WORKING SHEET METAL

Written and Illustrated by

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BY

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Printed in U.S.A.

LIBRARY OF CONGRESS CATALOG
CARD NUMBER 93-091478

ISBN 1-878087-13-4

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CONTENTS

INTRODUCTION

Working sheet-metal is probably among the oldest of crafts. Even though modern sheet-metal products are produced mostly by machines it was not so originally. Craftsmen laboriously forged metals into sheets and then worked it into useful or ornamental items by hand methods. Gold and silver, being very ductile, were hand forged into leaf form and used to overlay wood, such as in the case of the Ark of the Covenant as described in the Bible. Early cultures produced many utensils, tools and impliments of sheet-metal. And as recently as half a century ago sheet-metal work was an honored trade everywhere in the industrial world. Today many alloys are readily available in sheet form at moderate cost. Countless products are spewed out by modern machinery while the sheet-metal workers craft is all but forgotten. But that does not mean that individuals can't take it up again. And it may come as a surprise to many that much of what is produced commercially can be as well produced by simple hand methods at very substantial savings in cost. Working sheet-metal is challenging and rewarding and it does not require a great outlay of cash to begin.

Ordinarily the items we would like to have made of sheet-metal are not really very complex. But when we ask the local sheet-metal shop operator to cut and form them for us the cost is so high that we usually declare it a luxury we can't afford. It is not so difficult to understand why his price is so high when we learn how much his equipment costs. And even though the present-day sheet-metal worker is little more than a machine operator his wage scale is quite high. So if you want to produce items in sheet metal affordably you will have to do the work yourself. But that does not mean that you must purchase the exotic equipment used in modern commercial shops.

In reality a determined individual can make just about anything of sheet-metal, including a fender or hood for his automobile, with little more than ordinary hand tools. A bold statement to be sure. And I hasten to add that you probably should not begin by trying to make a fender or a hood for an automobile. But the point is that it can be done and it is being done and this means that the more reasonable items are well within your reach. In this manual we'll discuss simple equipment you can build at low cost and the methods you can improvise to accomplish those operations that are done commercially with expensive machinery.

The challenge we face is to lay out the work, cut it from the sheet, form it up and fasten the seams. Only a few manual skills must be acquired and none of them are difficult. But there are tricks to the trade that will speed progress and save you from discouragement. Some will be discussed in these pages and others you will discover yourself as you become intimate with this rewarding craft.

Sheet-metal layout is a fascinating study in plane and solid geometry. Once you understand the few basics it's easy to lay out even very complex work and it requires only a little study to master it.

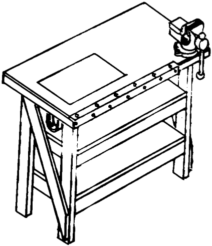
Cutting and forming sheet-metal is hardly more difficult than laying it out so this should be of no concern. It would be nice, of course, to have a power shear or even a foot shear. And as well it would be nice to have a press brake, slip rolls and various forming machines. But every one of these operations can be done with hand-bench tools and the simple devices that will be described a bit later.

Joining the work at the seams might seem to be the most difficult challenge of all. But there are a number of modern fastening systems that are quite cheap and they have a quality, professional appearance. And welding, brazing and soldering are skills easily acquired in the event that your projects must be liquid-tight.

The most important consideration of all will be your safety and the safety of anyone who happens to visit your shop. As in every craft there are dangers in sheet-metal work. And it is not only the obvious hazards of being cut or punctured by the metal or the tools you use. Soldering and welding processes create toxic fumes and so do some cleaning and finishing processes. You may handle substances that are toxic on contact or by accidental ingestion. There is the ever present danger of accidental fire. Eye injuries, cuts and punctures are the most common hazards but nothing should be overlooked. No attempt will be made to point out every hazard or even a majority of them. It is entirely your responsibility to inform and protect yourself and visitors. So fully read and understand the labels and warnings on every product and device in your shop. And provide every protective device for safe operation.

While quality sheet-metal work has an artful appearance this craft does not require anything by way of unusual talent. These are simple procedures, hardly more difficult than turning the pages of this book, and you will soon be turning out useful articles in sheet metal.

The workbench illustrated in the sketch on page 4 is the foundation for our sheet metal shop.



THE SHEET-METAL WORKBENCH

CHAPTER I

SHOP EQUIPMENT

Before you can do any serious work in sheet metal you will need a surface to work on. While some basic operations might be carried out on an ordinary table, or even the floor, a rather specialized workbench will be required for most cutting and forming operations. You can quite easily build a practical workbench that will enable you to carry out most of the operations that are done commercially with expensive machinery.

THE WORKBENCH

The basic requirement is a solid, smooth surface at a convenient working height. Then we embellish it with features that enable us to bend, fold, roll and otherwise shape and form the metal. It can be as large as you can accomodate in your work area. But 24" X 48" is probably the smallest practical size. Because many of the operations require moderate force and considerable pounding the bench structure must be quite hefty and solid. Of course structural steel can be used in place of wood. And a commercially made bench or any other solid bench already on hand can be adapted for use. Consider this as a broad guide and adapt the size and design to accomodate personal needs and what is available.

BENCH LEG OPTIONS

While structural steel or pipe may be the most durable material for the frame it requires some equipment that is not found in most home shops. The more common choice will be wood since it is readily available and easily worked. For the sturdiest frame choose 4" X 4" stock. But 2" X 4" legs would be adequate for light to moderate work. And if the bench is to be exposed to weather or a dirt floor in the shop it would be best to use treated lumber. Shelf rails and top rails can be 2" X 4" lumber. Diagonal braces at ends and cross bracing at back can be 1" X 4" or strap iron. Shelves can be plywood or lumber. And plywood panels might be used on ends and back in place of diagonal bracing. Assembling with 16 or 20 penny nails and glue will make a very sturdy frame. But if you ever intend to disassemble it the better choice will be screws or lag bolts without glue. Take the time to do this work well so that you will have a solid bench. Consider the end frame design illustrated in figure 1.

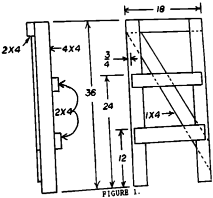


FIGURE 1.

THE WORKBENCH LEGS

Once the legs are assembled it is a simple matter to add front and back rails of 2" X 4" stock at the top, and crossed diagonal 1" X 4" braces at the back. The shelf brackets were set back 3/4" from front and back to allow for 1" X 4" rails to stiffen the plywood shelves. While you might take the trouble to make a half lap joint for the cross braces it will work OK to simply bend the outside board. As mentioned earlier, plywood panels at ends and back will eliminate the need for diagonal bracing. The finished frame will look like figure 2 from the rear side.

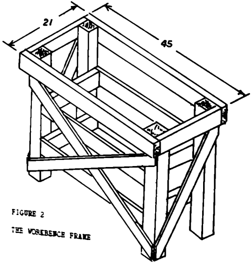


FIGURE 2

THE WORKBENCH FRAME

THE WORKBENCH TOP

A truly wonderful material for the workbench top would be steel plate on a structural steel frame. But most of us will have to settle for something less. Common 2" dimension lumber is 1 1/2" thick and that would serve quite well for most purposes. If you hold to the size in the suggested plan a single 4' X 8' sheet of 5/8" or 3/4" plywood will furnish two shelves and a double thickness top. There should be an overhang where the top meets the frame to accommodate clamping work. The suggested design allows 1 1/2" all around but more than that can prove useful at times. Countersunk flat head screws will serve very well to fasten the top to the frame.

WORKBENCH ACCESSORIES

A hefty vise will be indispensable and you should get the best one you can afford. It will serve to hold small work for cutting and forming and also to hold accessories that you will improvise for specific jobs. It can be mounted to either end of the bench top.

A most desireable piece of equipment in a sheet metal shop would be a brake. In addition to a brake it would be nice to have a slip roll machine and a universal turning machine. Of course spot welders, rivet machines, and roll formers would all enhance the shop. But these are all very costly and it is unlikely that most could justify the expense. The operations that are performed by these wonderful machines are quite simple: Bending, folding, rolling, edging and fastening at the seams. All of this can be quite easily done by hand if you add a "bar clamp" to the bench. And you will be amazed at the range of work you can accomplish at a reasonable rate of speed.

THE BAR CLAMP

The bar clamp is nothing more than a length of structural steel angle with a series of threaded holes that are used to bolt a flat bar or another angle that holds the work. Actually a specialized vise, but a bit more than that. It is mounted to the bench with countersunk flat head screws. With an assortment of bars and specialized clamps it will enable you to form countless shapes in sheet metal, round or rectangular, simple or complex.

Of course the design can be enlarged or reduced. The size suggested here accomodates the 48" long bench with a vise attached at one end. With 36" between the extreme end bolts you can work the full width of a standard sheet of metal. And you will have the distance from floor to clamp and clamp to ceiling for clearance to determine the girth of a duct or any rectangular figure you might want to form. This size capacity should be adequate for work normally encountered in a home shop or small custom shop.

The foundation of the clamp is a length of structtural angle iron that is drilled and tapped at intervals so that clamping members can be bolted to it to hold the work. It is mounted on the edge of the workbench with flat head screws. It can be as long or as short as you wish. But keep in mind that long clamps used to work heavy metal must be of greater weight. My experiments indicate that a 1 1/2" X 1 1/2" X 1/4" angle iron is practical for a clamp to work 36" wide soft steel sheet metal of 20 gauge thickness or less. If you anticipate working 20 gauge or heavier in 36" length to a sharp bend, such as for auto body work, you should consider using say a 3" X 2" X 3/8" angle iron. The wider flange is mounted to the bench for better leverage, and the greater mass absorbs the hammer blows as you work the metal. The lighter clamp will work heavier metal in shorter lengths and that is why the series of clamp bolt holes are provided.

Begin by carefully marking out all holes and center punching them. Note that the hole patterns differ on each flange so that the mounting screws will not interfere with the clamping bolts. Be very accurate in laying out the clamping bolt holes on center and equally spaced so that the clamping members can be inverted or reversed. If you are working with a drill press drill 1/4" pilot holes at every center. Then fasten the clamping angle iron to the base angle with vise-grip or C-clamp and drill through the base angle to ensure that the clamping angle will mate. Now enlarge the clamp bolt holes in the base angle to 3/8" and tap them 7/16"-14. Enlarge the holes in the clamping angle to 15/32". And countersink the 1/4" holes in the mounting flange to accomodate #14 flat head sheet metal screws. Sheet metal screws look very much like wood screws. But they have threads right up to the head and they are of stronger steel than wood screws. The base angle is mounted to the edge of the bench with the flat head screws. And 3/8" clearance holes are drilled through the clamp bolt holes into the edge of the bench. Finally the tap is run through the clamp bolt holes into the bench edge so that a 7/16"-14 X 1" cap screw can be screwed in to its head.

If you are working with an electric hand drill it will be easier to drill 1/8" or 3/16" pilot holes at all centers and then increase to final size by steps. This will ensure that holes remain on the intended centers and it will save labor.

The details of the suggested bar clamp are shown in figure 3.

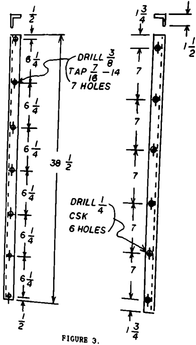


FIGURE 3.

THE BASE ANGLE IRON

While the base flange might be mortised into the bench top it will be easier to add an auxilliary top of 1/4" tempered hard board. But wait to see if you will elect to add other bench accessories before you do that.

In use the sheet metal is clamped at the bend line and a succession of hammer blows brings the bend progressively sharper. If a wide expanse of metal is above the clamp hand pressure starts and aids the bend. While any hammer will do the work a metal hammer will surely mar the sheet metal. So it is better to use a wooden mallet or a soft-faced hammer. They are available with changeable plastic or rubber-like faces. The bend is worked from end to end, back and forth, gradually to avoid distortion. While this is not as fast and efficient as a leaf-brake or a press-brake the end result is the same. The final bend can range from a fairly large radius to a sharp crease, depending upon how hard the final hammer blows. With just a little practice you can produce work that appears to have been done by machine.

The bar-clamp has the greatest strength and capacity when the clamp-bar is arranged with the flange up as in figure 4. But you will find that the bend will not lie flat due to rebound so it will be less than 90 degrees. When the clamp-bar is inverted as in figure 5 you can easily bring the bend to a full 90 degrees or greater but the clamp is not as strong. When working heavy metal in full width you may have to bring the bend to the desired sharpness with the flange up and then invert the clamp-bar to bring it to the desired angle.

An assortment of clamp-bars of various widths and shapes will expand the range of the bar-clamp. It will serve for most forming operations.

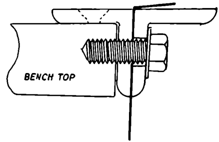


FIGURE 4

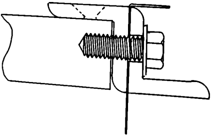


FIGURE 5

A row of holes in the clamp bar that match the tapped holes in the base bar will make it more or less universal as to width of work. But extra holes will slightly weaken the bar so you may want to have a full length bar without extra holes for heavy work.

The greatest strength will be between the close spaced holes so the bar-clamp can work heavier metal in narrow widths. You may find it convenient to have some short clamp bars to avoid handling the long bar for short work.

While the flange on the angle iron clamp-bar adds to its strength there may be instances when it gets in the way. You may find it useful to have a clamp bar of flat stock from 1/4" to 1/2" thickness. If one edge of the flat bar is ground to a bevel as in figure 6 it will enable you to make sharp bends to start a hem or a wire edge.

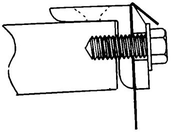


FIGURE 6

The bar-clamp has a broad range of capabilities. And you are not limited to rectangular work. Since rolling operations are really a series of axial bends you can easily form cylinders. To enable you to form cylinders of smaller diameter you may want to make one or more clamp-bars of round stock or pipe as in figure 7.

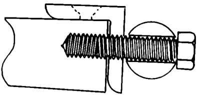


FIGURE 7

THE BENCH BAR

Now you are well equipped to form a broad range of rectangular or cylindrical work within the size capacity of your bar clamp. But there are limitations and some additional equipment will expand your capabilities. The bench bar is really in the nature of a long anvil. It can be used to close seams, set rivets and form odd shapes.

By far the most desireable material for a bench bar would be a length of railroad rail. Find one at the local salvage yard if you can. But you might have to settle for a length of steel bar-stock of say 2" or 3" diameter and perhaps 48" long. In any case it will be quite heavy and it must be supported at both ends. A befty metal sling on the bench can support one end and a portable stand for the other. A common use for the bench bar will be to close a seam on cylindrical work, after which it is easy to raise the bar off the stand to remove the work. The bar can be stored on one of the bench shelves when not in use.

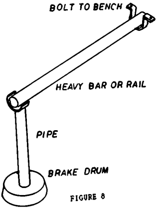


FIGURE 8

THE BENCH BAR

THE BENCH PLATE

An additional improvement to the bench will be to add a plate of steel 1/4" thick, or as thick as the bar-clamp, and 12" or so square. This will be a great aid to turning a flange on circular work or any other work that requires pounding on the bench surface.

At this point the bench is essentially complete. And as a final touch you can fit a sheet of 1/4" tempered hardboard with cut-outs for the bar-clamp and the bench plate. Fasten this auxilliary bench top in place with only a few countersunk flat head screws and it will be easy to replace if it becomes worn or damaged in use.

BENCH TOOLS

Nearly everything used in the shop might be termed a bench tool. But in this category we are speaking of those accessories to the bench that will be used to cut and form sheet metal. These include specialized dollies and stakes that will "evolve" as you tackle various projects. To begin with a 2" length of 3" or 4" round steel bar-stock will find much use in turning up flanges on round work. An old "sad-iron" like grandma used to iron grandpa's shirts makes a useful dolly. A small bench anvil of from 5 to 15 pounds is very handy. And an assortment of rings made of various sizes of pipe about 2" long will be helpful for forming semi-spherical work and other jobs. In short, nearly any bit of hefty scrap iron might become a useful tool at the bench. And it won't be long before you have an assortment stored on the shelves beneath the bench. In addition to being useful in many operations the weight will help to keep the bench from moving about as you work.

CHAPTER II

BASIC OPERATIONS

The objective in sheet-metal work is to begin with a raw sheet of metal and to cut, form and join it into a useful product. This is presuming that you have a plan or pattern to follow. Layout and pattern development will be covered in detail a bit later. But for now we are concerned with how to do those basic things to the metal that will produce the desired result.

CUTTING SHEET METAL

Once you begin working sheet metal it will not be long before you cut or puncture your hide. Edges are sharp even when cleanly and squarely cut. But the danger is far greater if the cutting is done carelessly. It will both reduce hazards and improve the appearance of your work if you take the trouble to learn how to do it right.

Shears and snips are the common hand-tools used to cut sheet metal. In general shears have longer cutting blades than snips. But today the terms are used as though they are interchangeable. The difference is not really important but how you use them is.

There are a number of designs available and you will surely end up with more than one type in your tool kit. Beware of cheap imports that may discourage you altogether, for they will not cut cleanly if at all. To begin with you might want a medium straight pattern shears with 3" or 3 1/2" cut. These cut straight or curved up to about 24 gauge. A set of compound aviation pattern snips includes one to cut right, another to cut left and a third to cut straight. They will cut up to 18 gauge.

All of these tools are arranged so that hand pressure tends to close crossing blades to shear the metal. The capacity of the tool is determined by the ratio of length between the handle portion and the blade portion. Long handles with short blades can cut heavier metal than short handles with long blades. Compound action snips have an additional pivot arrangement to multiply the leverage so that heavy metal can be cut with compact snips.

In general you will find that as you view the snips while cutting the blade on the right will be forced downwards while the blade on the left tends to move upwards. When properly done the metal to the right remains straight and the metal on the left must be curled or rolled upwards in order to keep advancing the cut. The best plan is to address the work so that the waste, if any, will be to your left.

With straight pattern snips you will find that it is quite easy to make a curved cut to the left but it will be difficult if not impossible to turn to the right. Aviation pattern snips are specially made to overcome that problem. Those with red handles are arranged like straight snips and they cut to the left. Those with green handles are made in the opposite configuration and they cut to the right. The yellow handled ones cut straight or curved to the left. If you happen to be left handed it is likely that a pair of green pattern snips will become your favorite hand tool. Pattern snips are especially valuable when you must cut an opening in an expanse of metal, such as for the filler neck of a tank.

The secret to cutting cleanly is to avoid closing the blades completely until you come to the end of the cut and to make sure that the blades remain in the original cut as you take each successive bite. If the blades close completely the metal will be distorted and require dressing later. And if you do not carefully guide the blades in the original cut there will be a tiny sharp burr each time you advance the snips. Aviation pattern snips have serrated blades and they leave a rather jagged edge even when carefully used, but the same rules apply. You can dress a cut with a file and tap it flat using a hammer on the bench plate.

There is a limit to the weight of metal that can be cut with ordinary hand snips and shears. One way to cut heavier metal is to hold it in the bar-clamp with the cutting line just barely exposed and shear it off with a hammer and cold chisel. The cut off metal will surely curl as you cut, just as it would with hand-shears or snips. But if you work carefully it will not be stretched or distorted. The edge will certainly have to be dressed if you cut with a chisel.

While you can chisel a straight cut in the bar-clamp that will not serve for circular work in heavy metal. But a variable speed electric jig-saw with a bi-metal blade will cut on any curved line. Even 14 or 12 gauge metal can be easily cut in this manner. The cut will be a bit jagged but it is easily dressed.

There are both hand and powered nibblers that will cut very heavy metal. And both electric and air operated shears are available. All very nice tools to have if you can afford them. But the above mentioned methods will enable you to handle just about any job that is likely to come up in the usual home shop.

FORMING SHEET METAL

Whether bending right angles for a rectangular object or forming a curve for a cylindrical object the procedure is simple and straightforward. The amount of pressure and force is a matter of acquired judgement and it is not a difficult skill to learn. These are simple shapes but it is likely that some of the work you do will involve a compound shape and that requires a bit more skill.

A compound shape will be curved on more than one axis and nowhere on it can you find a flat surface. A cube, cylinder or cone is a simple shape while a ball, egg or bowl is a compound shape.

Sometimes commercially made articles have compound shape merely because it is cheaper and easier to make them that way. The design considerations may differ greatly if you must produce thousands by die-forming or just one or a few by hand methods. For example a gas tank might be made by ribbon welding two die-stampings together, which would be extremely difficult to do by hand methods. And the stampings may have intricate patterns of ribs that are embossed to stiffen the light metal, which is also difficult to do. But we can re-design it as a cylindrical or rectangular shape and make it of heavier metal that does not have to be embossed to stiffen it. A bit of study before-hand can make a job easier. But sometimes an item will simply have to be made in compound shape and there are simple ways to do it.

The two common processes are termed "sinking" and "raising". As you must have guessed, one refers to sinking the metal below a plane surface while the other refers to raising it above the plane surface. This may sound intimidating and you may think that this is something that could be done only by an artisan who has served a long apprenticeship. But they are simple processes that anyone can learn to do.

Lacking a battery of presses and a crew of die-makers, producing compound shapes is essentially hammer work. Ordinary ball-pein hammers can do much of the work. But sometimes a specialized hammer will be neccessary. The type of hammers used by auto-body repairmen are ideal. These are made to reach deep areas and the striking faces are specially shaped and finished. And the various shaped dollies used by bodymen can be useful too. You also need something in the nature of a form to aid in shaping the metal. The type of form will be determined by whether you decide to sink or raise the contour. Since sinking seems to be the easier process to learn we'll begin with that.

SINKING SHEET METAL

What is required for sinking is a solidly supported depression into which the metal is forced by the hammer blows. The short rings made of various sizes of pipe mentioned earlier can be useful for some compound work but deep work requires something more. While special forms can be cast in metal or produced in a machine shop these processes are not usually available in the home shop. A sinking block made of a length of hardwood log is simple, affordable and very effective. An example is illustrated in figure 9.

The log is about 12" to 14" in diameter and of a convenient height, determined by whether you work standing or sitting. The various sized depressions are bowl shaped. They do not have to be perfectly hemispherical and it is not difficult to cut them with chisel and gouges.

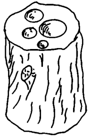


FIGURE 9

THE SINKING BLOCK

One end of the log might have depressions of say 6", 4", 3" and 2" diameter. The other end might have a single depressoin of 8" or 10" diameter. The depth can be about 40% of the diameter so the 10" would be 4" deep, the 8" about 3 1/4", the 6" about 2 1/2", the 4" about 1 1/2", the 3" about 1 1/4" and the 2" about 3/4" deep. These will cover most work likely to be encountered and it will not be difficult or costly to prepare a special block in any reasonable size.

A good exercise to learn to use the sinking block will be to form a bowl shape. Certainly you can get a bowl for your cornflakes without labor and at little cost. This is not about making a bowl, which might seem an aimless pursuit to some. But it is about forming a bowl shape, which might become the domed end of a tank or some other useful article. This simple skill is worth learning and it will cost but little to try it.

Some metals are more ductile than others and the easiest metal to work is gold. Copper is easy too and more readily available than gold. Brass is good too. And steel can also be worked quite easily. But aluminum is probably the better choice for the beginner for obvious reasons. So lets begin with a disc of aluminum sheet of .050" thickness or heavier.

A simple way to determine the size of the disc of metal is to construct a right angle triangle with the base equal to the radius of the desired bowl shape and the vertical leg equal to the finished depth. The hypotenuse of that triangle will be approximately the correct radius for the disc. If a flange or wire edge is intended we add to this base dimension. More about addendums later.

Pounding on metal tends to harden and embrittle it, which is termed "work-hardening" If you continue to work the metal without annealing it may split or crack. Copper is annealed by heating it to a dull red and quenching quickly in water. Brass is heated to a brighter red and allowed to cool naturally in still air. Steel is annealed by heating to a bright red and cooling is retarded by packing in ashes or other non flammable insulating medium such as rock wool or fiberglass. Aluminum usually will not have to be annealed unless worked quite deep. If it does become work hardened it should be heated but not above 700 degrees F. and cooled naturally in still air.

Temperature indicating crayons and other items of interest such as hammers and bench stakes are available from Centaur Forge, Ltd., PO Box 340-G, Burlington, WI 53105. Catalog fee is $5.00.

Now to begin forming the bowl shape select a depression in the block of about half the diameter of the disc and proceed to strike a series of closely spaced blows from 1/4" to 1/2" from the outside edge as you rotate the disc one full turn as illustrated in figure 10.

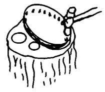


FIGURE 10

Proceed to work in the same manner in a series of circles towards the center as in figure 11. You might mark a radial line with crayon or chalk to ensure that you work systematicaly and uniformly. For a right-handed person the rotation will be counter-clockwise. Complete each circle of hammer blows before you move closer to the center. And work out any wrinkles that develop as you go. It is not widely known that metals can be cold forged. But you are actually forcing the metal to "flow" from one area to another. Some portions will be thicker than they were originally and some will be thinner.

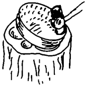


FIGURE 11

your hammers usually weigh a pound or less and the amount of force used is not great. More of a wrist and forearm action with about one blow per second a reasonable rate of speed. Naturally a robust swing of the hammer takes longer than a light tap so the frequency of blows is some measure of their intensity. When done in a natural, relaxed and rythmic manner two blows per second would be with less force than one blow per second. And of course a series of blows that each required 2 seconds would be quite violent. Again this is a matter of acquired judgement. You will soon learn the effect of hammer blows of varying intensity. And you will soon learn that magical "twist of the wrist" that will pursuade the metal to "flow" where you want it to go in order to "iron out" a wrinkle. At times you will move the work out of the depression to hold it on a flat area to be used rather as an anvil to either thin or thicken an area. You should be prepared to waste several discs of metal as you practice and learn what this craft has to teach you. Certainly a skill to be proud of and not unduly difficult.

You will vary the working angle as you progress as in figure 12. And when you have worked the series of circles right to the center you begin again near the outside edge. Repeat as many times as neccessary to reach the desired contour. Depending upon the contour of the shape, you might want to change to a different hammer as you progress.

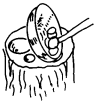


FIGURE 12

While you can achieve a moderately good finish by sinking it will require additional work with a dolly or a bench stake to get a really smooth surface that matches very nearly a die-formed piece. The process is called "planishing" and it requires a hammer with a very smooth surface called a "planishing hammer" or a "finishing hammer". Any small speck of dirt, or even a hair, on the face of the hammer or on the work will result in a mark that will effect the quality of the finish. The hammer face is kept clean and smooth by rubbing over emery cloth. And both the work and the hammer are frequently wiped clean. The palm of the hand is better for wiping than a cloth, for even a stray fiber can spoil a fine finish. The piece is worked over a dome-faced stake as illustrated in figure 13. A series of blows struck while the work rests squarely on the stake will work out minor high and low areas. And you will learn to force the metal to "flow" with that magical twist of the wrist that can be learned by any determined mechanic, but can't be taught by even the greatest master.

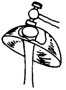


FIGURE 13

Planishing with a stake or dolly is usually worked from the center towards the edge. If you must limit expenditures you can make your own bench stakes to be held in the vise. The job at hand will dictate the size and shape. Hammers can also be made and modified.

Remember that at the outset the objective is to learn the effect of various styles of hammer blows and positioning of the work on the block. And not only the effect on the work but also the effect on your muscles and joints. Properly developed technique will not be painful or tedious.

RAISING

Raising is the opposite of sinking since we are raising the contour above the plane surface rather than sinking it below. It is also begun and ended oppositely. Raising is done with a dolly or a bench stake with a domed shape as illustrated in figure 13. The series of circles of hammer blows are begun in the center as is planishing or finishing as described previously. The object is to apply enough force to cause the metal to flow towards the center while raising the contour. It seems to be a rather more difficult skill to master than sinking. But some people seem to be especially gifted so you should try it just to find out if you happen to be one of those.

Now we have essentially covered the basic hand-methods for cutting and forming sheet metal. What remains to be learned will be best gained by experience. It is when you actually begin to apply tools and processes to the metal that you really begin to learn and to develop skills. Keep in mind that machine processes have evolved from hand processes so what you want to do is almost surely possible. Subsequent discussion will cover various methods of joining sheet metal and that will involve some forming techniques as well. And we will soon get into the fascinating topic of pattern development and layout.

CHAPTER III

JOINING AND EDGING

In this chapter we'll discuss the basic hand-process methods of joining and edging sheet metal. While the more exotic systems may not be readily available to you it is entirely practical to use these simple methods or combinations of them to accomplish nearly any reasonable end. The most important thing to know about seams and edging is the amount of extra material to allow so that the finished article will be exactly the right size. The rest of the work will be quite simple.

LAP SEAMS

The simplest of all methods to join metal is the single lap seam. This is where you simply allow a portion of metal at the finish to lap over the start. Or two fabricated pieces, such as piping or rectangular ducts will overlap rather telescope-fashion. The resulting seam might be fastened with screws or rivets and it might be made liquid-tight or air-tight by soldering, brazing or caulking. Refer to figure 14.

The correct allowance for the single lap seam will be the width of the seam. The seam will usually be fastened on the center line of the lap. So in the case of a flat lap or pipe lap one half the width of the seam will be added to each member to be lapped. Fastener holes are on the addendum line. The corner lap will also be fastened on the center line of the lap. But the entire widh of the corner lap seam will be added to one member. A variation of the corner lap is to bend a lap on both members, which will greatly stiffen the corner and it will be much easier to drill for fasteners.

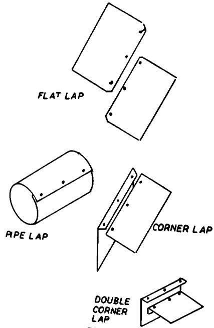


FIGURE 14

LAP SEAMS

POCKET AND SLIP SEAMS

A nagging problem with sheet metal fabrication is that the thin metal tends to "buckle" or become wavey at the seams. The problem intensifies if the seam is heated, such as for soldering or brazing. One way to deal with that is to form a pocket on one member so that the other member can be slipped into it, which will stiffen the seam. See figure 15 below.

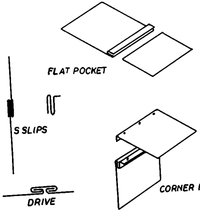


FIGURE 15

POCKET SEAMS AND SLIPS

Whether a flat or corner seam, the pocket can be formed as an integral part of the work. In that case the addendum will be twice the width of the seam for that member with the pocket and one width of the seam for the other member. The allowance for the corner pocket seam is the same unless you add a flange for fastening or stiffening.

The same type of seam can be formed separately, in which case it is called an "S-slip". Then it is used as an accessory to join two members.

The most common use of S-slips is in joining duct-work for heating, ventilating and air-conditioning work. The S-slips are used on the broadest sides of the duct and cleats of half the width of the lap are bent on the shortest sides of the duct. The joint is finished by a "drive-slip", which is driven over the cleats and bent over at each end.

A variation of the corner pocket seam is the common Pittsburg seam. See figure 16. The flange of the second member is slipped into the pocket and the seam is then hammered over to capture the flange so that no other fastening is required. It is usually shaped with a roll forming machine but it can be formed by hand on a conventional leaf-brake. It is difficult to form a pittsburg seam with the bar-clamp but simple pocket seams and slips can be easily formed.

FIGURE 16

PITTSBURG SEAM

LOCK SEAMS

The common seam for cylindrical work, such as a pipe or a tank, is the "grooved" lock seam as illustrated in figure 17.

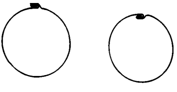


FIGURE 17

GROOVED LOCK SEAM

This is really a variation of the pocket seam. A total allowance of three times the seam width is allowed. It is first formed by bending over opposing flanges of the width of the seam at each end of the work. Then the flanges are nearly closed to form a hook by knocking them down over a piece of scrap about twice the thickness of the work as shown in figure 18. The work is then rolled up and the flanges are hooked together. Finally the seam is finished with a hand grooving tool or over a square edged bench bar or mandrel, depending upon whether the rib is to stand outside or inside the pipe. Hand groovers and other special equipment are made for this work. But you can fashion your own hand groover and accomplish the work as illustrated in figure 18.

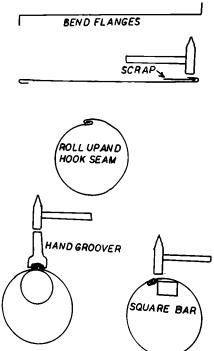


FIGURE 18

THE GROOVED SEAM

Hand groovers are made in a variety of sizes. For the usual range of work that would be encountered in a small shop a 1/4" tool would be adequate. It can be made by laminating mild steel stock if you don't anticipate heavy usage. And of course you can cut a groove in a block of steel with file or cold-chisel. Such a tool will endure for a considerable time but it will eventually deteriorate so you may want to make it of tool steel or purchase a commercially made tool if it is to recieve frequent use. Figure 19 details a home-made hand-groover that you can assemble with ordinary tools.

The width of the groove will be determined by the thickness of the center "T" shaped section of the "sandwich". So a 1/4" groover should have the center lamination 1/4" thick and the outside laminations should be about the same thickness. Note that the outside laminations are 1/8" wider so that there will be a 1/8" deep groove. The grooved portion should be from 2" to 2 1/2" long and the shank from 3" to 3 1/2" long. The shank is about 3/4" wide. And it will be a more rigid tool if you rivet a bar on each side of the shank. Assembly is best done by cold-set rivets of about 1/4" diameter. Clamp all three members together and drill through to assure alignment.

If you want to make a 1/4" wide seam you will bend a 3/16" hook on each member and set the seam with the 1/4" wide groover. This allows for the thickness of the metal and the bend radius. In this instance you would allow a total of 9/16" for the seam, which is three times the width of the hook. When joining a cylinder it is customary to add 1 1/2 times the hook width to each end of the work. When joining two members it is customary to add twice the hook width to one member and one hook width to the other member.

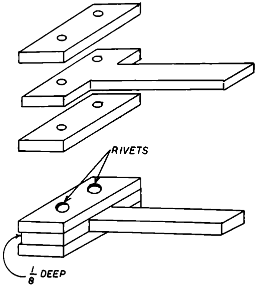


FIGURE 19

HOME-MADE HAND-GROOVER

A HAND FOLDER

This is a very simple home-made tool that can prove useful for repetitive folding operations on light gauge metal. Although it can function up to 18" width it is usually not made any wider than 12".

Laminated like the hand groover, but of lighter metal. The thickness and width of the center core determines the gauge of metal that will enter the groove and the width of the fold. Useful sizes would give folds of 3/16", 1/4", 3/8" and 1/2". So two folders would be adequate for most purposes and you could make up any other size that seemed convenient to your purpose.

Use them to fold hooks for lock seams, hems or starts for wire edging, drive slips for duct work or any simple folding operation.

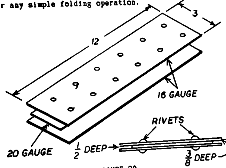


FIGURE 20

HAND FOLDER

TAB SEAMS

When it is necessary to join sheet metal and appearance is less important you can cut a series of slits at the joint to form tabs. Thus a strong and functional flat seam or pipe seam can be made as in figure 21. And the end of a cylinder can be closed or the cylinder joined to another member. Such a seam can be fastened with screws or rivets. And it can be made liquid tight by soldering, brazing or caulking.

The secret to making a presentable tab seam is to make it no wider than neccessary and to make the slits of uniform depth and width. Common practice is to make the slits 3/4" to 1" deep and to chop them randomly along the edge of the work. The result is not something you would want to sign your name to. 3/8" width is adequate for most work and such a narrow seam is more easily soldered or brazed. It can look quite sound and professional if carefully done. And in fact it can be made invisible by a neat caulking job.

To make the tab pipe seam as illustrated in figure 21 a line is scribed along the addendum, which is the width of the seam. And a series of uniformly spaced slits is cut along the marked edge to the depth of the line. Alternate tabs are bent slightly up and down so that the opposite member will enter. The pipe is rolled to a diameter a bit smaller than its finished size and the seam is joined and fastened.

To close the end of a cylinder slits are cut to a uniform depth and alternate tabs are bent inward to form a ledge for a disc of sheet metal. The disc is rested on the tabs and the remaining tabs are knocked over to close the seam. A simple and effective method for some classes of work.

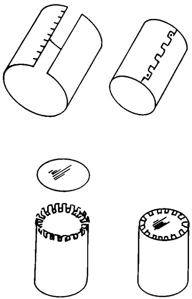


FIGURE 21

TAB SEAMS

DOUBLE LOCK SEAM

Sometimes called a bucket seam or canister seam, the double lock seam is the impossible looking joint at the bottom of a bucket. Seldom used now because modern machine sytems are faster and cheaper. But if your interest lies in reproducing old style copper and tin ware it will be of interest. And further it is a good exercise in turning a lip or flange.

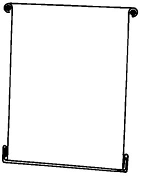


FIGURE 22

DOUBLE LOCK SEAM

An example of the double lock seam is seen in figure 22. Notice also the wired edge at the top of the sectional sketch. Both processes require turning lips or flanges and the work is well within the realm of hand crafting.

LIPS AND FLANGES

To raise a lip or flange along the straight edge of a sheet of metal is simply a matter of clamping it at the desired bend line and knocking it over with a hammer or mallet. But when it is to be done on a circular or otherwise curved figure the work becomes more interesting. So also turning a lip or flange on a cylinder. In the absence of bench mounted turning machines we resort to some simple devices together with the bench plate, the bench bar and such dollies and other "bucking" tools as must be devised for the job.

While you may lament the absence of turning, edging and "burring" machines in your shop it may be of some consolation to you that more skill is required to operate those devices than for the hand processes. In fact one or more semi-finished pieces are often wasted before a bench machine is properly adjusted. So when the job calls for only one or a very few like items even a skilled man may elect to turn lips and flanges by hand methods rather than to risk wasting his spent labor on the often temperamental "Jennies" designed for production work.

The first step is to start the bend uniformly along the line. While ordinary pliers can do the work it is quite tedious to guide the pliers along the bend line. So you should prepare a starting tool by cutting a slot in the end of a handy length of 3/8" square key stock with a hacksaw. See figure 23 for details.

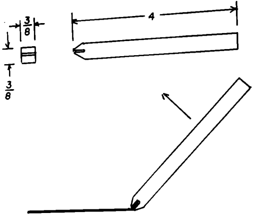


FIGURE 23

FLANGE STARTING TOOL

The depth of the slot in the flange tool will determine the width of the flange. 1/4" is handy for moderate sized jobs. You can prepare a number of double ended flange tools with different depth slots on each end for other sizes.

The flange is raised gradually by a progressive series of partial bends and it does not take long to bring it to 45 degrees or so. Thus a sharp crease is made along the flange line. And the flange is raised enough so that you can attack it with hammer and dolly. The work will be distorted at this point because of stresses. But only a bit of hammer and dolly work will relieve the stress so it will again lay flat.

If you are raising a flange on a disc, as you would for the bottom of a bucket, the outside edge will have to be shrunk. So you lay the work on the bench plate and use a hefty dolly to "buck up" at the bend line and attack the flange with the hammer. A hammer with a square face will slide along the bench plate nicely. That would be a tinners hammer or an auto-body hammer. As you work progressively around the disc the hammer blows will force the excess metal at the edge to "flow" together and thus shrink the outside edge. If improperly done it is possible to thin the metal at the edge. So you must observe the effect of your hammer blows and modify for proper effect. This is not a difficult skill to acquire.

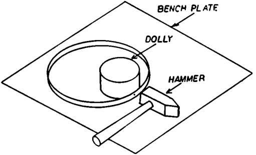


FIGURE 24

RAISING A FLANGE ON A DISC

If you are raising a flange on a cylinder the outside edge will have to be stretched. The work can begin with the flange starting tool, just as with the disc. But the hammer work is begun on the mandrel and finished on the bench plate as in figure 25.

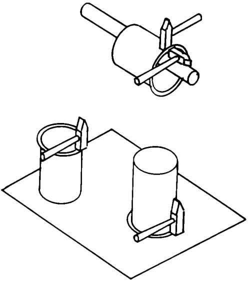


FIGURE 25

RAISING A FLANGE ON A CYLINDER

Once the flange is started uniformly and turned to about a 45 degree angle it can be placed on the mandrel and gradually turned by hammer blows to the end. It will also be neccessary to strike the cylinder directly behind the flange. And it may be neccessary to "buck up" behind the flange with a second hammer or a dolly. You can also set the cylinder on end on the bench plate and knock the flange down with hammer blows. And you can lay the flange end of the cylinder on the bench plate and true it up flat with hammer blows as shown in figure 25.

When you have turned a flange on the disc and cylinder you have both elements of the double lock seam as illustrated in figure 26.

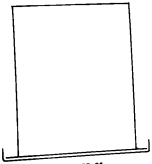


FIGURE 26

ELEMENTS OF DOUBLE LOCK SEAM

Then it is a simple process to begin to knock the flange of the disc down on the flange of the cylinder as in figure 27-A. This work can be done on the bench plate, anvil or an improvised stake clamped in the vise. Continue to close the seam as in figure 27-B until it is flat all the way around. Next the work is inverted over a stake or the end of the mandrel and worked with the hammer as in figure 27-C. It is progressively worked down until the seam is finished as in figure 27-D.

Naturally the metal does not simply yield to the hammer and lay just as you would like automatically. But it requires only moderate practice to develop this basic skill of the tinsmith. It is worthwhile to fabricate two or three cups or canisters to learn how the metal reacts to these simple operations.

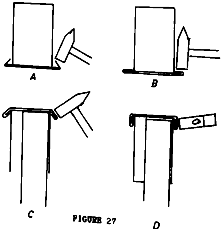


FIGURE 27

WIRE EDGING

The natural companion to the double lock seam on a cylindrical vessel is a wired edge. And it is a relatively simple matter to form a pocket and close it over a wire to stiffen the edge of the work and eliminate the cutting hazzard.

The allowance for a wired edge should be 2 1/2 times the diameter of the wire. So if you would use a 1/8" wire the allowance is 5/16".

While the preliminary forming of the pocket can be done before rolling a straight sided cylinder it is not that simple with a tapered or flared vessel. And when the wire is installed before rolling up the cylinder will be deformed at the wired edge until some hammer work is done. So the better plan is to first form the cylinder and then turn a flange just as you do for the double lock seam.

Again you could use pliers to begin turning the flange but the work will be easier and neater if you use a flange starting tool with a slot of the proper depth. It is usual to form the flange for the bottom seam and the wired edge before putting the bottom on a cylindrical vessel.

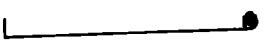


FIGURE 28

WIRED EDGE

Once the flange is begun, forming the pocket for the wired edge is the same hammer process as for the double lock seam. And the pocket is closed over the wire just as you closed up the double lock seam.

OTHER EDGE TREATMENTS

The purpose of edge treatment is to eliminate the cutting hazards inherent in sheet metal, to make the edge stiffer and stronger and to enhance the appearance of the finished article.

A simple hem is certainly the easiest and quickest way to accomplish all three objectives. Folding a narrow band of the edge back on itself will often do the trick. A second fold to form a double hem is appropriate when extra strength and stiffness is required. And it is relatively simple to fold a band of strap iron or heavy sheet metal into a single or double hem.

It is usually a simple matter to form an edge when fabricating a straight rectangular or cylindrical figure. But problems arise when the shape is conical or pyramidal. Then you might consider folding up an edge treatment separately to be added to the finished article as in figure 29.

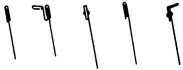


FIGURE 29

ALTERNATIVE EDGE TREATMENTS

CHAPTER IV

PATTERN & LAYOUT

With some basic equipment and the understanding of the processes outlined so far it is possible to produce an amazing range of products. If you had a pattern for a given article it would be easy to scribe around it with an awl and cut to the line. Then sheet-metal work becomes almost child's play as you fold or roll it into shape and fasten it at the corners or joints. Hardly more difficult than some of the projects we did with construction paper in elementary school.

No one really needs instruction in laying out a flat object, whether rectangular or circular. You simply scribe it directly onto the sheet-metal using divider, trammel or straight-edge and awl. And sometimes articles are assembled of an assortment of flat parts so that little study or discussion is required before proceeding.

But forming and fastening joints is a major time and labor factor so there is advantage to laying out a series of geometric shapes adjacent on the sheet so that the figure can be cut out, folded up and fastened at perhaps a single joint. There are actually but few rules and little mathematics involved so that no one should feel intimidated. If you can read a steel rule, do simple math like addition, subraction, multiplication and division and manipulate the dividers or trammel it will be no problem for you to do sheet-metal layout work.

Factors to consider such as the thickness of the metal and the radius of the bend can hardly be stated as hard and fast rules. And quite often they can be ignored. Experimental bends using scrap material will quickly and easily establish neccessary allowances when they are a factor. So we won't try at all to give a numerical value.

The seam allowance is usually expressed as a nominal amount. But in very demanding work it will be the sum of considerations including bend radius and metal thickness. Again there is little point in a theoretical discussion since the actual allowance must be learned from making experimental bends on the metal using equipment at hand.

If you will submit to some brief and easy exercises using thin cardboard or even stiff paper you can quickly grasp all of the principles involved in sheet-metal layout work.

RULES AND FORMULAS

While there are countless rules and formulas in the mathematical science we are concerned with only a few in practical sheet-metal work. You will sometimes be concerned with cross-sectional area and at other times with volume. As, for example; how many pints, quarts or gallons might be contained in a vessel? These are simple processes that will quickly be memorized if used to any great extent.

CROSS SECTIONAL AREA

Cross sectional area of a rectangle is found by multiplying the width by the depth. For example a duct measuring 10" wide by 6" deep has a cross sectional area of 60 square inches.

The same rule applies to a square duct. for example a duct measuring 6" on all four dimensions has a cross sectional area of 36 square inches.

The cross sectional area of a right triangle is found by multiplying the base by the vertical leg and dividing the product by 2. For example a right triangle with 10" base and 6" vertical leg has an area of 30 square inches.

Irregular straight sided shapes, such as trapezoids, are calculated by dividing up into rectangles and right triangles and finding the sum of the areas.

The area of a circle is found by multiplying the diameter by itself and multiplying the product by .7854. For example a 10" circle has an area of 78.54 square inches.

VOLUME

The volume of a rectangular or square figure is found by multiplying the width, by depth by length. So a tank measuring 10" wide by 6" deep by 12" long holds a volume of 720 Cubic inches.

A tank measuring 12" on all sides is a true cube and its volume is 1728 cubic inches or one cubic foot.

The volume of a cylindrical tank is found by multiplying its cross sectional area by its length. So a tank measuring 10" diameter by 10" long has a volume of 785.4 cubic inches.

The volume of a vessel becomes significant when you want to know how many units of a substance it will hold. For example one U.S. gallon is held in 231 cubic inches. So the above 10" diameter tank would hold 3.4 gallons or a practical 3 gallons when allowance is made for expansion and a vapor condensation area.

One cubic foot holds 7.48 U.S. gallons. One gallon of water at 62 degrees F. weighs 8.336 pounds. So a cubic foot of water weighs 62.35 pounds. Other fluids, such as fuels can weigh slightly less or more, depending upon temperature.

PERIMETER

This is the distance surrounding an area. In a square or rectangular figure it will be the sum of all sides. So a 10" square will have a perimeter of 40".

The perimeter of a circle is its circumfrence, which is found by multiplying the diameter by the factor 3.1416. So the circumfrence of a 10" circle will be 31.42"

The perimeter becomes significant when you want to determine the length of sheet required for a given shape. For example a 10" cylinder would require a length of 31.42" plus any seam allowance.

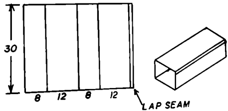
TRIANGLES AND CONES

While the problems of any triangle can be solved by the rules of trignometry and trig tables we will consider here only the law of right triangles. Such a triangle has a base and a vertical leg and the angle between base and leg is exactly 90 degrees. The side opposite the 90 degree angle is called the hypotenuse. The square of a number is the product of that number multiplied by itself. In a right triangle the square of the hypotenuse is equal to the sum of the squares of the other two sides. So if you must calculate the hypotenuse of a right triangle you simply square the dimensions of the base and vertical leg, add them and extract the square root of the sum to know the dimension of the hypotenuse. We won't go into the process for extracting the square root in these pages because you will almost certainly resort to a pocket calculator. And, besides, at the moment I forget myself how to do it.....

These few rules and formulas demonstrate how simple and straightforward the layout-man's craft is. And there is little point in devising tedious exercises to fix them in mind since only those that find frequent use will be remembered anyway. Whatever your specific needs will be, it will be no trouble to find it in published tables or through rudimentary math operations.

RECTANGULAR LAYOUT

It is neccessary to produce a duct with an area of 96 square inches and it can be no deeper than 8 inches. Using the above mentioned rules it is easily determined that a width of 12" and a depth of 8" gives 96 square inches. Available metal is in 30" X 96" size so it is practical to make the duct in 30" lengths. The layout is done as illustrated in figure 30 below.



Obviously the 8" X 12" duct is so simple it hardly needs discussion. But the example demonstrates the principle of laying out a series of adjacent parts on the same piece to eliminate the time and labor of making seams. Note that a single lap seam was allowed for and added to the final element. An additional amount could have been added to the starting element to greatly stiffen the joint by a double corner lap. That would also make assembly easier since it would support the corner while fastener holes are drilled. And of course a pocket seam could have been used as well

The procedure is only slightly more complicated when all sides of the rectangular figure are not parallel. For example a duct measuring 8" X 12" on one end and 8" X 10" on the other would have to have at least one side tapered. It could be layed out as illustrated in figure 31.

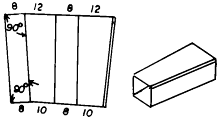


FIGURE 31

TAPERED DUCT

Again the work has been accomplished with only one joint instead of four and that is a significant reduction in labor.

The layout in figure 31 becomes easy if you first lay out the straight 8" side with the two tapered elements adjacent. Then a carpenter's square can be used to scribe the ends of the 8" tapered side at 90 degrees to one tapered element. The seam allowance can be added to either or both starting or finishing elements.

These principles apply to any rectangular article such as a duct, sleeve or tank. The objective is to lay out the work with the minimum of seams and to make the most efficient use of available sheet-metal.

Another layout problem often encountered is for box and pan work. For example a box or pan that measures 12" X 12" X 4" deep could be layed out as in figure 32.

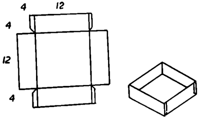


FIGURE 32

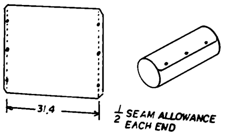
BOX OR PAN LAYOUT

Note that the seam allowance for the box or pan is layed out so that it will be formed at the same time the sides of the box are bent up. Careful planning will always result in labor and time savings. A reduced size paper model can serve to guide you in your planning.

If you have any difficulty in understanding these basic principles of rectangular layout you should lay them out on paper and fold them up. It will take but little time at negligible cost. These are the basic principles of all sheet-metal layout work.

CYLINDRICAL LAYOUT

The only difference between cylindrical layout and rectangular layout is that the work will be rolled rather than sharply bent. This work will include round pipe, sleeves, tubes and cylindrical objects such as tanks. Next to flat work these are just about the simplest of all layout problems. We simply multiply the diameter of the work by the factor 3.1416 and add appropriate seam allowance. For example a 10" pipe would have a circumfrence of 31.42" and it would be layed out as in figure 33 below.



If the round work is to be pipe, such as for air handling purposes it may be assembled telescope fashion. Then you would lay it out with one end about 1/4" smaller so that the sections would be slightly tapered. Thus one end of the pipe would be slightly more than 1/16" smaller in diameter so that it would slip into the large end of the next section.

CONICAL AND FLARING WORK

The best example of conical work would be a funnel, which is assembled of two truncated cones. A truncated cone has its peak cut off and it may taper at any angle less than 180 degrees. A cone, whether truncated or not, is layed out from its Apex as in figure 34.

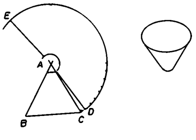


FIGURE 34

CONICAL LAYOUT

A cone is one of the simplest and fastest layouts. Simply draw a full scale elevation of the desired cone as A, B, C in figure 34. The apex is at point A where the lines of the two sides of the cone intersect. The base of the cone is line B C. And the horizontal line below the apex is where the cone is truncated or cut off.

The dividers or compass is set for the distance between the apex and point C. Begin at a point just a short distance from point C to scribe a long arc past point B. (Estimate somewhat longer than the circumfrence of the base of the cone.)

Since this is circular work we can multiply the diameter of the base of the cone by 3.1416 to find the true circumfrence of the base. Because the base line of the cone is layed out on a curve it is not possible to measure it with the rule. So you will have to set the dividers to a convenient distance to "step off" the circumfrence of the base along the layout line.

Mark point D a short distance from point C and scribe a line from point D to the Apex. "Step off" the distance from point D along the base layout line to equal the true circumfrence of the base of the cone to find point E. Scribe a line from point E to the apex.

Finally, set the dividers to the distance between the apex and the line of truncation and scribe the small arc.

To complete the layout add seam allowance at both start and end of the layout.

If you are at all confused simply follow step-by-step on paper to see how easy it is.

Cones that taper rather sharply, as in the forgoing example, are easily done because the apex is found in a reasonable distance. But if the taper is slight the apex will be so far away that it becomes impractical to merely scribe an arc and step off the circumfrence. Then the process of triangulation must be used. That will be discussed a bit later.

Flaring work is fundamentally conical work but more intricate because the cone is either off-center or truncated in an unusual manner. Consider the pitcher with flaring top illustrated in figure 35.

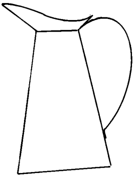


FIGURE 35

PITCHER WITH FLARING TOP

Obviously the body of the pitcher is solved as a simple truncated cone just like the funnel. But the flaring top presents some new considerations. Study figure 36 and read the following text to see how easy it is to solve.

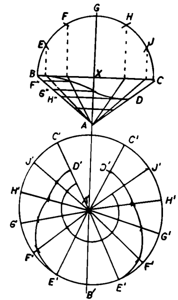


FIGURE 36

FLARING TOP LAYOUT

This process of pattern development is called RADIAL LINE DEVELOPMENT and the term will help you to understand it and to remember how to proceed. As the name implies, the layout is developed by a series of radial lines that divide the figure into segments. In figure 36 we have divided half the figure into 6 equal segments so the complete layout will have 6 pairs of segments or a total of 12. Follow the procedure step by step and actually lay it out on paper to learn how easy it is to do.

Since the figure is an inverted truncated cone with the base trimmed to an unusual contour, the first step is to draw the profile of the full cone as A, B, C in figure 36. A is the apex and the cone is truncated at the horizontal line above the apex. Then draw in the contour as B, D to complete the profile.

Only three true dimensions can be found in this drawing and that is the foundation for the layout. Using a new apex as A', set the dividers at the distance from A to B and scribe a circle. Draw a vertical line through the center of the circle as B' through A'. This will be the center of the layout and each suceeding dimension will be duplicated on each side of center. Mark B' at the point where the vertical line intersects the circle.

A vertical line drawn from the apex of the profile will intersect line B C at X. Using X B as radius scribe arc B C. Then using X B as radius and B as pivot scribe arc F. Using G as pivot scribe arcs E and J. And using C as pivot scribe arc H. This divides arc B C into six equal parts. Letter each division as E, F, G, H and J. The dimension of each division is the true dimension if the cone were not trimmed on the curved line B D.

So begining with B' on the layout step off the six divisions on each side and mark them E', F', G', H', J'and C'. Draw radial lines from A' to each division point.

Set the dividers at the distance from A to the line of truncation on the profile. Using A' as center scribe the small circle from radial line C' to C'.

It remains only to find the true lengths of the radial lines to complete the layout and that is easy to do.

Drop vertical lines from each division point on arc B C to intersect with line B C. Draw radial lines from the apex of the profile to intersect with the divisions made by the vertical lines on B C. And from the intersection of each radial line with the contour line B D draw horizontal lines to intersect with line A B. Mark those intersections F", G" and H". You now have the true length of every radial line.

Now this is the point where most people give up and the task requires only a few more minutes to complete. So persevere and grasp this principle and you will have little difficulty in mastering every other aspect of sheet-metal pattern layout. It is unlikely that you can absorb this information by reading the text only. So take the time to actually do the work on paper.

Study the profile and you will see that only the dimensions from A to B and A to D can be true. All other dimensions are distorted because they are viewed at an angle. The horizontal lines drawn from the intersections of the radial lines with the contoured line have the same effect as if the profile were rotated to view each radial line on the line A B, which will give the true dimension of each radial line.

Notice that the horizontal line drawn from radial line E gives the same dimension as A B so mark the layout intersections E' the same as B'. The horizontal line from radial line F is somewhat shorter than E so set the dividers from A to the intersection of horizontal line F" and mark that dimension on radial lines F' on the layout. Set the dividers from A to G" and mark that dimension on radial lines G' on the layout. Notice that H, J and D are the same dimension so set the dividers from A to H" and mark that dimension on radial lines H', J' and C' on the layout. Now connect each intersection mark on the layout using graceful curved lines just as you would a child's connect-the-dot puzzle and the layout is complete.

As in all layout work an amount is added for the seam and for the joint where the flaring spout is fastened to the vessel. And an amount is added for a wired edge if desired.

It would hardly be worthwhile to produce a pitcher with a flaring lip in galvanized metal since you could surely buy its equivalent in metal or plastic cheaply. But if carefully crafted in copper, pewter or even tin plate it can bring a good price.

It would require dozens of examples and hundreds of hours of study and practice to discuss the full range of applications for radial line development. But these few principles will set you on the road to discovery.

TRIANGULATION

If you have taken the trouble to master radial line development you will have no trouble grasping the principles of triangulation for the process is quite similar. And if you remain a bit confused about radial line development you will be aided by an understanding of this process. As with each of the other procedures, we divide the figure into segments that will be layed out adjacently. The only difference being that we discover TRUE dimensions from APPARENT dimensions by the use of triangles.

You are almost certain to feel intimidated by this process for at first glance it will seem that you must learn a great deal before you can begin. NOT TRUE! You need only know how to use a simple right triangle as a measuring tool. That is no more difficult than using a ruler, and you will quickly see how easy it is. See figure 37 to view a triangle from various perspectives.

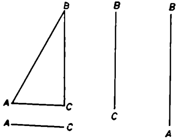


FIGURE 37

Consider that you are viewing the triangle in figure 37 in its true size. You could set the points of your dividers or compass between any two corners and that would be the true dimension of the line that joins those two corners. But if you viewed the triangle from its bottom edge the only dimension that could be seen would be the distance from A to C. And the same would be true if you viewed the triangle from directly above.

THIS IS IMPORTANT: If you viewed the triangle from directly above you would not be seeing line A C, you would be seeing line A B. But line A B would appear to be the same length as line A C. Compare line A B with line A C and you will see how great the difference is between the APPARENT length of A B in this view and its TRUE length.

Again, consider that you are viewing the triangle from its left hand edge and you will realize that again its apparent length is not true. In fact the only way you could see the true length of line A B would be to view it at an angle exactly perpendicular to its axis. That is simply not practical in layout work.

THIS IS IMPORTANT: You need to know the distance from A to B, but you are seeing the distance from A to C. The problem is to convert the APPARENT length of that line to its TRUE length.

The solution is simple: You draw a SOLUTION TRIANGLE with its base the apparent length A C and its height C B. Then merely measure the distance from A to B on the solution triangle and apply it to the layout. Apparent lengths will be clearly visible in a simple top plan view. The elevation is found in a side or end view. And the true lengths are instantly revealed by the solution triangle. An example follows.

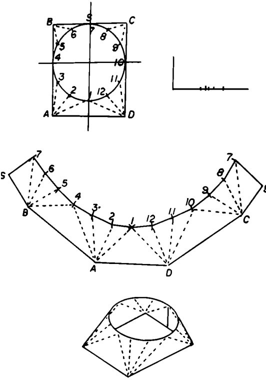


FIGURE 38
TRANSITION LAYOUT

In figure 38 is an illustration of a transition layout. The top plan view is drawn to actual dimension and it displays every vital dimension for the layout except the elevation. The dotted lines from each corner to the divisions on the circular part are the APPARENT lengths of the dotted lines seen in the perspective sketch. The solution triangle will enable us to convert the apparent lengths into true lengths .

THIS IS IMPORTANT: It is unlikely that you can absorb this process by merely reading the text. But if you will do it step-by-step as an exercise it will soon become clear.

The perspective view has no value or purpose in the actual layout. But I offer it here to help you envision the problem. Your objective is to determine the true lengths of those imaginary lines that connect the four corners of the rectangular base to the 12 divisions of the circular part. Thus the layout becomes a series of simple segments layed adjacently. And the end result will form up into the desired figure.

Begin by drawing the top plan view in true size. It is usual to begin with crossed lines and the circular part is drawn from the center of the cross. This automatically divides it into four segments. And it is then further divided into 12 or 16 segments as we did in the radial line process. The rectangular portion is then drawn in the desired position. The divisions of the circle can be numbered and the corners letterd to help keep you properly oriented. The "S" indicates the seam.

The solution triangle is drawn near by with its base-line of random length and the vertical leg true to the actual height of the figure.

Now the top plan view contains dimensions that are true as well as some that are apparent. For example the diameter of the circle is true and so are the divisions of the circle. Also the base dimensions are true from corner to corner and from corner to seam. And the true height of the figure is shown in the solution triangle. So it remains only to discover 12 true dimensions to complete the layout. We have everything needed to begin.

Actually we could begin at any point. But since this figure divides neatly into halves I elected to begin with the base-line A D. Since both halves of the figure are identical this means that each solution can be used twice so there are really only 6 true lengths to find.

So allow plenty of room on your paper and simply draw base-line A D to true length. This length is found in the top plan view.

The next step is to establish point 1 on the layout and for that we need the solution triangle. Now view the dotted line between A and 1 on the plan view and remember that you are really looking at a diagonal line that is the hypotenuse of a right triangle. The line is really much longer than it appears to be. Set the dividers to that APPARENT length on the plan view and transfer it to the base-line of the solution triangle. Thus the TRUE length of the line from A to 1 is found. Set the dividers to the hypotenuse of the solution triangle. Using point A on the base-line, scribe a short arc about mid-way above the base line. Since the distance from point D to 1 on the plan view is the same as that from point A to 1, use the same setting to scribe a short arc from point D on the base-line to intersect the first short arc.

The intersection of those two short arcs establishes point 1 on the layout. The area A D 1 on the layout is the first segment. And we now have the foundation for the two segments that will lie adjacent to it. We continue to use points A and D to solve 3 more lengths from the plan view.

Set the dividers from point 1 to point 2 on the plan view and scribe short arcs on both sides of point 1 on the layout.

Then set the dividers from point A to point 2 on the plan view and use the solution triangle to find the true length. Set the dividers to the hypotenuse of the solution triangle and, Using points A and D on the layout as pivots, scribe short arcs to intersect the arcs on each side of point 1 on the layout. Mark those intersections 2 and 12 respectively. We now have the two segments that lie adjacent to the first.

The next two segments are solved and layed out in the same manner to bring us to points 4 and 10 on the layout. Now it is obvious that points A and D can no longer be used so we must establish points B and C on the layout.

Set the dividers from point 4 on the plan to point B. Use the solution triangle to solve that true length. Set the dividers to the hypotenuse and, using point 4 on the layout as pivot, scribe a short arc an estimated distance from point A. Then set the dividers from point A to point B on the plan and use point A on the layout to scribe a short arc to intersect the arc drawn from point 4. Mark that intersection B. The same steps establish point C on the opposite side of the layout. Now we can use point B to solve the true lengths from B to 5, 6 and 7. And of course the same dimensions will apply to points 9, 8 & 7.

When point 7 has been established on both sides of the layout set the dividers to the height of the solution triangle, which is the true height of the figure, and scribe short arcs from points 7 on the layout. Finally, set the dividers from point B to point S on the plan and use points B and C on the layout as pivots to scribe short arcs to intersect the arcs drawn from points 7.

Now we simply connect all the intersections with lines as though it were a child's connect-the-dot puzzle. Of course an addendum is required for the seam. And some addition must be made at both the round end and the rectangular end to provide for joining with other members of the system.

Now while I realize that this discussion may have been tedious for you, the entire process can be carried out in 15 minutes or less on any ordinary pattern problem. And a properly layed out figure will not only look and function better, it will be faster and easier to make than any of the dreadful concoctions people devise in their determination to avoid learning how to do basic layout work. It is worth the effort and study to know how for the sake of pride in craftsmanship alone, not to mention the better product.

Certainly countless problems could be used as examples and exercises. For triangulation is an almost universal system for solving pattern problems. However we are not going to carry the topic that far in these pages since there are good texts already available. But you can apply these principles to your own specific problems and soon gain the level of skill you need for your pursuit.

PARALLEL LINES

The Pattern development systems we have discussed so far all depend upon dividing the figures into segments so that true dimensions can be learned from simple views of the objects we want to lay out. This system of parallel lines works in a similar way and it will complete your "kit of layout tools" so that you will be fully equipped to solve any sheet metal pattern problem. We have already used parallel lines to discover the true lengths of the radial lines in the flaring cup problem. Now we will use them to solve problems where cylindrical figures intersect. Figure 39 gives some views for discussion and study.

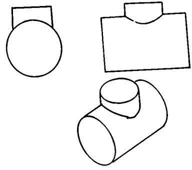


FIGURE 39

A "T" FITTING

As with earlier examples figure 39 shows more than is required to develop the pattern. But the extra side view and angular view help to define the problem. What is required is a series of true dimensions that will enable us to lay out the pattern for the smaller cylinder so that it will interesect the larger cylinder neatly. Once we have the smaller pipe neatly fit it will be easy to scribe its outline on the larger cylinder and cut the hole to join the two members. For that we need only the end view. Figure 40 will illustrate the entire process.

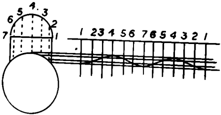


FIGURE 40

"T" FITTING LAYOUT

Simply draw the circle representing the true diameter of the larger cylinder and draw the profile of the smaller cylinder intersecting it.

Draw a half circle centered on the profile of the intersecting cylinder profile and divide it into equal segments as we did in the triangulation process. Number the division marks. Drop vertical lines from each division point to intersect with the contour of the large cylinder below.

Extend a horizontal line from the top of the intersecting cylinder and divide it into as many equal segments as you used on the plan view. Number the division marks, remembering that the sequence begins and ends with 1. Drop vertical lines from each division point.

Finally, extend a series of PARALLEL lines from each intersection in the plan view to intersect with the vertical lines dropped from the layout line. Mark the corresponding intersections at each segment and it remains only to connect the marks to establish the contour. An allowance is added for the seam.

The examples offered in this chapter are only a few of hundreds that could be used. Because texts on sheet metal pattern layout are usually very large and intimidating I offer these basics to pursuade you that it is really a simple craft that you can master if you apply your mind just a little. Of course there are complex problems that use two or more of these systems. But most ordinary work involves only one and you really can turn out the majority of patterns in 15 minutes or less if you trouble to learn these basic systems. .

What you are doing in the pattern development process is studying the plan or profile view, which is very easy to draw, to discover a universal view that will yield every dimension for the layout process. Once you realize that all of the information you need is in that simple view you will be motivated to search it out and apply these simple systems to solve all of yor layout problems.

CHAPTER V

FABRICATING

The objective in sheet metal work is to begin with raw sheets of metal, which is quite cheap, and end up with useful articles that would be very costly if purchased in finished form. What has been presented here may seem rather scant when compared with equipment found in a modern shop. But it really is adequate for most ordinary projects. The secret to success lies in a strategy or plan of attack. The idea is to forget about what we don't have and effectively apply what is on hand to do the job.

Many projects may seem beyond you at the outset. For example if you wanted to install a duct system for heating or air-conditioning you would immediately face serious obstacles. While you can buy duct, pipe and fittings reasonably you would not be able to buy the plenum chambers or any special transition pieces required from stock. The reason is that common pipe and fittings are mass produced and offered at competitive prices while plenums and transitions are not. When custom made in a modern commercial shop, prices for these articles are shocking to say the least. I have seen such work priced so high as to offset any savings gained by installing your own system. But with the basic equipment described here you can produce them yourself at great savings. And while you can't assemble your work with machine formed pittsburg seams it will function just as well as if it were.

Quite often a project will require you to replace an item that was originally commercially made. A gas tank for a vehicle is a good example. Prices for such articles are high enough so that you may not feel able to justify purchasing them. But the cost of the raw sheet metal is low enough to justify making it yourself. However you will probably have to change the design a bit to bring the project within the scope of your shop.

REDESIGNING

Most likely the tank you want to replace will have failed due to rusting out or serious damage in a collision. But enough of it will be left to determine basic size and shape.

It probably was made originally by ribbon-welding a pair of stampings together and you obviously can't do that in your limited shop. But it will be no problem to make it in round, square or rectangular shape to fill the original need.

The original tank was probably embossed with ribs or other designs to reinforce it so that metal of lighter gauge could be used to cut costs. You can't reasonably duplicate such work but you can use heavier metal so that the embossing is not neccessary.

Some parts, such as filler-neck, vent fittings, gauge unit mounting and fuel pickup would be very difficult to duplicate. But you can salvage them from the original tank or another tank from salvage.

Special caution is required when working with fuel tanks for they can be a deadly bomb. You must make absolutely certain that NO AMOUNT of fuel remains in the tank before coming near it with torch or any heating equipment used to de-solder fittings. The mere vapor from a very small amount of fuel is enough to burst the tank and cause serious injury or death if ignited. Steam cleaning or hot water with detergent is effective if properly and thoroughly done. The object is to be ABSOLUTELY CERTAIN that no fuel remains in the tank.

Fittings are sometimes riveted or spot-welded in addition to being soldered so you may find it neccessary to cut away a portion of the old tank to salvage the fittings. Be sure and make a note of their location before destroying the old tank so that the new tank will fit properly.

Some sacrifice in total capacity may have to be made in the final redesign. But be especially careful to ensure that the new design will fit properly in the old location. It will usually be possible to retain original profile and critical dimensions. And any lost capacity should not amount to enough to be concerned about.

The Jeep gas tank illustrated in figure 42 is a good working example.

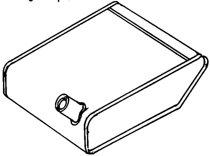


FIGURE 42

Some details of the original tank are not apparent in figure 42. The lateral seam is ribbon-welded, which is impossible in the small shop. The end panels are embossed and they have a machine formed pocket seam, both of which are at the very least impractical for the small shop.

Figure 43 illustrates a practical redesign that can easily be made in the home shop.

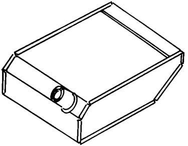


FIGURE 43

The rounded corners of the original design would have made the end panels more difficult to form. The filler neck will be somewhat easier to fit on the flat beveled surface than it would be on the radius of the original round corner. And the layout of this simplified design will be easier. Not that the original design couldn't be nearly duplicated by hand methods. But the question is whether the end result is worth the labor. And if it is to be payed for, is it worth the cost?

There are options on the seams and weight too. So this job can be brought within simple means. Keeping in mind that the tank must be absolutely liquid tight because it will hold flammable fluid, we can consider options and resolve the final details.

The lateral seam could be a simple lap seam but it would require a closely spaced double row of rivets to be adequate for a fuel tank. A grooved seam will be the stronger choice and it will be easier to do.

The original design used a machine formed pocket seam that would have been difficult to form by hand on the rounded end panels. But it becomes an easy job with the simplified design. This would be the best choice if metal near the gauge of the original tank will be used.

While the tank could be made with metal as light as 26 gauge, that is really too flimsy for safety when you consider that the flammable fuel it holds will weigh in excess of 80 pounds. The forces from starting and stopping the vehicle, not to mention accidents, could be enough to cause failure. 24 gauge or 22 gauge will be the safer choice. And they can be worked easily enough to form the pocket seam in the end panels.

If you elect to build the tank of 20 gauge or heavier metal you can forgo the pocket seam and use a simple standing seam. This could be riveted and soldered or brazed, or it could be welded if that equipment is available. Welding or brazing is less practical for lighter gauge metal because of the distortion of the metal that will surely result from heating. But in any event the joint will have to be made liquid tight.

Soldering will be the easiest and least costly method of sealing in most cases, and that simple craft will be discussed in the next chapter

Since the main body of the tank is simple in form no discussion is neccessary on laying it out or forming it. But the end panels may raise a few questions in your mind.

Whether you choose a pocket seam or a simple standing seam an allowance must be made for the thickness of the metal and the bend radius. Both seams are seen in profile in figure 44.

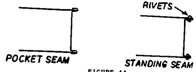


FIGURE 44

The pocket seam has the advantage of capturing the edge of the tank securely so that distortion from soldering heat is minimized or eliminated. The triple thickness of metal at the seams will greatly strengthen it. And solder will flow very nicely in the pocket seam.

If very heavy metal is used it will be quite difficult to form a pocket seam by hand methods. So the simple standing seam is the better choice. Unless it is welded or brazed it will have to be secured by rivets or screws. Solder alone does not have the mechanical strength required for such a joint. But the standing seam lends itself very nicely to acetylene welding or arc welding if that equipment and skill is available. And of course the job is ideal for a wire-welder.

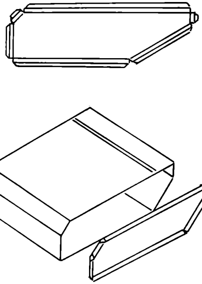


FIGURE 45

It is evident in figure 45 that you need only fold up a sheet-metal sleeve for the tank body and join it with a lock seam. The ends are easily layed out and pocket seams quickly formed. Just knock the ends on and solder to finish.

CHAPTER VI

SOLDERING & WELDING

To teach such crafts as soldering and welding is a demanding task that would take a book much larger than this one. And in addition it would require a shop atmosphere with equipment to demonstrate the many techniques involved. The broader topic is simply beyond the scope of this manual. If you have no experience or knowledge in it at all you may need to take a class at a near-by vocational school. But if you are able to do it but feel that your skills could be improved this discussion may prove beneficial.

These crafts are really quite simple and failures can be due only to three factors: 1. Improper or inadequate equipment, 2. Insufficient knowledge or misinformation. and 3. Insufficent practice. All of these deficiencies can be quickly and easily corrected so no one should feel intimidated. knowledge comes from study and skill comes from practice. You can know what others know and you can do what they do.

Improper or inadequate equipment is not the most important factor even though it was mentioned first. Obviously if the right equipment is not on hand it will have to be purchased, rented or borrowed and you need no instruction for that. But quite often the wrong process is selected or the available equipment supplies not enough or too much heat. A good job can't be done with the wrong tool.

The factor of too much or not enough heat is the clue to most problems with welding and soldering so something can be gained from a discussion. A full understanding of how both systems work and how they differ is vital.

Welding requires that the temperature of the parent metal be raised above the melting point. And any metal added to the joint must also be melted.

Soldering is done with lower temperature alloys and it is neccessary to raise the temperature of the parent metal only to a bit above the melting point of the type of solder used.

The main difference between the two processes, the temperature, is instantly obvious. But there are other differences to consider.

There can be great danger in both processes so the first and most important thing to do is to learn to recognize hazards and protect yourself from them. There is danger to others who might be in the area too. So your responsibility goes beyond yourself. Not only the obvious hazards of fire or explosion, but of fumes that are not only obnoxious but dangerous to humans and animals. Make it your business to know the nature of metals that you work with. For example cadmium vapors are quite poisonous so you must use precautions when welding plated metal. Zinc vapors can make you very ill. And the smoke and vapors of fluxes are harmful.

WELDING

Welding might be done by gas flame, usually Oxy-Acetylene, carbon arc, electric arc using flux coated rods or electric arc using inert gas envelope. Instruction is readily available for each process along with the equipment, which is generally quite expensive.

When you have learned to light and adjust the torch or strike and hold the arc it remains only to learn how to concentrate the heat where you want it. That is a skill to be acquired only through practice and it does not take long to become good at it.

The first thing to do is to become familiar with the equipment, including, and especially, goggles, helmet and recommended protective devices and clothing. Experimental welds on various scrap materials will teach you what to expect when you strike an arc or play the torch flame on the work. The temperature is effected not only by the size of the flame or the intensity of the arc, but by the rate of travel as well. Your work can improve only as you become familiar with the process and begin to relax. By observing the effect of your own technique critically you will soon learn to control the puddle of molten metal and lay a neat uniform bead.

Welding a standing seam of mild steel with a gas torch is one of the easiest techniques to acquire. Because you have two members clamped close together it is usually not neccessary to use a filler rod since the parent metal of both members will melt and flow together nicely. However the heat of gas welding is intense and areas adjacent to the seam can become distorted.

By making experimental practice welds you will learn the effect on adjacent areas of the work so that both your technique and judgement will improve steadily.

Whether to weld or solder a joint depends on the type of joint and the mass of metal involved. If you are working with nonferrous alloys welding may not be an option except with special equipment. Light gauge metals will surely become badly distorted by excessive heat so welding will generally be reserved for heavier work.

SOLDERING & BRAZING

Soldering includes all of the low temperature alloys, including silver solder. And while brazing is not called soldering the process is the same except that it requires higher temperature.

Soldering equipment is generally cheaper and it seems easier to learn the techniques, perhaps because it is less intimidating. There are many different alloys used for soldering and several ways of applying the heat.

The wonderful thing about soldering is that if you have properly prepared the joint and applied the right heat with the right choice of solder and flux it's quite impossible to have a failure.

Soldering heat might be applied by torch flame, a soldering iron that is heated by gas flame or other fire, an electric soldering iron or even a match flame. The determining factors are the mass and weight of metal to be joined and whether flammable fumes are present. The important thing about it is to make certain that the parent metal is hot enough to melt the solder. When properly done the solder will become chemically bonded to the parent metal. Improper heat or faulty preparation can spoil the bond and the joint will soon fail even though it might look solid.

Preparation of the joint includes cleaning and fluxing. Cleaning might be done by scraping, filing or with an abrasive. There must be absolutely no paint, oil, grease, dirt or any foreign substance. Only bright bare metal. Flux may enable you to do a poor job of soldering a dirty joint. But flux is not a substitute for cleaning the joint.

Fluxes are chemical compounds that reduce the melting point of impurities so that they become fluid and separate from the solder to ensure a bond with the parent metal. Fluxes are compounded for specific purposes so make sure you are using the right one. In general resin flux is used for copper and its alloys and acid flux is used for iron and its alloys. But there are special fluxes for alloys such as stainless steel and aluminum. Soldering fluxes are usually applied to the joint while brazing fluxes are applied to the rod or spelter, as it is called. And there are solders that have a flux core for both copper and iron work.

If a heated iron is used it must also be properly prepared. It is virtually impossible to make a successful soldered joint with a dirty iron. And the combination of a dirty iron and dirty joint will surely have you talking to yourself and it won't be polite.

A soldering iron must be "tinned" before use. It is cleaned and dressed to shape by filing the point. And then it can be tinned by heating it to working heat and applying solder to it while rubbing on a block of "Sal-Amoniac", which can be purchased at some hardware stores and from suppliers to the sheet-metal trade. When it is properly tinned the working surface of the tip will be covered with solder and it will brighten when wiped on a piece of waste. It will remain nicely tinned for a long time unless it is over-heated. If over-heated the tinning will burn away and the tip will become pitted. Then it must be cleaned and dressed and re-tinned.

As with welding you can teach yourself a great deal about soldering. Some simple exercises will help you to evaluate your technique and improve.

There actually is little that you can do to control the flow of solder once it has melted and come in contact with a prepared compatible surface that is heated above the melting point of the solder. So the real object of these exercises is to observe how the stuff acts. You just prepare the joint, heat it and apply the solder and watch what happens.

If you are not familiar with the phenomenon of capillary attraction you should obtain a copper coupling of small size, as used for plumbing, and a short length of copper pipe to fit the coupling. If the copper is clean and bright you can simply apply soldering paste to the joint and slip it together. Otherwise brighten the joint inside and out with abrasive cloth or sandpaper before fluxing and assembling. clamp the assembly upright in the vise or by some means and heat the joint until it is hot enough to melt the solder. continue to heat and apply the solder wire to the bottom edge of the joint at any point and continue to feed it until it hangs in a drop. Wait for it to cool and examine the joint. If properly cleaned and fluxed the solder will have climbed upwards to fill the joint and it should be visible at the top surface inside the coupling. The point is that there is no special technique to making solder flow upwards. In fact you can't prevent it if the joint is properly cleaned and fluxed and heated to melt the solder. If it does not work it is because the joint was dirty, the flux was wrong or it was not heated completely.

The above copper pipe joint is said to be "sweated". When properly handled solder always acts that way. Prepare your soldering iron and heat it for use. Take two scraps of sheet-metal and prepare a simple lap joint by cleaning and fluxing. Weight the assembly or clamp it so that it will not move under the iron. Now heat the joint and apply solder at the edge while you draw the iron along. If properly done the solder will be pulled through the joint by capillary attraction and the joint will be liquid tight. You can test the joint by forcing it apart cold to see if there are any voids. If the solder did not penetrate fully it is due to dirt, improper fluxing or inadequate heat. Remember that the iron must be as clean as the joint and tinned.

Two pieces of metal sweated together makes quite a strong joint, depending upon the solder alloy used. And the sweat-soldering technique is very useful for patching metal vessels as well. You can sweat a piece of metal over a hole or a number of holes in a tank for a repair that is as strong and durable as the parent metal.

The phenomenon of capillary attraction, or sweating, makes soldering ideal for tank construction. For it will completely penetrate a grooved seam or a pocket seam and it makes the joining of filler necks and other tank fittings liquid tight.

While grooved seams, double lock seams and pocket seams are strong enough to be soldered alone, flanges and other surface mounted fittings need rivets or screws in addition to solder to make them strong enough. But cadmium and chrome will not bond with solder so unplated fasteners must be used.

Anything that is true of soldering is true of silver-soldering except that temperatures used are much higher. And the same is true of brazing with still higher temperatures. Of course the higher temperature alloys are stronger too.

Copper and brass are very pleasant to work with because they solder so nicely. Replicas of some types of antique vessels are in demand and bring good prices in some markets.

Stainless steel solders nicely too and some alloys of silver solder work well on it. There are a variety of alloys available in stainless steel and some are easier to work than others.

Alumuminum is in a class by itself. It can be welded with special rod and there are specialized devices using inert gas and high frequency arc equipment that are seldom found in a small shop. It can be soldered too with special solder and flux. But aluminum is quite active chemically and no solder I have found will remain permanently liquid tight on aluminum. As soon as it becomes a bit damp the process of electrolysis begins and the joint begins to deteriorate. I suspect that the only way to achieve a liquid tight joint with aluminum is by inert gas welding or by some of the newer epoxy compounds.

CONCLUSION

There remain an infinite variety of examples we might choose. And it would be easy to let this become a plan or project book. But now you have the means to plan your own projects and the only limitation is your imagination. Whether you want to fabricate a tank or chimney cap, a tool-box or a hood to exhaust fumes from your shop or any other article in sheet-metal you can adapt these simple principles to the job.

The important thing to do is to assemble your basic shop and get your hands on some sheet-metal. Familiarize yourself with the nature and characteristics of the various weights so that you will know how much to allow for thickness and bend radius. Use scrap to learn how to form a seam, to turn a flange and each basic operation.

Your equipment will surely seem scant to start. But you can adapt and modify to accomplish nearly any operation. For example you can install a number of "T" nuts in the bench top so that you can clamp a special job, like a box or pan, at the edge of the bar-clamp. Work can be shaped on a wooden block cut to required size and form. And each job itself will suggest just what sort of forming block or clamp you need to devise.

Having spent more years than I care to count working in commercial shops, I can tell you that these methods will accomplish nearly everything machines can do. And sometimes even better and faster. While specialized equipment has much appeal, it requires a substantial cash outlay and a significant volume of business to retire it. A hobby pursuit may not justify investing in exotic equipment. But that does not mean that you can't do the job anyway and enjoy it in the bargain.

If you are a shop hand working with limited funds it is likely that you frequently need an article in sheet metal that you feel ill equipped to make. So here is some good news for you. It is not the equipment you lack, but rather the knowledge of how to accomplish what the equipment would do for you if you had it.

Even a very small commercial sheet metal shop would have a leaf-brake, jump-shears, slip roll, bar folder, roll forming machine and a series of bench machines as a basic set-up. This together with a bench grinder, electric drills and countless hand-tools already totals many thousands of dollars even at second-hand prices. And workers in that shop would consider it poorly equipped. But you can produce nearly any article that could be made in that shop even though you do not own a single piece of that exotic equipment.

Sheet metal equipment and machinery will cut, bend, fold, roll and otherwise shape and form sheet metal into useful articles and impliments and it will do it neatly and rapidly. But the same jobs can be done by hand methods using simple devices assembled right in your shop. And much of the work can look as though it were done by a machine.

Whether you want to assemble a duct system to heat and cool your home or fabricate a fuel tank for your Jeep or Dune-Buggy, the simple methods and devices in this book will enable you to do it.

Sheet metal work remains a noble craft even though much of what was once made of sheet metal has been replaced by plastic. And as the plastic stuff deteriorates not long after we buy it it won't be long before we will be making something of sheet metal to permanently replace it.

ISBN 1-878087-13-4