapter 1, you may find it rewarding to read it later. It should provide a ready source of ammunition with which to respond to any expressions of amazement that you are learning COBOL.