

NOVEMBER 1989 \$1.95

# Popular Mechanics

**SPECIAL  
WOODWORKING  
GUIDE**

Make Great Furniture With Only Hand Tools

- Hand Joinery
- Dovetails
- Classic Details And More!

## SUPER TANKER, SUPER MENACE

Safe Tanker Technology Exists Now. Here's Why The Oil Companies Won't Use It.

**1990 LIGHT TRUCKS**  
All The New Models, Options, Features



■ We Road Test 3 Methanol-Powered Cars

■ Lab-Testing 12 Long-Play Audio Cassettes



# LES



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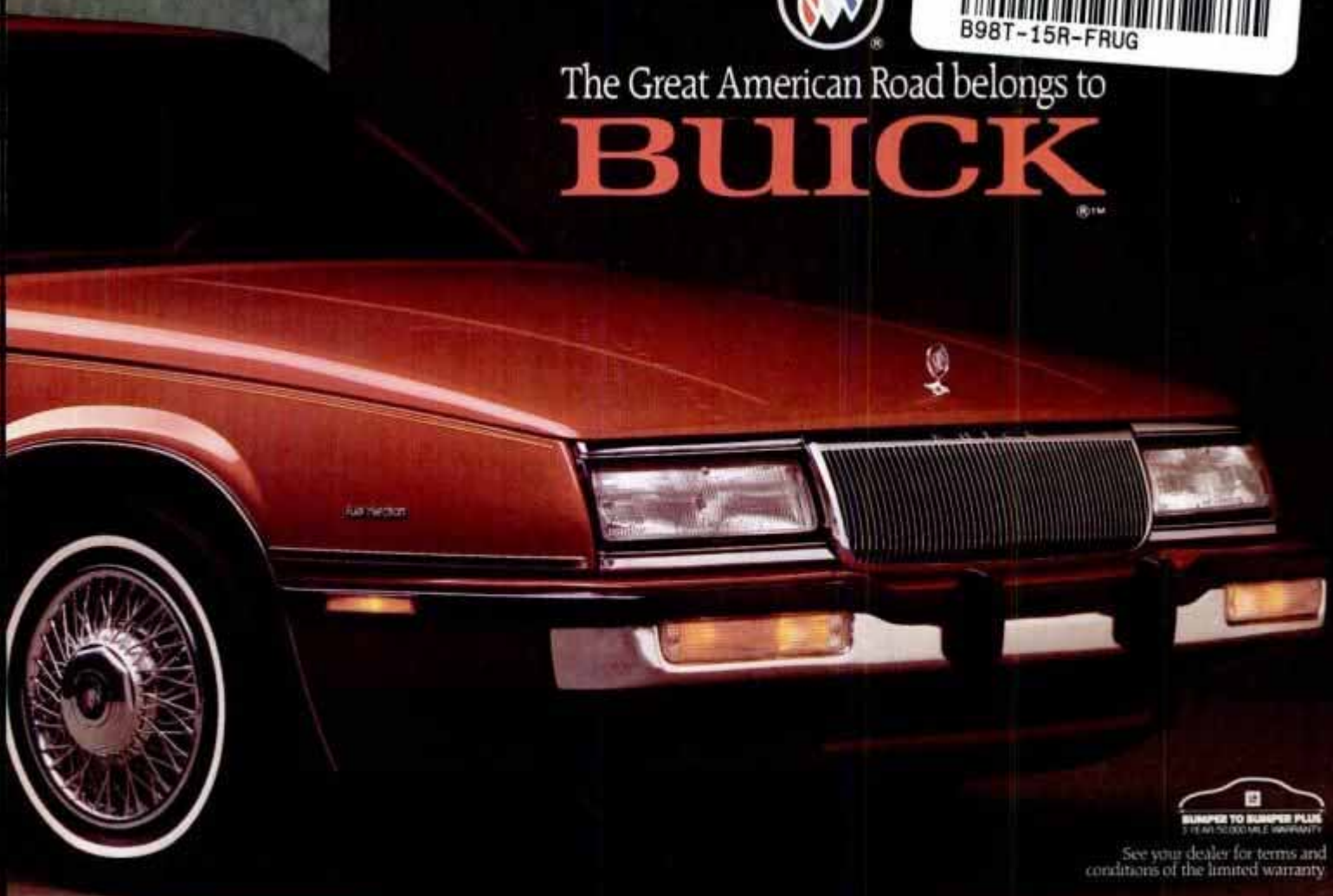
\*J.D. Power and Associates 1989 Initial Quality Survey covering November and December, 1988. Based on owner-reported problems during the first 90 days of ownership.



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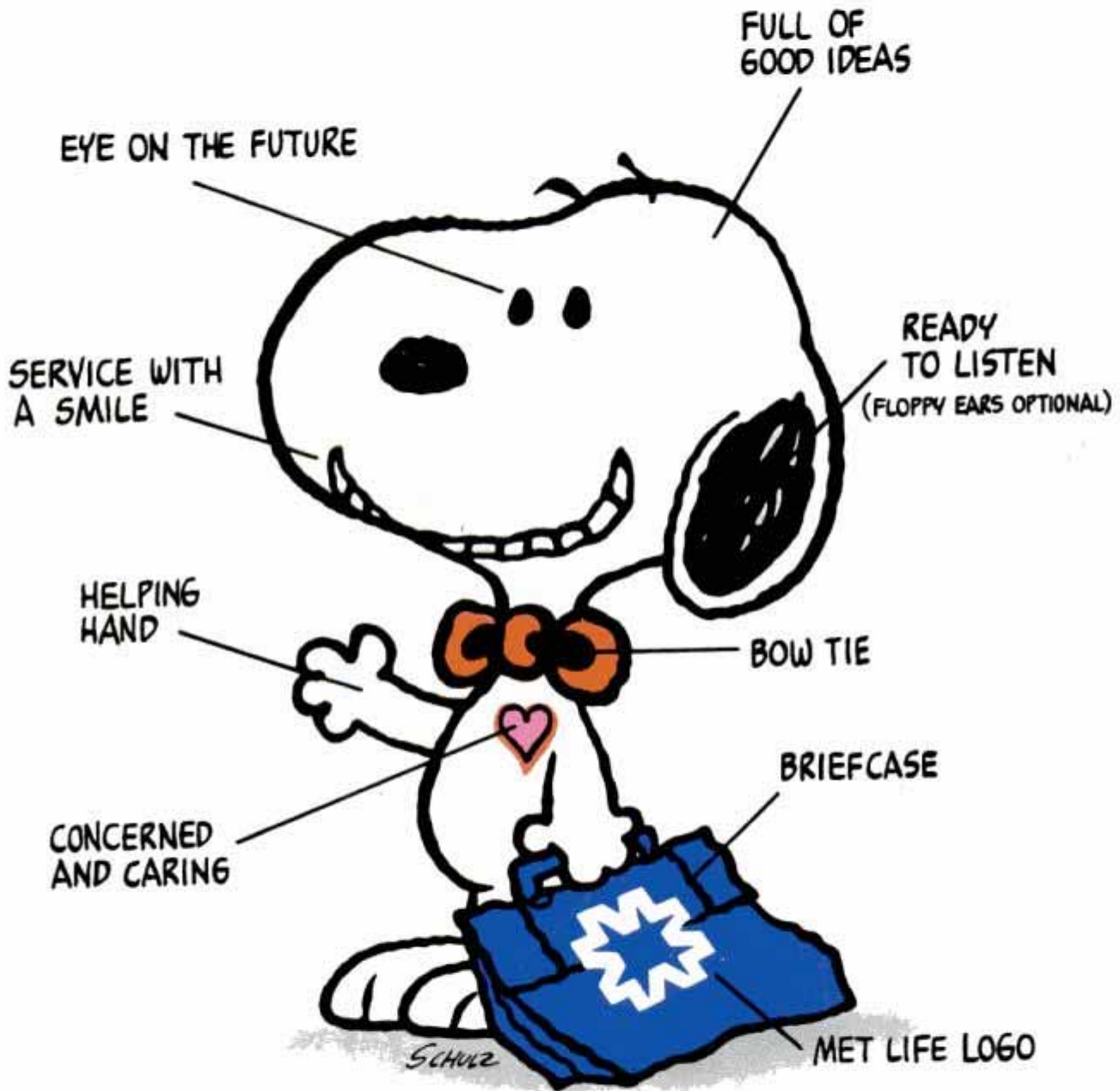
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# HOW TO SPOT A MET LIFE REPRESENTATIVE.



**GET MET. IT PAYS.™**

**Metropolitan Life**™  
AND AFFILIATED COMPANIES



## 51 COVER STORY

Investigations have raised disturbing questions about the design and construction of modern tankers.

—PM illustration by Attila Hejja

**60 Coalaholics**

**67 Power truckin'**



## 63 Tale of the tapes



## WOODWORKING GUIDE

### 71 Using Hand Tools

### 72 Hand-Built Elegant Furniture

### 75 Stock Preparation

Smoothing out rough-sawn lumber—quietly.

### 81 Joinery And Shaping

Timeless details.

### 87 Dovetails

The classic joint.

### 89 Assembly

Building time.

### 93 Drawer Making

A project in itself.

### 95 Finishing

Doing it right.

### 99 Tools Of

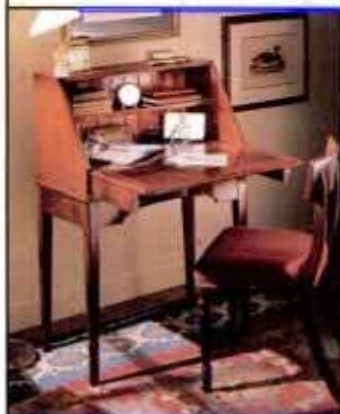
The Trade

All the essentials.

### 107 The Cutting

Edge

Sharper tools.



## AUTOMOBILES

### 24 Imports

New-generation Celica and Accord.

### 30 Detroit Spy Report

Saturn's debut is orbiting on schedule.

### 40 Car Clinic

Got a car question? We've got the answer.

### 44 Freewheeling

On the rocks: Ford shows off its 1990 4x4s.

### 55 Fuels In Your Future

Tomorrow's cars will be burning more than just gasoline and rubber.

### 60 Coalaholics

Check out our test drive report on three methanol-powered cars.

### 67 Power Truckin'

Sport/utes and pickups power the '90s with more muscle and greater variety.

### 117 Saturday Mechanic

How to diagnose and stop shimmy that's caused by steering system, suspension or tires.

## HOME/SHOP

### 46 Old House Restoration

Moving an old house to a better site can give it a new lease on life.

## SCIENCE/TECHNOLOGY

### 15 Tech Update

Manufacturing on the Moon, stargazing with computer-aided optics, simulating micrometeors with a helium gun, and more.

### 38 Science

Cleaner gasoline comes on line as refineries tackle the problem of air pollution.

### 51 America's Oil Tanker Mess

Recent oil spills have created some of the worst environmental and economic disasters facing our nation. Tanker design is one of the causes.

## ELECTRONICS

### 34 Electronics

Filmless photography puts your snapshots on the television screen.

### 63 Tale Of The Tapes

It's the new 100-minute audio cassette versus the 90-minute lengths in our comparison test shootout.

## OUTDOORS

### 26 Outdoors

A PM tribute: Craig Arfons' boat topped 400 mph on its final run.

## DEPARTMENTS

**4 Editor's Notes**

**9 Letters**

**10 Time Machine**

**130 Hotlines**

## EDITOR'S NOTES

**T**HE HIGHLIGHT of this issue, and every November issue for the past umpteen years, is our annual Woodworking Guide. Every year, it's a veritable feast of fabulous projects, plans, techniques and ideas for home shop enthusiasts. This year's Guide (page 71) is no exception. But there is an interesting twist this year. The emphasis is on hand tools only. No power allowed. Hey, wait a minute! Before all you power drillers and power sawers turn the page, take a look at the section. Tom Klenck, Associate Home and Shop Editor and our resident hand tool enthusiast, insists that, in many ways, hand tools are just as convenient and perform better than electric power tools. We thought the idea worth pursuing so that you could understand how traditional hand tools work and perhaps add them to your tool box and repertoire of woodworking skills. Klenck planned the section, then worked with Contributing Editor Ro Capotosto to develop the editorial material. Ro is generally considered the dean of home workshop writers. Nobody knows his way around a woodshop like Ro. Still, it took him four solid months of constant work to develop the articles in our Woodworking Guide. Ro's work then went back to our staff where Home and Shop Editor Steve Willson, Klenck, Assistant Home and Shop Editor Roy Berendsohn and Assistant Lynne Abbate worked it over into the finely honed and polished section you see in the magazine. If you've never made anything strictly with hand tools, give it a shot. I think you'll have a good time. . . . **This month's cover story** (page 51) is the kind we don't like to run. The terrifying rash of oil spills in the past six months almost forced us to look into the




Capotosto working wood—and wonders.

situation, though. Why were they occurring? Was human error a good enough excuse in light of the terrible damage inflicted on our planet? Yes, we need oil. But couldn't something be done to prevent spills when the inevitable human error did occur? These were all the thoughts churning through my mind as we dispatched Contributor Abe Dane to come up with the answers. The answers are, frankly, disturbing. Yes, there is a lot more that can be done, now, to prevent disasters in the future. The knowledge and technology is in place right now to ensure that another *Exxon Valdez* incident never happens again. The question is, how much are we willing to pay for that assurance? . . . **And when the oil wells do run dry, what then?**



Allen investigates alternate fuels.

What are our alternatives? Methanol looks like the best possibility, as Assistant Auto Editor Mike Allen tells us in the test of three coalburners in "Coalaholics" (page 60). Meanwhile, refiners still insist that there's plenty of oil left, and that a cleaner gasoline could avoid having to make the switch to methanol. [See how in Science, page 38.](#) Till next time.

  
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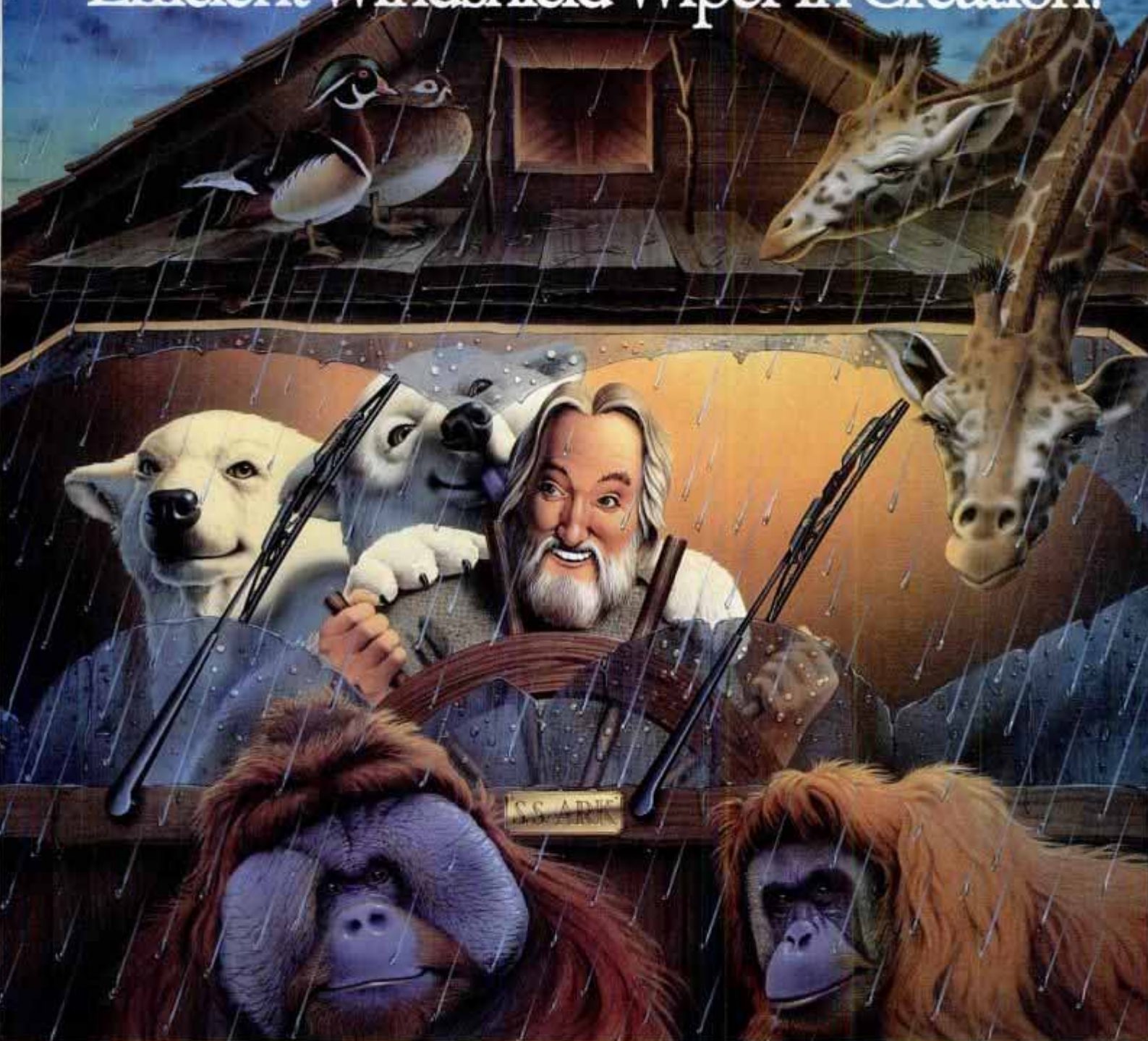
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When You Know It's Going To Rain  
Day After Day, You Want The Most  
Efficient Windshield Wiper In Creation.



Trico Windspoiler™ windshield wipers perform in even the most notoriously bad conditions. Because of their unique design, Windspoilers actually catch the wind and use it to keep the wipers on the windshield. Even in stormy weather, Trico Windspoilers stay in place for better vision and less streaking.

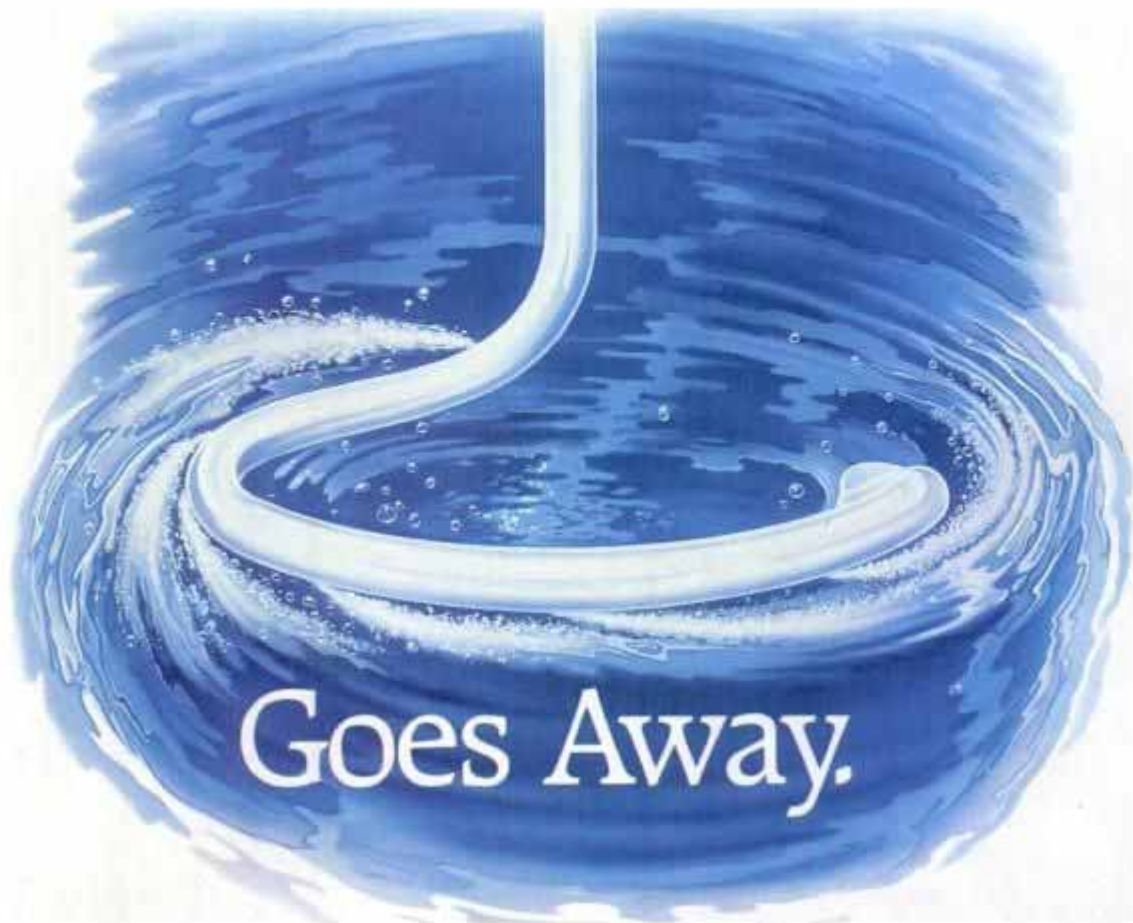
So when you get the word that bad weather's on the way—be prepared. Pack a pair of Trico Windspoilers. The most efficient windshield wipers in creation.

**TRICO**

Trico Products Corp., 817 Washington Street, Buffalo, New York 14203

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## Reliance Sta-Kleen® gas water heater prevents sediment accumulation—automatically.

No matter how clear your water, it's full of minerals. Minerals that are beneficial to you but when they settle on the bottom of a water heater, destroy efficiency, increase energy consumption and promote corrosion. All of which spells an early death for water heaters.



That's the bad news.

The good news is a Sta-Kleen gas water heater is designed to prevent this—*automatically*. With its patented Aqua-Force Ring, it creates a vortex of turbulence inside the tank which swirls the sediment up, up and ultimately away with the hot water.



Couple this design efficiency with the fact that gas heats water for one-half the cost of electricity and you have a water heater that provides years of trouble-free performance, years of more hot water for less money.

Look into self-cleaning Sta-Kleen today. Call 1-800-365-4054 for the name of your nearest dealer.

 **RELIANCE**  
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130 Cumberland Street, Ashland City, Tennessee 37015  
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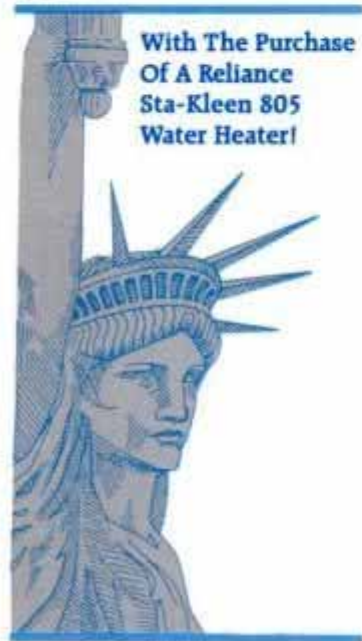
Gas. America's best energy value.

Gas heats water for one-half the cost of electricity.

## For A Limited Time You Can Get A \$50 U.S. Savings Bond Automatically!



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Buy A Reliance Automatic Self-Cleaning Sta-Kleen 805 Water Heater Between November 1st and November 30th, 1989—and you'll get a \$50 U.S. Savings Bond!

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No purchase necessary to enter sweepstakes. Void where prohibited by law. See your nearest Reliance retailer for complete details. Offer ends November 30th, 1989.



# LETTERS

## A Foot In The Door

**A**PPROXIMATELY five years ago my husband and I built four leaded-glass French doors for our home following POPULAR MECHANICS step-by-step lesson ("Two Sets Of French Doors You Can Build," page 104, Dec. '84). The doors turned out beautifully, and eventually lead to a family glass business.

We now do bevel and glass leaded windows for some of the finest building contractors in the Northwest and have participated in home show tours, too.

Thanks, POPULAR MECHANICS, for giving us the start!

RAY AND  
SHEILA DRURY  
BLACK DIAMOND,  
WA



PM's French doors launched a business.

*You never know when you'll find a window of opportunity from a story in PM. This letter reminds us of old PM ads with the headline "Be Your Own Boss!" Plans for the French doors that started the Drurys' business are available for \$5.25 from POPULAR MECHANICS, P.O. Box 1014, Radio City Station, New York, NY 10101.*

### Showing Our Age

I was most interested in your issue of May 1989 with "The American Adventure" section, because my wife and I visit the U.S. every year on vacation. We plan this year to visit some of the interesting places you discuss, and travel in particular along some of the roads in "All-American Highways," (page 66) such as the Blue Ridge Parkway, Virginia, and the Wild Montana Route (Boise to Kalispell).

However, one remark of yours puzzles me, and that is when you warn readers that when driving in mountainous regions to keep an eye on the coolant temperature, because the boiling point goes down as the altitude goes up. I

agree that this is very true when you have an unpressured radiator, but I put it to you that since every modern automobile has a fully pressured radiator, with the pressure therein being held at not more than 13 to 14 psi, it does not make any difference on the boiling point of the coolant—it will boil at the same temperature, whatever the altitude.

B. E. CLARKE  
ROOSEVELT PARK,  
SOUTH AFRICA

*You're right—our advice would only make sense for drivers of very old cars. But do remember that cooling efficiency is somewhat lessened at higher altitudes due to the thinness of the air.*

### Go With The Grain

I am a general contractor with several years experience repairing slate and tile roofed buildings. While I agree with many points raised by Mr. Vila ("Old House Restoration," page 34, Aug. '89), one important fact was left out. The slates currently available in many supply houses are inferior to old slates. Many slate quarries cut slate shingles without regard to the grain of the stone. When these improperly cut slates weather for a few years, they split, crumble and allow moisture penetration. When undertaking a roof project, the homeowner should insist upon antique slates or those split with the run of the grain.

BURK K. SHOTTON III  
DREXEL HILL, PA

### The Right Signal

Thanks for your April Audio column ("Better FM Reception," page 68). I bought an indoor antenna from Radio Shack for \$25 and it works great—pulls in stations I could never get with a rooftop antenna.

FRANK T. SCHUBERT  
OAK LAWN, IL

# TIME MACHINE

75 YEARS AGO: NOVEMBER 1914

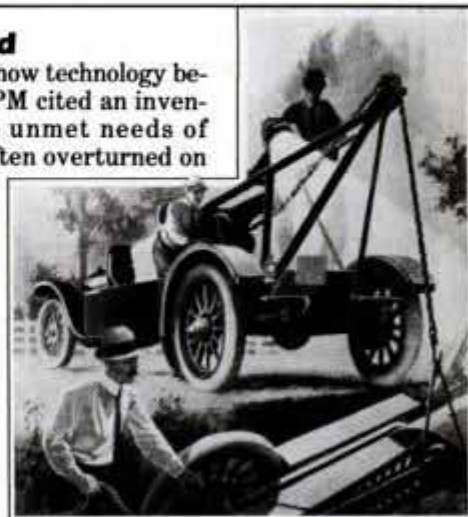


## Science Of War

The European conflict three-quarters of a century ago both fascinated and repulsed America—still untouched by the war. A lengthy analysis of battlefield technology concluded that the ends and means had changed little. Whether it was Roman catapults or German howitzers, the task remained to hurl dangerous objects at an enemy's lines in hopes of eliminating the ranks. Increases in range and firepower brought improved defenses—in war's deadly spiral.

## Motor-Minded

In one example of how technology begets technology, PM cited an invention to meet the unmet needs of motorists. Cars often overturned on the crude highways of a newly motorized America, requiring a machine to recover them. Enter the wrecker—angle-iron booms, a sheave for chain and a hand crank—fitted on the stern of a light truck.



50 YEARS AGO: NOVEMBER 1939



## Flexo-Train

The steamliner illustrated on PM's cover represented a technological refinement of an existing concept. The articulated train from American Car and Foundry Co. had an engine in each car so the locomotive could be lengthened or shortened according to distance and passenger load. As envisioned, small oil- or gasoline-burning engines in each car fired the steam boiler, and power would be transmitted via gearbox or through a hydraulic torque converter.

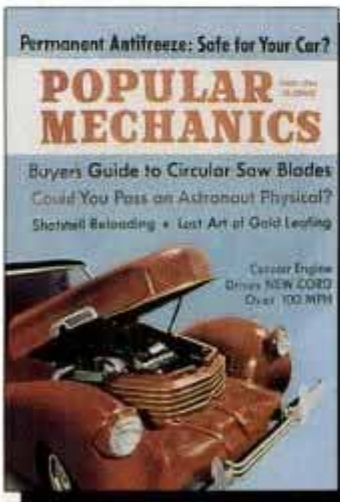
## German Juggernaut

PM editors had the November, 1939 issue complete before the Nazis' blitz began. Coverage of the German military modernization thus appeared timely with the introduction of a vehicle meant to settle the ongoing "wheeled versus tracks" debate. The German testbed had wheels that swung into position for high speed on improved roads, and tracks for

offroad work. It turned out that the Panzer divisions scarcely needed this trifling improvisation as they overran Eastern and Western Europe.



25 YEARS AGO: NOVEMBER 1964



## Golden Oldie

We drove the old and discovered the new with our first-impression report of the 1964 Cord—an  $8/10$ -scale remake of the 1930s classic. A front-mounted Corvair powerplant pushed our version, however, and the body panels were molded from a single sheet of plastic called Royalite. Laminations of weather-resistant plastic encased a durable core material which expanded under heat. A one-piece body mold pressed the plastic into shape and the Cord was reborn.

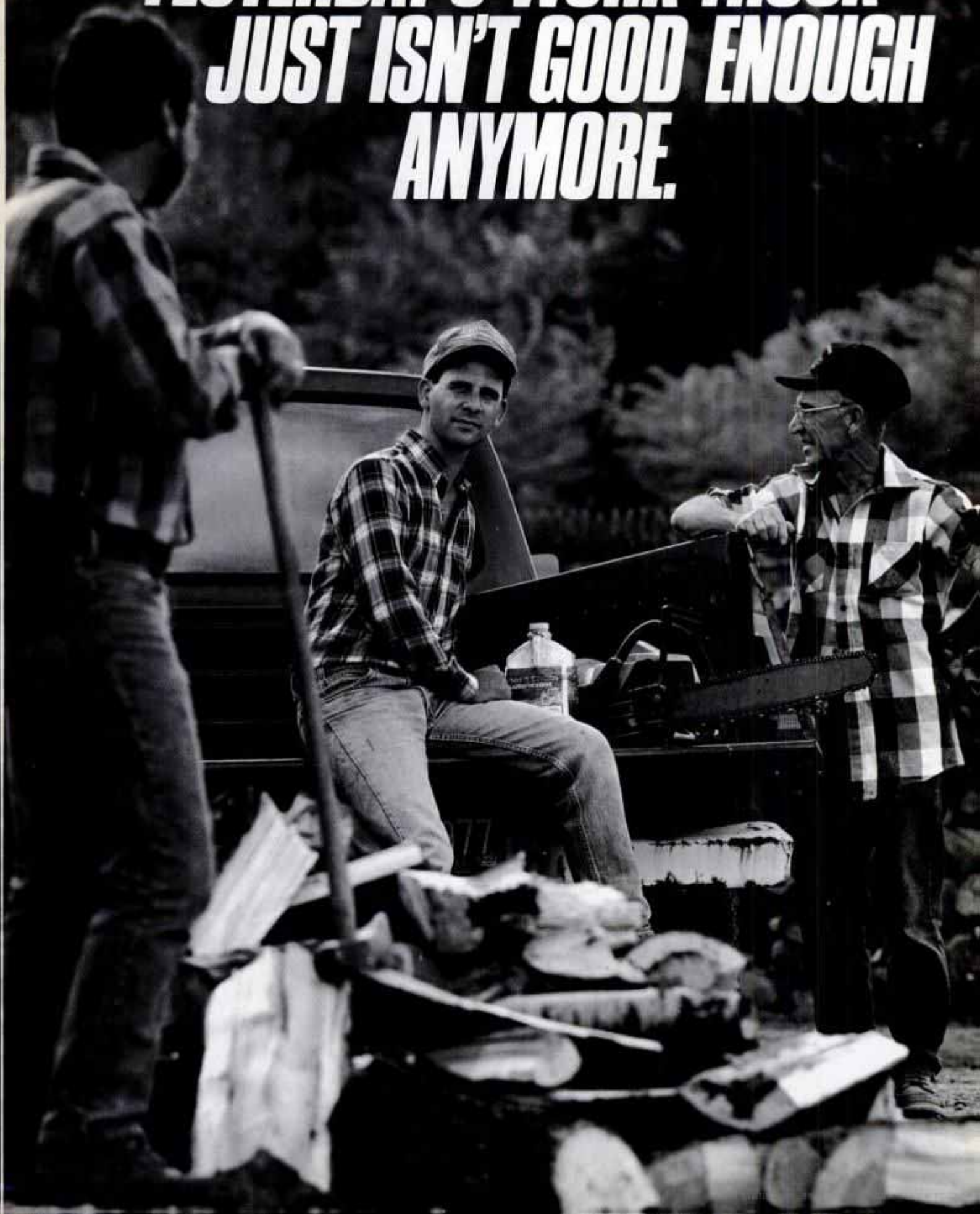
## Flying Flops

We also focused on an assortment of ingenious, but impractical planes. Among them: The XFV-1, launched vertically from its cruciform tail; the Goblin parasite

fighter, dropped from a bomber; and the Chance Vought Flying Pancake (below), reportedly able to hover in place. **PM**



***YESTERDAY'S WORK TRUCK  
JUST ISN'T GOOD ENOUGH  
ANYMORE.***



Yesterday's work truck isn't good enough anymore.

# TODAY'S NEW CHEVY WORK TRUCK

## 1 New Duragrille.

Chevy Work Truck's new grille is built strong to help resist stone damage. Because our new Work Truck has to do more than look pretty. It's built to work.

Yesterday's truck is history. Today's Chevy Work Truck is ready to go to work for you. Today.



## 2 More total cab room than Ford.

Chevy gives you more leg room. More shoulder room. More total cab room than yesterday's pickup from Ford. And when you add Chevy's excellent ride and visibility, that means a lot of comfort no matter where you work.



## 3 More standard 1/2-ton power than Ford.

Chevy Work Truck's standard 4.3L Vortec V6 puts 10% more horsepower to work for you than Ford's standard Six.

## 4 Heavier Gross Vehicle Weight Rating than Ford.

The 2-wheel-drive Chevy Work Truck's 5600-lb. GVWR, including passengers, cargo and equipment, beats Ford in working ability day in, day out.



## 5 More two-sided galvanized steel than Ford.

More of Chevy's body panels are made of two-sided galvanized steel, front, sides and rear. Including the cargo bed. So your Chevy will fight corrosion for years. Plus a hot-wax chassis treatment to help seal the frame from road salt and chemicals. You can't get that on a Ford.

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Let's get it together...buckle up.



W/T 1500

# OUTWORKS FORD 10 WAYS.

## 6 Bigger, heavier 4x4 frame than Ford.

Chevy's full box-section "Strongbox" frame construction up front is stronger than Ford's "C"-section. And Chevy's frame is bigger and heavier overall, too.

## 7 Two-tier loading Ford doesn't have.

Put 2x6 planks in the pickup wall grooves, and you've got a platform to carry just about anything. While your tools and other materials stay conveniently stowed underneath.



## 8 More ground clearance than Ford.

On site or off road, you need a pickup that won't leave you high-centered. And Chevy Work Truck's high-stance construction can take you over obstacles Ford's 1/2-ton pickup can't clear.



## 9 3-year/50,000-mile Bumper to Bumper Plus Warranty.\*

It covers hundreds of nonpowertrain parts 2 years longer than Ford's. Electrical parts. Chassis parts. In fact, everything but the tires, which have their own warranty.



\*See your Chevrolet dealer for terms of this limited warranty. A deductible applies after 12 months or 12,000 miles.



## 10 Standard Insta-Trac™ 4WD. No backing up like Ford.

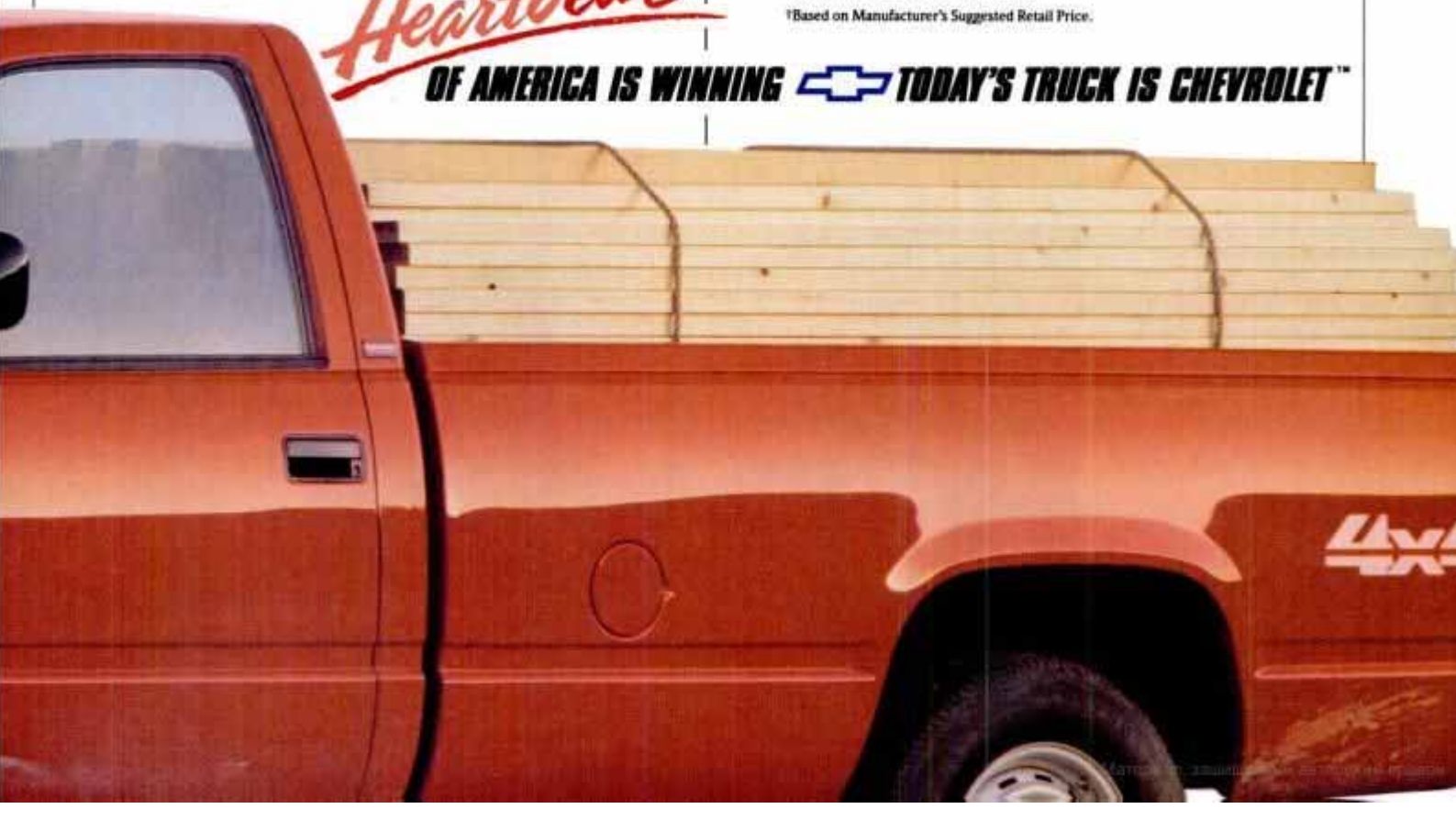
Just shift between 2- and 4-wheel-drive High and back, on-the-fly. Ford actually makes you stop and back up ten feet to go into freewheeling 2WD. And the new Chevy Work Truck is priced to work for hundreds less than the lowest-priced Ford.†

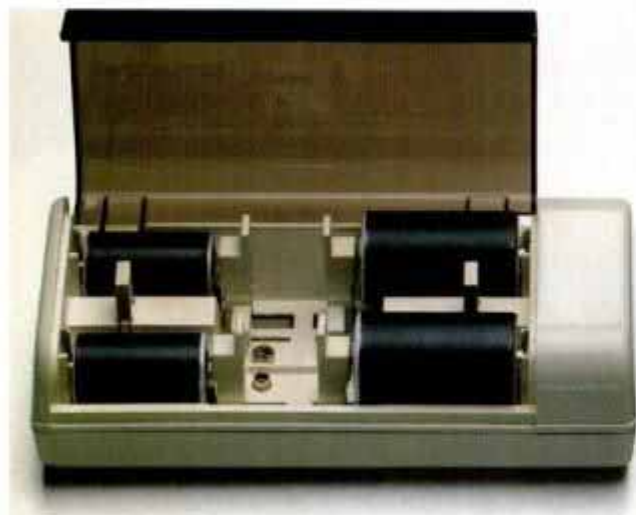
When it comes to working value, nobody's winning like The Heartbeat of America.

†Based on Manufacturer's Suggested Retail Price.

THE  
*Heartbeat*  
OF AMERICA IS WINNING

**TODAY'S TRUCK IS CHEVROLET™**





**14 Hour charge time**



**1 Hour charge time**

# You'll have to excuse our competition. They're a little slow.

Introducing the Eveready® Generator™ One-Hour Rechargeable Battery System: Eveready Generator one-hour rechargeable batteries and chargers. Just pop AA, C or D size Generator batteries into the Generator charger and the charger lets you know when your batteries are ready to use. You just need one hour!

That makes our Generator One-Hour Rechargeable Battery System up to 14 times faster than the others. So when you compare the Eveready Generator System with the competition, you realize *there isn't any.*



**EVEREADY.**  
**Generator™**

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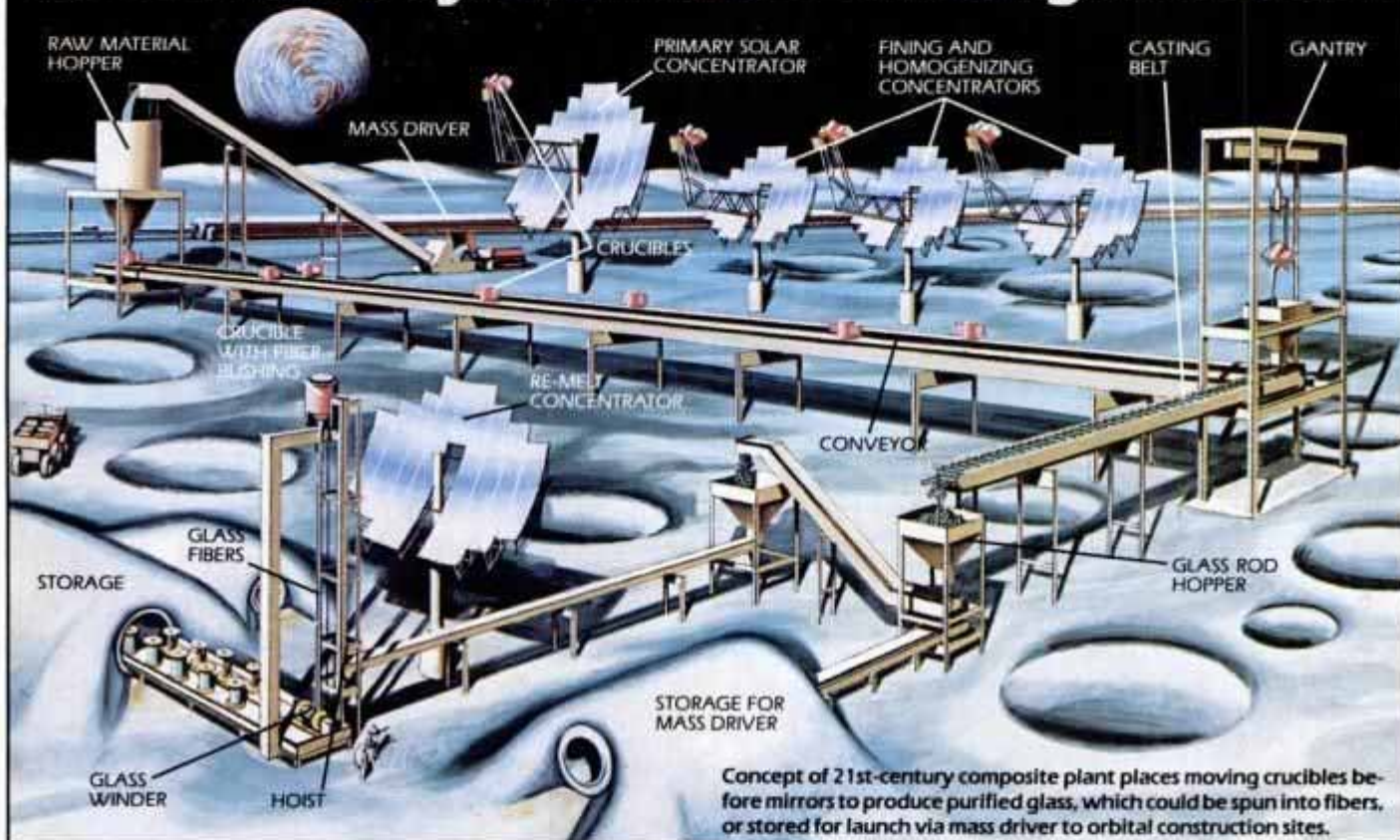
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# TECH UPDATE

News Of Tomorrow's Technology Today

## Moon Factory Will Make Building Materials



Concept of 21st-century composite plant places moving crucibles before mirrors to produce purified glass, which could be spun into fibers, or stored for launch via mass driver to orbital construction sites.

PM ILLUSTRATION BY ADOLPHE BROTHMAN

TORRANCE, CA—By spinning composite fibers from moon dust, a solar-powered installation now being studied by Goldsworthy Engineering, Alcoa, McDonnell Douglas and Princeton's Space Studies Institute could open the way to lunar colonization without importation of materials from Earth. The tremendous cost of such imports is the main obstacle to producing structures on the Moon.

Samples of lunar regolith brought back by the *Apollo* missions show the presence of large concentrations of feldspar and basaltic rock—substances that would produce fibers comparable in strength to terrestrial glass.

To make fibers, rock is first melted in crucibles held at the foci of parabolic solar

reflectors, then allowed to fall in thin strands through a platinum bushing, and wound onto spools.

The greatest challenge is producing substitutes for the organic resins with which fibers are normally impregnated. Current plans call for using a small reflector to fuse flakes of the fiber material into mats of fiber to produce solid panels.

The first plant landed on the Moon would probably be a lightweight version, with a single reflector adequate to produce fiber for simple shelters. Later, additional mirrors could be landed to maintain the temperatures for homogenizing and fining, or

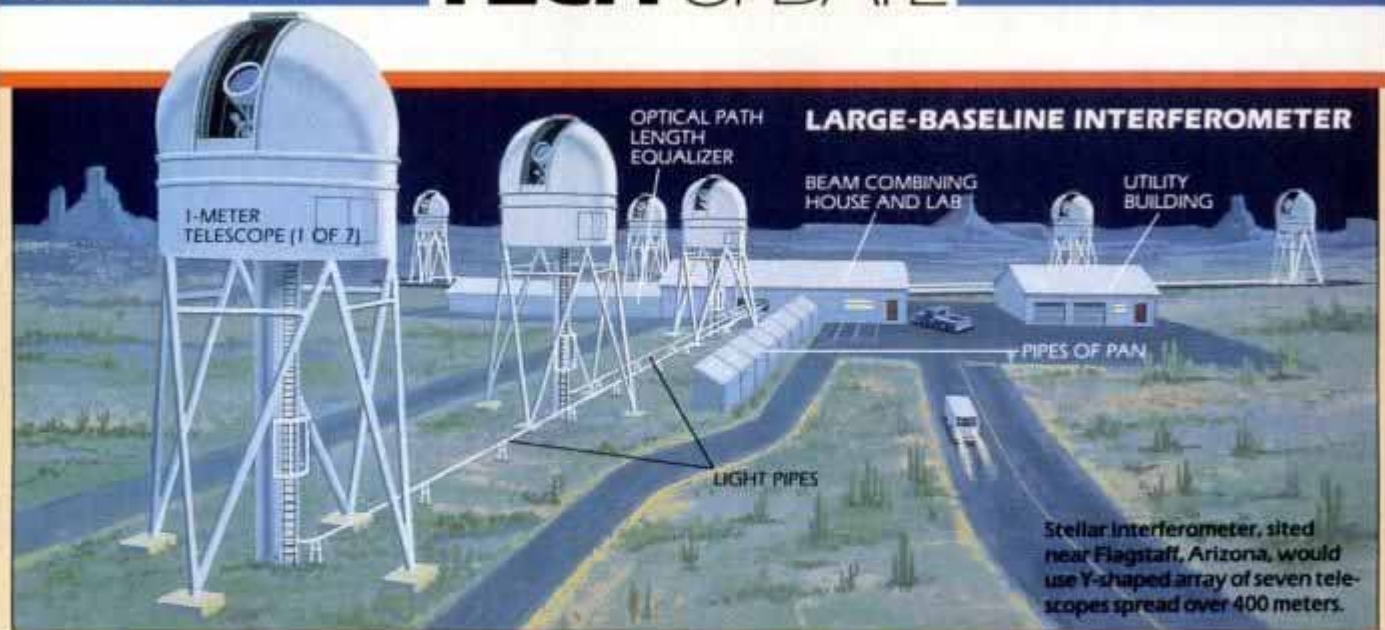
purification, of the glass. The resulting high-quality fiber

Moon with magnetic mass drivers to build space stations and satellites.

### Highlights This Month

- **Stargazing**—Computer-aided optics pierce Earth's atmospheric boundary.
- **Hypervelocity Impact**—Helium gun aids study of micrometeor hazards.
- **Biotechnology**—Living, manmade matrix replaces blood vessels.
- **Parallel Progress**—Innovative architecture speeds supercomputing.
- **Air Power**—Massive research effort spurs jet-engine advances.
- **Ocean Architecture**—35-story concrete barrier floated to North Sea platform.
- **Energy For Tomorrow**—Self-cooling reactors may revive nuclear power.

Editor: Tim Cole  
Assistant Editor: Abe Dane  
Contributors: Mike Fillory,  
Thomas G. Murphy



Stellar Interferometer, sited near Flagstaff, Arizona, would use Y-shaped array of seven telescopes spread over 400 meters.

PH ILLUSTRATION BY DEAN ELLIS

## Special Report: Optics Clear Air For Astronomers

NEW YORK, NY—Even as the launch date nears for the Hubble Space Telescope, astronomers are improving their ability to peer through the murky air that the orbiting observatory will take them beyond. Key is a new generation of optics that uses electronics to augment mirrors and lenses.

One example, called an adaptive optics coronagraph, is under development at

Johns Hopkins. Like a traditional coronagraph, it uses a mask, or occulting disc, to block light from the center of a star so the surrounding corona is visible. The new instrument, however, will add two computer-controlled mirrors to reshape distorted wavefronts.

After entering the instrument, light will strike a mirror of flexible Mylar stretched over a bundle of piezoelectric

actuators. These deform the Mylar in response to computer commands. A second, rigid mirror tilts to perform larger-scale corrections.

Information to control the mirrors comes from light screened out by the occulting disc, and reflected into a 4-pixel, or quadrant, CCD pickup, which feeds an IBM-AT computer. Meanwhile, the corrected corona image passes through an apodizing mask to screen out distortion from the telescope's structure, and strikes a 221,564-pixel CCD, which sends it to a computer for storage.

Another instrument, con-

ceived by teams at Georgia Tech and Georgia State University, could do certain basic



NASA PHOTO

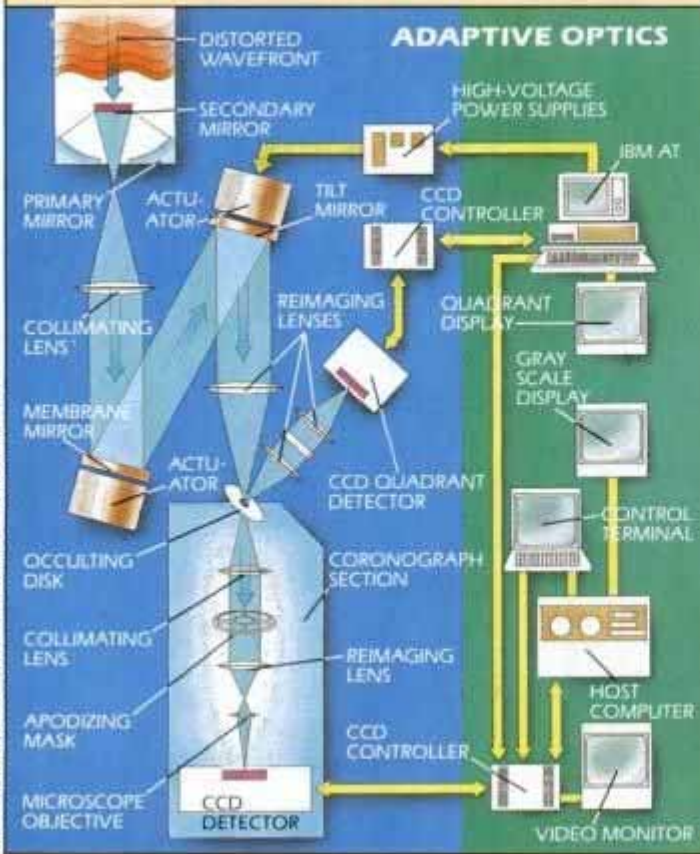
**CORONAGRAPH ON 1-METER TELESCOPE**

Final tests being performed on the 25,000-pound Hubble Telescope—the ultimate solution to atmospheric distortion.

astrophysical measurements more precisely than the Space Telescope. Called a stellar interferometer, it combines images piped from seven 1-meter telescopes. To compensate for differences in pipe length, each image passes through one of a set of fixed links known as pipes of pan, and into an optical path-length equalizer consisting of seven computer-controlled sliding mirrors. The array's 400-meter baseline enables the interferometer to achieve resolution equivalent to a 400-meter telescope.



Left: Computers (on green) adjust optics (on blue) for sharp coronagraph image. Above: Present version uses tilt mirror to perform corrections.



PH ILLUSTRATION BY ADOLPHE BROITMAN, JOHNS HOPKINS PHOTO

## HYPERVELOCITY GAS GUN



## Gun Simulates Micrometeors

BRISTOL, ENGLAND—The devastating energy of tiny space particles is being studied with a 10-meter gun that blasts samples with pellets moving at 7200 mph.

Power comes from helium pressurized to 2800 psi. Upon release, the gas forces a piston along a 35-mm tube with a copper seal at the far end. Pressure ruptures the

Physicist focuses 2-million-frame-per-second camera through port in impact chamber, releasing a 20,000-psi burst of gas.

Funneled into an 8-mm launch tube, the gas accelerates a polypropylene projectile toward an evacuated impact chamber, where a high-speed camera documents the results.

## Manmade Blood Vessel

CAMBRIDGE, MA—Biotechnologists have found a way to grow living tissue that could one day replace damaged blood vessels, without danger of rejection by the immune system.

Based on a speeded-up version of the natural tissue formation process, the technique involves adding immunologically neutral donor cells to a solution of proteins and nutrients which causes them to organize into a matrix. Blood vessels are formed by growing a matrix of smooth muscle cells in a layer around a mandrel. Outside this, connective tissue reinforced with synthetic mesh is grown. Then the mandrel is removed and a lining of endothelial tissue, which prevents blood clotting, is added to the interior.

In years to come, the vessels could be implanted to treat conditions such as stroke and arteriosclerosis.

### VESSEL STRUCTURE



Matrices of donor cells are grown in nutrient vials at Organogenesis, Inc. (below), forming layers of living blood vessel equivalent (above).



## Shield Aids Orbital Experiment

HOUSTON, TX—A simple panel of metal towed alongside an orbiting Space Shuttle will multiply the vacuum of space a millionfold, pro-

ducing a near-perfect environment for the deposition of ultrapure semiconductors.

Now being built at the University of Houston's

Space Vacuum Epitaxy Center, the wake shield facility consists of an electropolished stainless-steel skirt surrounding a chassis that holds equipment to perform molecular beam epitaxy, a method

of depositing thin, highly ordered crystalline films.

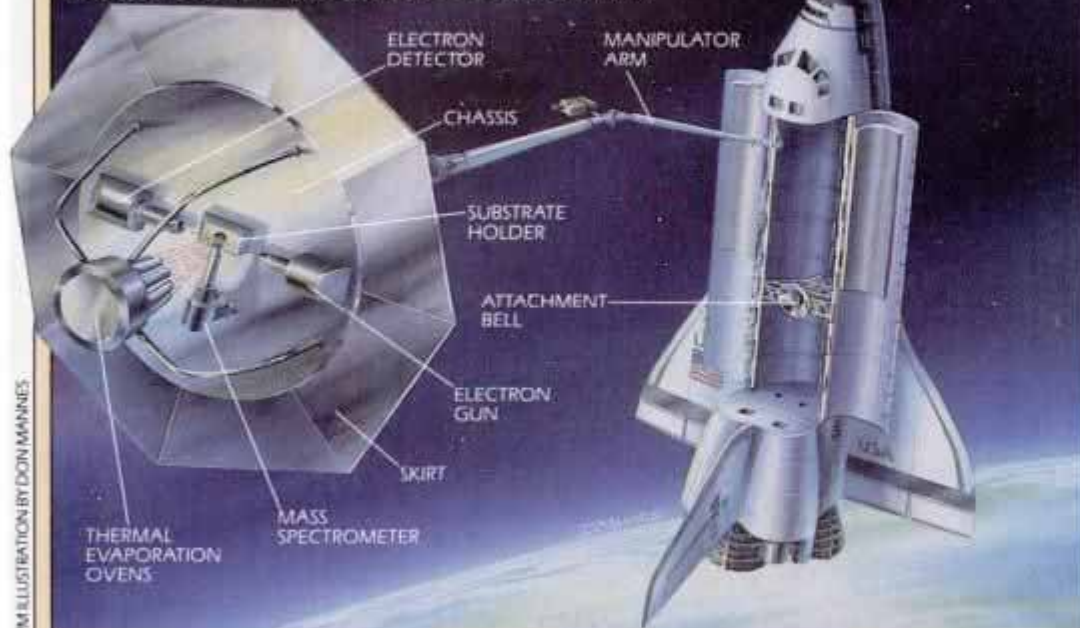
Scheduled for launch in January, 1992, the shield will be extended from the Shuttle's cargo bay on the remote manipulator arm with the craft in orbit 200 miles up. Traveling at about eight times the speed of orbital gas particles, the shield will sweep a conical area evacuated to  $10^{-17}$  atmospheres. (The best vacuum chambers achieve only  $10^{-14}$  atmospheres, and are too small for epitaxy).

Thermal evaporation ovens will emit beams of gallium arsenide toward a carousel holding seven 3-in. substrate wafers.

As deposition progresses, a mass spectrometer will measure the ovens' atomic flux, and an electron detector paired with an electron gun will track the quality of the growing films.

The result of this project is expected to be semiconductor films with unique electro-optic qualities.

### WAKE SHIELD ULTRAVACUUM FACILITY



Wake shield trailing alongside Shuttle sweeps ultravacuum path through orbital gases.

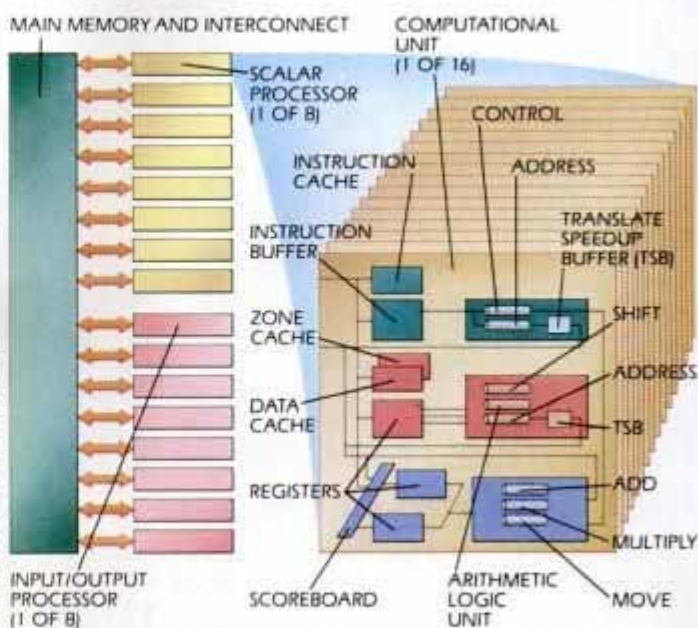
## Parallel Super-computer

MOUNTAIN VIEW, CA—A new American competitor has entered the supercomputer field with the first machine to use parallel processing. Evans & Sutherland's ES-1 has eight processors with 16 computational units each. These cooperate to solve individual parts of problems simultaneously. Other supercomputers use sheer processing muscle to race through one instruction at a time. Unlike massively parallel computers using thousands of processors, ES-1's moderately parallel structure works with conventional software.



ES-1 circuitry (above) has up to 128 computational units. In flow diagram (right), units shunt commands from green instruction area into blue floating point and red integer areas for processing. Data from main memory is prefetched into high-speed cache memory, and even higher speed register memory, so processors aren't kept waiting.

### MODERATELY PARALLEL ARCHITECTURE



## Consortium Aims To Double Jet Performance

WRIGHT-PATTERSON AFB, OH—An initiative overseen by NASA and the Department of Defense is marshalling the nation's resources to perfect jet-engine technologies at the heart of continued air superiority.

Dubbed the Integrated High Performance Turbine Engine Technology (IHPTET) Initiative, it will focus on advanced materials, structural design and aerothermodynamics. The goal is to produce engines twice as capable as the best now in use by the turn of the century.



Instrumented-technology demonstrator engine is fired up to test IHPTET components.



The turbine blades (above), each one a single crystal of alloy, are latest materials technology. Burner (right) tests future alloys.

Materials under study include metal matrix composites reinforced with ceramic fibers, ceramic matrix composites that overcome the brittleness of monolithic ceramics, and coatings that permit the use of high-specific-strength carbon-carbon composites in severe environments.

Advances in aerothermodynamics brought about by

supercomputer simulations will guide designers in making optimum use of the new materials. Compressor rotors with integral, swept airfoil, hollow composite blades would develop higher pressures in fewer stages. Afterburners could be eliminated by combustors that operate at highly efficient, near-stoichiometric temperatures. And improved turbine sections would reduce thrust lost to cooling. Historically, strides in engine development have paced progress in aircraft performance. Spinoffs from IHPTET will be the key to planes ranging from

the advanced tactical fighter to 21st-century hypersonic craft.



Computer model tests aerothermodynamics. Pressures are highest in blue, lowest in orange.

EVANS & SUTHERLAND PHOTO

PM ILLUSTRATION BY MARIO FERRO

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Материал заготовлен

## Mammoth Wave Barrier

STAVANGER, NORWAY —Phillips Petroleum has floated a 700-million-pound concrete seawall—the largest of its kind—into place around an oil and gas processing platform 180 miles off the coast of Norway. Rising 348 ft., or nearly 35 stories, from the ocean floor, it will protect against towering North Sea storm waves. The project was begun in 1985, after it was discovered that gradual subsiding of the sea bottom would lower the platform dangerously close to the water's surface. In June of this year, a convoy of 17 tugs towed the barrier's two

halves more than 300 nautical miles from Alfjorden, Norway. After waiting for a 72-hour spell of calm weather to be forecast, they maneuvered one half up to the platform's western side, where it was partially ballasted with seawater. The eastern half was pulled into place and partly ballasted as well. Then the barrier's underbase was grouted, and its halves joined with steel plates and concrete.

With the two halves se-

## MATING BARRIER HALVES

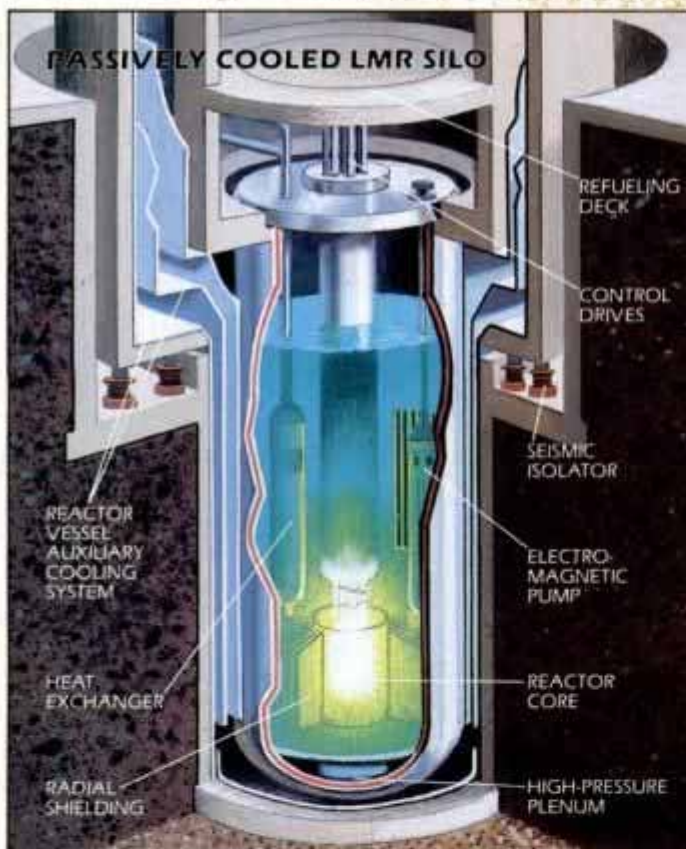


PHILLIPS PETROLEUM PHOTO

curely mated, an upper screen wall was erected, and a final load of solid ballast, consisting of sand and rock,

was added. Thus completed, the structure's weight now totals close to 2 billion pounds.

## Passively Safe Breeder Reactor Powers Tomorrow



PH ILLUSTRATION BY DEAN ELLIS

Coolant in PRISM liquid-metal reactor is circulated by electromagnetic pumps. External air channels provide cooling in emergencies.

SAN JOSE, CA—A new generation of safe nuclear reactors is being studied to meet 21st-century power needs. Relying on passive cooling features, they need no human intervention or external power to cool in an emergen-

cy. Among the most promising is one called PRISM (Power Reactor Inherently Safe Module), a small, liquid-metal cooled breeder reactor designed to be ganged into a complex comprising nine modules which are sunk into

below-ground silos.

In an emergency, the reactor would self-cool by engaging a passive reactor vessel auxiliary cooling system. This consists simply of air channels surrounding the containment vessel. The natural convection in these channels would maintain safe temperatures even if a massive structural failure blocked 90 percent of the airflow.

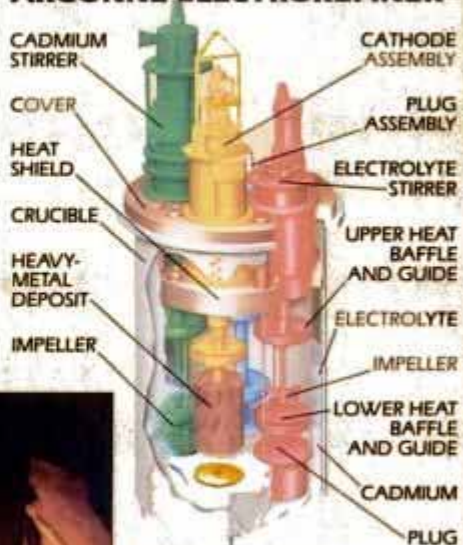
To be economical, the PRISM system would require

facilities to recycle the fissionable products of its breeding capability into usable fuel. Argonne National Laboratories is developing a process called electrorefining to meet this need. Fuel rods, removed from the reactor after a certain percentage of their

fuel content was spent, would be dissolved in a 900° cadmium bath. There, high-temperature electrochemical activity would cause ions of plutonium and uranium to be deposited on a cathode, from which it could be removed for reuse.

The resulting closed-loop fuel cycle would allow the PRISM reactor to operate with only small additions of new fuel, and relatively little nuclear waste.

## ARGONNE ELECTROREFINER



Heat and electrochemical activity produce heavy metal deposits on cathode of electrorefiner (above). These are cast into fuel rods (left).



ARGONNE NATIONAL LAB ILLUSTRATION; ARGONNE PHOTO

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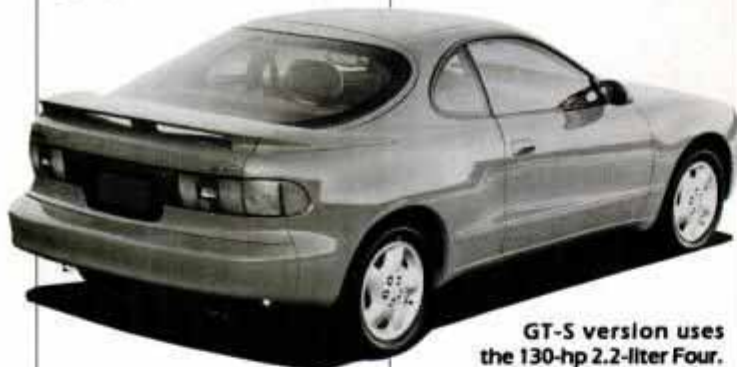
BY BILL HARTFORD

## Unto The Fourth And Fifth Generation

**C**ELICA. It's not a name out of the Old Testament. It just seems like it's been around forever. It goes back to when the Japanese started writing the bible on how to build efficient and exciting small cars. Even before there was a column in PM specifically devoted to imported cars, there was a Toyota Celica. In fact, in the same issue that "Imports" debuted (Jan. '73), there appeared one of PM's exclusive Owners Reports—on the Celica ST (page 86). In that survey we talked to owners of the sporty '71 and '72 models, the



Toyota Celica: Fifth generation, seen here in All-Trac Turbo bodywork, puts a new shape on the road.



GT-S version uses the 130-hp 2.2-liter Four.

first years for Toyota's newly created specialty-car category. At that time, the 97-hp ST was the only model with the Celica nameplate. Owners bought it for the styling, and 88 percent judged workmanship to be good to excellent.

### 1990 Celicas

The fifth-generation Celica is a full line of models, with the top gun rated at twice the hp of the original ST. The other impressive power specs are for the sound system—220 watts from six amplifiers, driving 10 speakers, giving a maximum sound pressure level of 112 dB. You can call it the Woodstock option, but Toyota pegs it simply as System 10, since it was developed with

the Fujitsu Ten Corp. The killer sound system includes CD, graphic equalizer and alterations to the car itself, like a so-called double-labyrinth seal at the window glass to turn the doors into giant subwoofers.

The base model ST uses the 1.6-liter, twin-cam, 16-valve Four (103 hp); the GT and GT-S Four displaces 2.2 liters for 130 hp; and the All-Trac 2.0-liter is turbocharged for 200 hp.

### Honda Accord

June 1976. Some new-car introductions you never forget. The Accord's was one. First drive for the press in the 3-door hatchback was a competition. For taking first place in the slalom, I brought home a

top-line CB (remember CB radios?).

After such glory, I couldn't help but think this is one impressive car. I wasn't the only one impressed. In '79, when the 4-door arrived, it became the standard for sedans that pleased the senses and made sense in every way.

For 1990, the fourth-generation Accord is here. Styling changes are subtle, with un-

### EX For Exodus

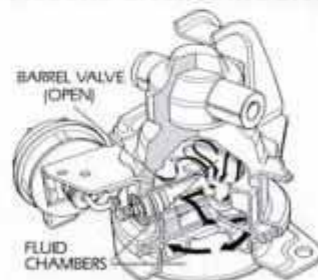
Three Accord models are available and already in Honda dealerships. The DX and LX mount a new 2.2-liter, single overhead-cam, fuel-injected, 16-valve Four rated at 125 hp. In the EX, this new engine is fine-tuned for get-up-and-go with a dual exhaust system and 130 horsepower. Foot to the floor and you're outa here. **PM**



Honda Accord: Fourth generation is faster and further refined.

covered halogen headlights being the most visible change. All dimensions are increased (wheelbase and length by roughly 5 in.) and the greenhouse is larger. Refinements abound, right down to an electronically controlled engine mount that soaks up vibrations at idle (under 850 rpm) by filling two hydraulic chambers. At driving speeds, the mount firms up by closing off one of the chambers.

### ACCORD ENGINE MOUNT



At idle, two chambers fill to damp low-frequency vibration.



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See NASA Tech Briefs for technical details, 1986, 1987 and 1988.

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# OUTDOORS

BY JOE SKORUPA

## Final Run For A Speed Legend

**C**RAIG ARFONS, of Sarasota, Florida, died on July 9 from injuries sustained during a boat crash at more than 400 mph while attempting to set a world speed record. The pursuit of speed was in Craig's blood from an early age. His father Walt and uncle Art started the Arfons' family tradition in 1949, building the first of many *Green Monster* speed machines. Craig began traveling with them by the age of seven, but showed no early interest to follow in the Ohio-based family footsteps.

Walt and Art achieved many milestones that brought them fame and footnotes in record books. But their efforts really paid off in 1964, when they each set land speed marks on the Bonneville Salt Flats.

Walt went on to achieve another record the following year, averaging 336 mph in the standing mile. But the pursuit was taking a toll on the racer's family. In 1965, Walt announced he was finished with Bonneville. He continued drag racing for several years, but gave it up, too, in 1970.

Craig was busy working for nonracing family businesses during this time. But he was restive. In 1975 he was offered the opportunity to race jet dragsters and



Fastest man on the water: Craig Arfons 1949-1989.

jumped at the chance. Like his dad and uncle, Craig climbed to the top and set many records, including 324 mph in the quarter-mile.

"My whole life has been a *POPULAR MECHANICS* kind of life," he said to me one day at dinner last July. "I'm really glad you're going to be a part of this."

He was referring to his imminent water speed record run on Lake Jackson, in Florida. As we got to know each other, I came to understand

exactly what he meant.

"We have a family rule that says you have to build it to drive it," Craig explained one day. "But driving is also a big thrill, because when I get in the boat and strap myself in, I feel one with the machine I've created."

Craig invited me to become a member of the crew for his run for glory. He and partner David Loebenberg even painted the PM logo on the side of the sleek 3-point hydroplane.

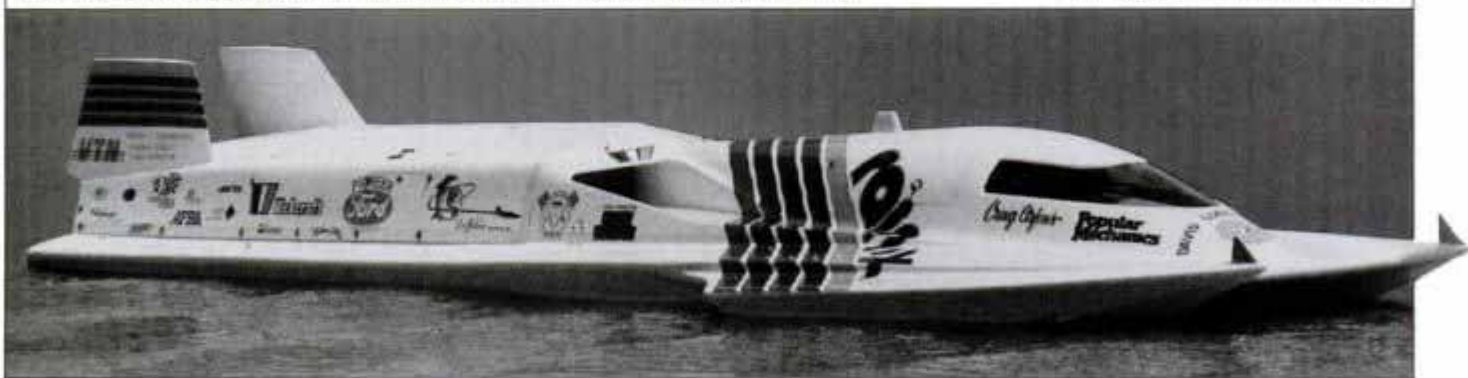
On Saturday, July 8, Craig made two aborted attempts to shatter Australian Ken Warby's 317-mph record. Conditions were too rough.

Sunday, however, was perfect. At dawn, Craig lit his GE J85-17 jet engine and seconds later punched the afterburner. But Craig burned the AB too long. Sponson walking commenced at about 350 mph. Beyond 400 mph the boat aired out—lifted from the water and bounced back down. In an instant the boat kited, and exploded into pieces as it somersaulted on the deadly water.

Paramedics pulled Craig from the enclosed cockpit and resuscitated his heart on the way to shore. In the ambulance, he was put on life-support systems. But his internal injuries were severe and he died shortly after reaching the hospital.

Craig's 18-year-old son, Chad, called him a "genius," and few who knew him would doubt it. I know he was one of the most courageous, intelligent, imaginative people I've ever met.

To his family and friends, of course, Craig was more than this. He was the father of two children, a member of a wonderful family, and a straightshooter to all he met. And he sure did know how to build magnificent machines. Craig, you'll be missed. **PM**



Arfons' sleek 26-ft.-long, 32-in.-high hydroplane, with a Kevlar-reinforced cockpit cell, was powered by an F5 Freedom Fighter jet engine.

Available at most large JCPenney stores. Prices higher in Alaska, Hawaii and Puerto Rico. © 1989 JCPenney Co., Inc.



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**Best-built American cars.**

The best-built American cars are built by Ford. This is based on an average of consumer-reported problems in a series of surveys of all Ford and competitive '81-'89 models designed and built in North America. At Ford, "Quality is Job 1."

All 1990 Mustangs are equipped with a driver air bag supplemental restraint system.

# Ford Mustang GT

Have you driven a Ford...lately?



# DETROIT SPY REPORT

BY JIM DUNNE

## Saturn Project Nears Production Readiness

**A** SPY SHOT, snapped near General Motors' Mesa, Arizona, proving grounds, shows that the new Saturn subcompact line of cars is all but ready for the assembly line.

Although tooling is not yet in place at GM's new Spring Hill, Tennessee, Saturn production facility, all indications are that the project is on target for its intended October 1990 introduction.

The prototype seen here is Saturn's formal 4-door sedan. Though the coupe version of the car is much sportier, both Saturns reflect current General Motors small-car styling trends.

Bodywork of the new cars will also be in keeping with recent GM manufacturing innovations—plastic panels mounted over a steel subframe. The technique was pioneered with the Pontiac Fiero and is used today with the new GM APV minivans.



Saturn 4-door sedan appears to be final engineering and styling sign-off prototype.

The character line running down the middle of the body sweeps upward from the front to the rear, starting at the midpoint of the front wheel well and passing over the top of the rear wheel opening.

A severe slope to the wind-

answer seems to be yes.

Along with some of the more expensive Japanese sedans like Maxima, Mazda 929, Lexus and Infiniti, the newly styled Pontiac displays a marked similarity to the German luxury cars.

A sloping hood drops down to cat's eye headlights in front, while the angled C-post dominates the shape at the rear.

Fixed quarter windows in the doors allow glass to drop completely out of sight when lowered.

The Cadillac pull-type door handles are gone, replaced by conventional flip-up releases that blend in with the surface of the door.

Overall, the body has a smooth, rounded appearance, without the severe aero look of Taurus or Audi.

### Low-Cost Computers

It's one way Chrysler Corp. product planners hope to reduce car prices.

The addition of computer controls to automobiles has come at an uneven pace in recent years. Now, Chrysler is taking a longer look at what is needed, and how to cut the costs of computers.

Here's their plan: Use only three main computers for a car, each to handle a major system. One takes care of the engine—including spark and valve timing—plus transmission shift points and fuel delivery.

A second is used for chassis control—shock absorber damping rates, power steering effort, antilock brakes

*(Please turn to page 33)*



Buick's 1992 Skylark reflects evolutionary change.

### Subtle Skylark

If you are expecting something revolutionary to come out of GM styling for the future Buicks, you will probably be disappointed in the cars that actually reach showroom floors.

Spy sightings of the 1992 Skylark show that the Buick subcompact will have a mixture of themes in its coupe styling, rather than one strong central theme.

The front end is dominated by a scoop-shovel grille, while the roof has an all-glass look at the rear.

shield glass puts the wipers out in the open, atop the hood line. Large, composite headlights are arranged in a line along with side marker lights, turn signals and parking lamps to form a wide band of reflective glass on both sides of the grille and around the front fenders.

### Bonneville, 1992

Has BMW found the ultimate styling secret for 4-door sedans? Judging by the number of apparent imitators, a list that seems to include the 1992 Pontiac Bonneville, the



Pontiac Bonneville for 1992 suggests BMW influence.

# Interplak cleans circles around your ordinary toothbrush.

The Interplak® Home Plaque Removal Instrument is one of the most important advances in home dental care since the invention of the toothbrush.

It doesn't look like an ordinary toothbrush. And it doesn't work like one.

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## It cleans teeth nearly plaque-free.

Clinical studies show that manual brushing removes only some of the plaque that builds up daily on your teeth.

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Dental professionals across the country have enthusiastically endorsed the Interplak instrument and they've recommended it to their patients. It's even accepted by the American Dental Association.

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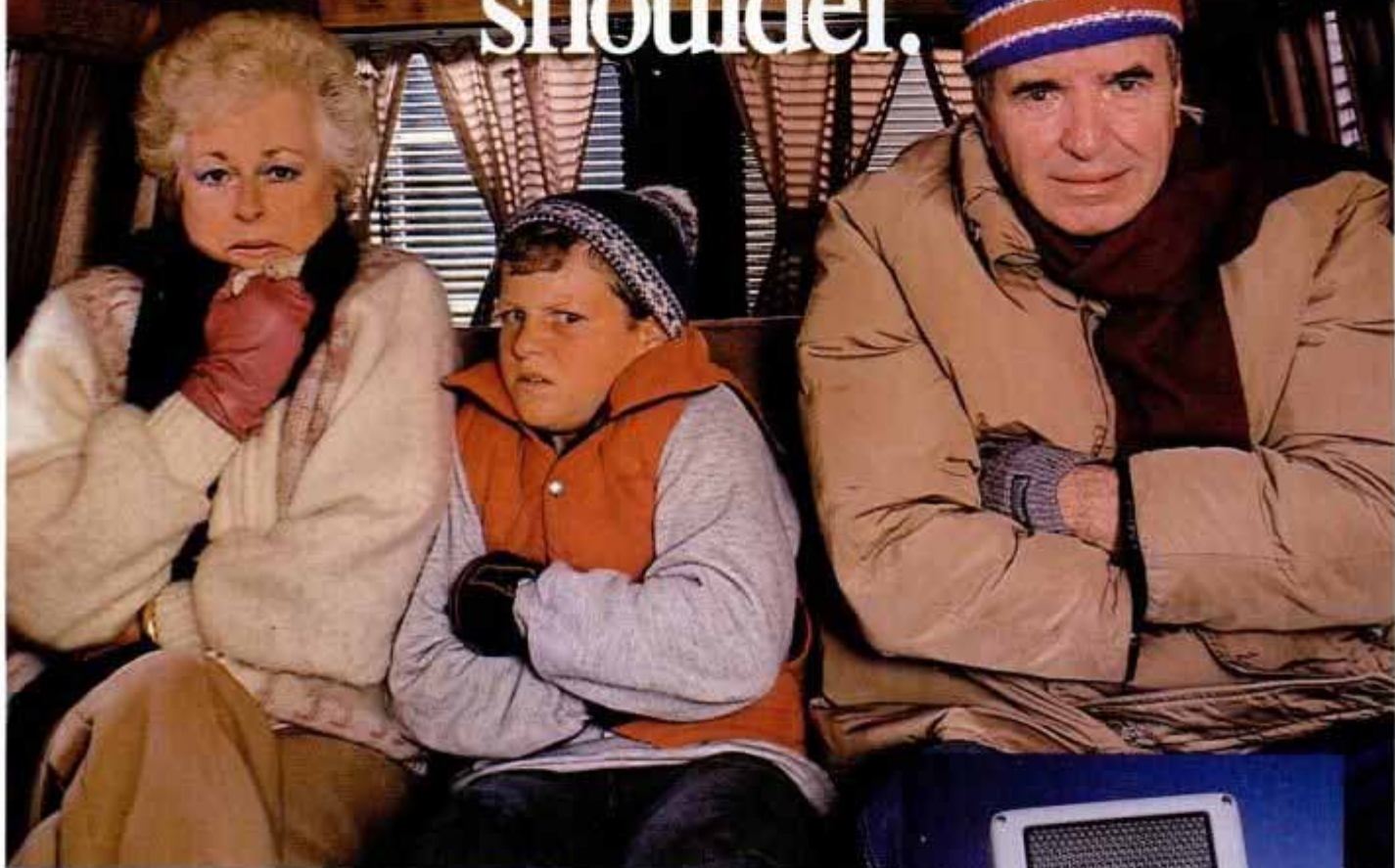
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and traction control. The last is slated for body functions like travel information and climate control.

Chrysler executives report that the cost of computers has dropped significantly from the \$500-\$600 per car of five years ago, and that, along with a more orderly use, will help keep car prices level.

### Truckin' With LEDs

Truck trailers will soon have a new type of side marker light to help define their clearances.

Light-emitting diodes (LEDs) may replace regular lightbulbs on big rig trailers if current road testing is successful.

The LED markers are said to last more than 10 times longer than standard lightbulbs, and are more resistant to damage from vibration. Costs are expected to be less too, after all maintenance and replacement figures are weighed together.

If the LED side marker experiment works out, look for LEDs to wink on all over 18-wheelers. Brake lights will probably be the next candidate for LED replacement.

### GM's V6 Trend

Faced with the prospect of tighter fuel-economy standards in the years ahead, GM seems to be stacking its chips behind V6 engines as the best compromise between horsepower and fuel efficiency. The General's 1990 array of cars reflects this trend. Some 54 percent of GM's new cars will be powered by V6 engines, compared to 29-percent 4-cylinders and only 16-percent V8.

The various V6s are spread across almost the entire range of GM models, which means that Fours are limited to the smaller end of the spectrum and V8s to Cadillacs, Corvettes, Caprices, Camaros and Firebirds.

### Add-On Antilock

It costs about \$250 less to install an add-on antilock brake system in a car than it does to integrate antilock into the original design of the chassis.

That report comes from Chrysler, where they figure that an antilock built into the chassis of the car from the start inflates the showroom price by \$800, while the add-on design runs about \$550. The reason: Antilock suppliers are becoming smarter about fitting systems to cars without the auto company making major changes to body, frame, braking layouts and underhood packaging.

As a result, Chrysler has begun asking its antilock suppliers to fit their systems to the cars that are already being produced, instead of having the suppliers ask Chrysler to redesign cars to accept a generic antilock system.

### CHMSL Scorecard

If you've been wondering how effective those center-mounted stop lights on newer cars have been, here's the answer. A study by NHTSA reports that rear accidents in 1987 model cars—those equipped with center high-mounted stop lights—declined 17 percent from the average for earlier model cars without the lights. The conclusion is that the stop lights made the difference.

### Allanté Grounded?

Rumors suggest that the unique air bridge that carries Allanté bodies be-

tween Turin and Detroit will be stopped within a year, if it has not already been canceled.

Slow sales of the Allanté are said to be the reason for the change. Cadillac reportedly is figuring that the air shipment in 747s specially equipped to handle the Pininfarina bodies is too costly when measured against the low number of bodies needed for production.

If the Allanté skytrain is grounded, Cadillac will either institute a conventional sea/rail shipment system from Italy or attempt handling the bodywork at home in Michigan. **PM**



Since radar displays only one number, the operator has the responsibility to decide which vehicle is being clocked.

## Why radar makes mistakes. How to protect yourself.

It's hard to believe, but traffic radar does not identify which vehicle is responsible for the speed displayed. It shows only a speed number. The radar operator must decide who to blame.

#### How radar works

The radar gun is aimed at traffic and it transmits a beam of invisible radar waves. Moving objects reflect these waves back to the radar gun. Using the Doppler principle, the radar calculates speed from the reflected waves. But there's a problem.

#### The best guess

Remember, these reflections are invisible. And truck reflections can be ten times stronger than car reflections. How can the operator know for sure which vehicle is responsible for the number?

The truth is, in many cases he can't be sure. The result? You can be ticketed for somebody else's reflection.

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# ELECTRONICS

BY STEPHEN A. BOOTH

## Filmless Photography Arrives

**J**UST THREE years ago this fall, POPULAR MECHANICS reported Canon's debut of the first filmless camera for professionals ("Electronics," page 56, Sept. '86). Now, filmless point-and-shooters for amateurs are here, courtesy of Canon and Sony.

Like their professional cousins, the Canon Xap Shot and Sony Mavica record color images on a magnetic disk, for instant retrieval and review on any TV. Compared to film cameras, their price is high—about \$1000.

In conventional photography, the light-sensitive chemical film serves as both the pickup device and the storage medium when it is exposed to images admitted through the camera's lens. Once the film is exposed, it can't be reused—and until it is processed, it can't be displayed.

With still video cameras no processing is required because they use a magnetic disk instead of film. Much like videotape, images recorded on the magnetic particles may be retrieved and displayed immediately after exposure. The magnetic storage medium also may be erased, and reused to record new images.

Although the magnetic disk is still video's image-storage medium, the image pickup device is a small microprocessor chip mounted behind the camera's lens. In the same manner as video cameras and camcorders, the pickup chip reads lightwaves admitted through the lens, then converts them to electrical signals for magnetic storage.

Although the 47mm-dia. disk is called a video floppy, it's actually housed in a hard, 2-in.-sq. plastic shell about the size of a 35mm slide in its mount. Only one side of the floppy is used for recording. Despite this, there's room for



New, all-electronic still video cameras from Sony (above) and Canon (right) record images on magnetic disks instead of film. The images are displayed directly on a TV monitor—no developing is required.

up to 50 images, each recorded on a concentric track, beginning with Track 1 at the circumference and ending with Track 50 near the center of the disk. Not surprisingly, the tracks are quite narrow—only 60 micrometers wide, or 24 ten-thousandths of an inch. A 12-micrometer blank band separates one track from the next. The disk spins counterclockwise at 3600 rpm and costs about \$8.

Each recording track can hold a single TV field of 262.5 vertical scanning lines. In the NTSC system used in the United States and elsewhere, a full TV frame consists of two interlaced fields, for a total of 525 lines. At this writing, all amateur still video cameras record single-field images only. Some pro cameras can record 25 full-frame images.

Despite single-field recording, on-screen image quality is quite good, because amateur SV cameras use the High-Band recording system similar to that of the Super VHS and High-Band 8mm motion video formats. Theoretically,

High-Band recording should yield horizontal resolution of up to 560 lines. In practice, though, Xap Shot and Mavica record 300 lines—still better than conventional videotape's roughly 240 lines.

### Easy to use

Another area where Xap Shot and Mavica differ from their professional forebears is in user convenience. With each SV camera, the built-in disk drive records images and plays them back. Earlier pro models required a separate deck for playback. Instead, the amateur SV cameras connect directly to a TV monitor through a combination AC adapter/battery recharger and video-input cable. In Sony's case, the unit is called a playback controller, and includes pushbutton controls for operating the Mavica. These controls are duplicated on an infrared remote. With Canon's Xap Shot, all controls are built in.

In size and physical appearance, Xap Shot and Mavica resemble compact binoculars—

with a single lens. Each weighs in around 1 pound, including its built-in rechargeable battery. Xap Shot uses an 8-volt lead-gel battery while Mavica has a 6-volt NiCd. Each is rated for about 500 exposures, or 250 with flash, and recharges in about an hour.

As you might expect in a point-and-shoot camera, all exposure functions are automated—including flash. Focusing is not automatic—it's fixed. Everything beyond 3 ft. is in focus with Xap Shot, 4.5 ft. with Mavica. A macro-switch lets Xap Shot focus as close as 1 ft. Mavica requires a macroconverter lens.

In specifications, Xap Shot's 11mm f/2.8-22 lens offers shutter speeds from  $\frac{1}{30}$  to  $\frac{1}{500}$  sec. The shutter speed of Mavica's 15mm f/2.8-16 optic ranges from  $\frac{1}{60}$  to  $\frac{1}{500}$  sec. The 11mm and 15mm focal lengths do not represent superwide-angle lenses. They're actually the equivalent of about 60mm in a film camera. Why the low measurement? Because the chip that serves as the focal plane of an SV camera has a smaller area than a 24x36mm film frame. To calculate the film-camera equivalent of an SV lens, multiply its focal length by 4 for a  $\frac{2}{3}$ -in. pickup (Mavica) and by 5.33 for a  $\frac{1}{2}$ -in. chip (the diagonal measurement of Xap Shot's chip). Another area of comparison with film is the light sensitivity of SV cameras.

For both Xap Shot and Mavica, flash sync speed is  $\frac{1}{125}$  sec., triggered automatically. In terms of film speed, the SV cameras have a rating equivalent to ISO-100. In an age of ISO-3200 and faster films, this is quite slow. But SV cameras probably will increase their light sensitivity rapidly, much as motion video camcorders did. **PM**

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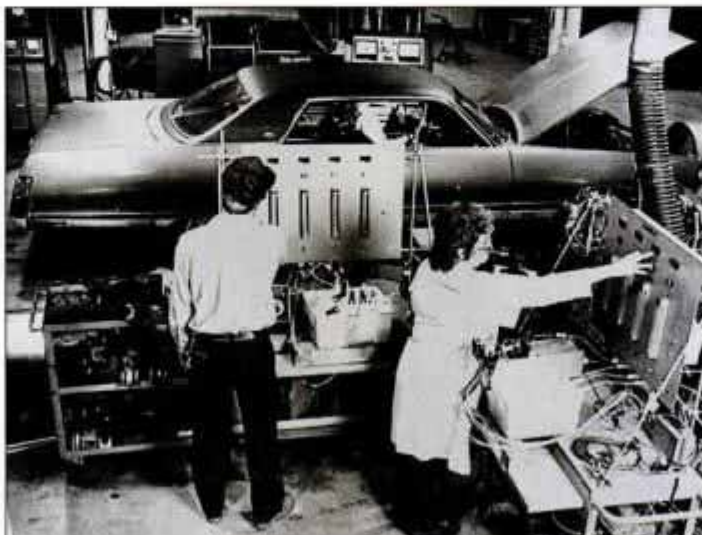
## Cleaner Gasoline Comes On Line

**A**IR POLLUTION and fears of future gas shortages may seem to be pushing gasoline to the verge of obsolescence. But don't count big oil out too soon. Pressured by calls from President Bush and Southern California regulators for alternative-fueled vehicles, the industry has suddenly pulled out an ace they may have had up their sleeve for a while. Arco calls it Emissions Control-1, EC-1 for short, and they say this reformulated version of gasoline reduces air pollution from pre-1975 cars by 15 percent.

In a sense, EC-1 is a shrewd public relations move. The technology to produce such blends is not new, and some of it is already available in other brands that don't make Arco's claims. Still, while the breakthrough may be primarily one of packaging, the package may end up serving a very useful purpose.

On sale only in Southern California as of September 1, EC-1 is the quickest relief that the miserably polluted Los Angeles area can expect. Although not as clean as methanol, the leading contender among the alternatives (see "Fuels In Your Future," page 55, and "Coal-alcoholics," page 60, for detailed accounts), EC-1 is unique in being an emissions control step that requires no modification of cars, or the fuel delivery infrastructure.

The cars it's intended for—nontalyst models now burning leaded gas—currently account for only 15 percent of Southern California's auto population, but produce nearly 30 percent of its vehicular air pollution. If all these cars switched to the new gas, Arco estimates it would be equivalent to taking 20 percent of the region's worst pol-



Chassis dynamometer is used to test emissions from EC-1-fueled car.

luters off the road. They also claim that driveability and mileage will be unaffected, and that their additive package will substitute for lead, which older cars rely on to lubricate their valve seats.

### Making the cut

Even Arco admits that EC-1 is nothing revolutionary. Simply tinkering with the standard hydrocarbon cocktail produced a gas that gave off 5 percent less nitrous oxides, 4 percent less reactive organic gases, 9 percent less carbon monoxide and 80 percent less sulfur dioxides when burned. The key was

cutting out certain components of the usual mix.

A basic gasoline blend, or "cut," is made up of crude-oil distillates drawn from a refiner's fractionating column, essentially a large and very precise still. Arco's cut eliminated the lightest and heaviest of the crude-oil fractions.

The light end of the evaporative spectrum consists mainly of butane. This helps gasoline vaporize, making cold starting a lot easier. But the same characteristic means significant amounts of it escape during storage and transport, which causes smog. At the heavier end are

hydrocarbons known as aromatics and olefins. Although high in energy content, large amounts of them pass through the engine unburned.

Aromatics and olefins are, however, important as an octane enhancer. To restore octane, a new additive, called methyl tertiary butyl ether (MTBE), was introduced to the mix. MTBE also oxygenates gasoline so it evaporates and burns more easily.

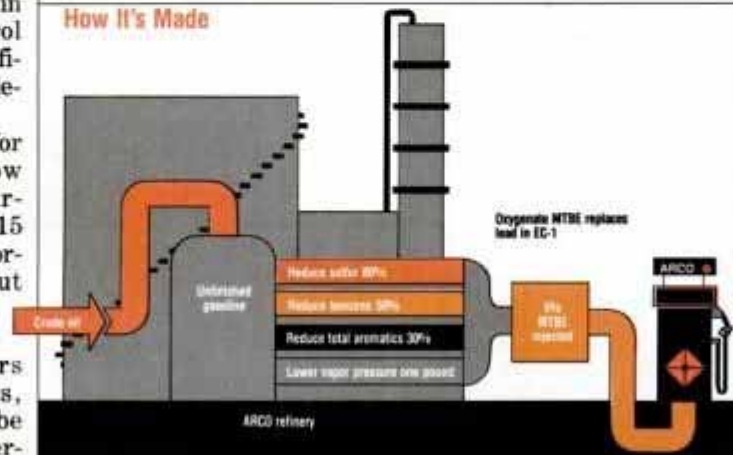
The potential of reformulated gasoline as a route to emissions reduction is as yet uncertain. Developing a version for more recent, catalyst-equipped cars will be more complex, for one thing.

Another problem may be price. Although EC-1 now costs Arco only 2 cents per gallon more to produce than leaded regular (Arco will absorb the cost for now), bringing it to markets larger than Southern California would require large-scale replacements of refining equipment. Also, it is possible that low-pollution blends may waste crude by leaving surpluses of unmarketable compounds. Even if some of the surplus is re-refined into useful products, the end result would still be higher costs.

The most optimistic estimates of the total amount pollution could be cut by reformulating gasoline are in the area of 30 percent. But experimental evidence to back this up is lacking. All the same, with Southern California choking under a blanket of smog so bad that plans are in the works to limit use of barbecue charcoal starter fluid and paints, using EC-1 and similar products may be one of the least painful steps Southern Californians—and perhaps soon the rest of us—are forced to take.

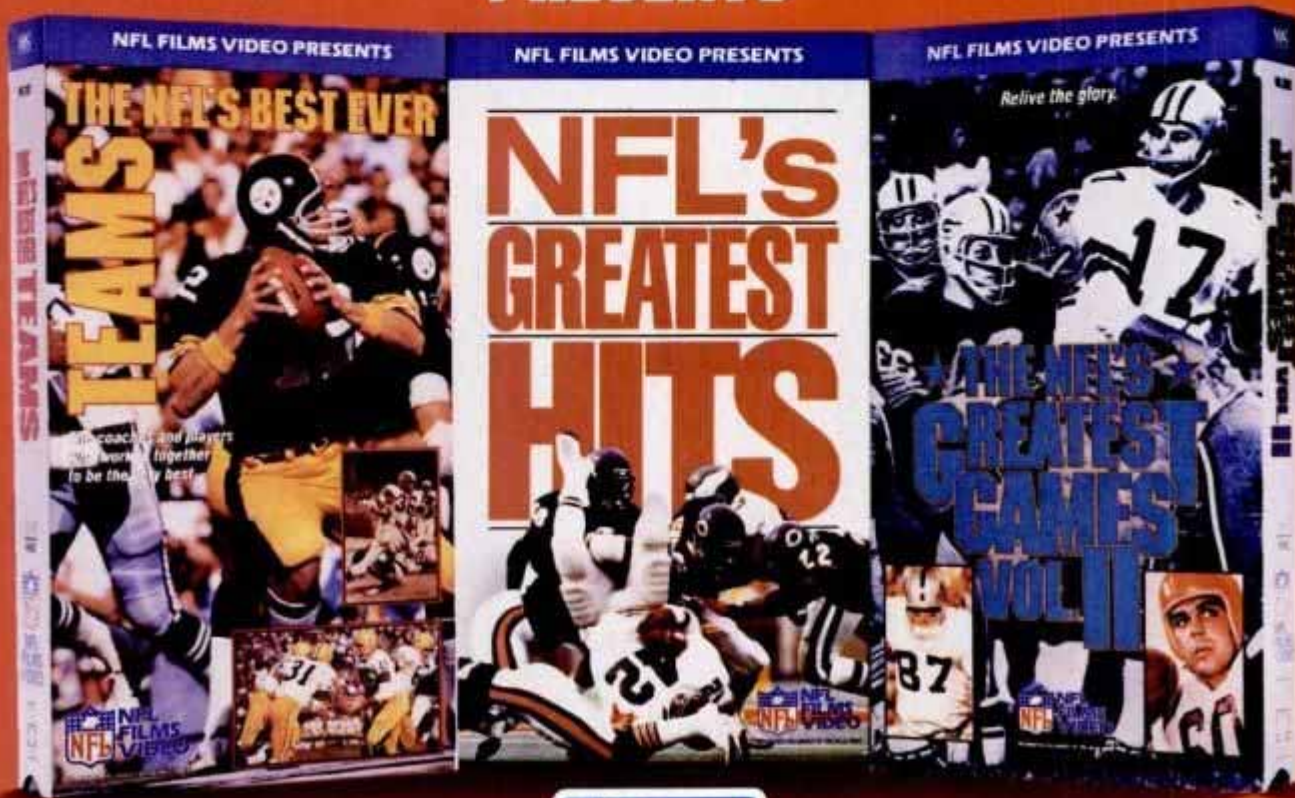
—Abe Dane

### How It's Made



Arco graphic shows what's cut out and what's added to make EC-1.

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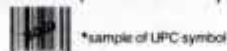


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# CAR CLINIC

BY MIKE ALLEN

## Surging Flyer

**I**HAVE A 1989 Itasca Sunflyer 31-ft. motorhome with the 454 Chevy engine and automatic transmission. On several occasions, after climbing 6-percent grades for several miles, I experienced a surging loss of power. I had to pull over and stop, but after a few minutes of fast idle, everything returned to normal. The dealer checked the fuel pump, filters and so on, but found no problem. Could this be electrical or fuel?

ELROY SMITH  
EUGENE, OR

*You've got vapor lock. And I've gotten a lot of vapor-lock-related mail lately, because gasoline has a higher vapor pressure now than ever. Refineries are putting higher octane, higher vapor-pressure fractions into the gasoline*

*blends nowadays to compensate for lack of lead.*

*There are several things you or other readers with vapor lock can try. Anything that reduces underhood temperatures will help. Be sure the radiator is clean, the fan clutch is hooking up, the belts aren't slipping and the cooling system is up to spec.*

*All fuel-injected cars, and many carbureted cars, bypass some of the fuel back into the tank, so cool fuel is always circulating. If you don't have such a system, add one.*

*Park the vehicle in the shade, or at least head-in to the sun, so the fuel tank stays as cool as possible on sunny days. Also, keep the fuel tank at least half full.*

*Insulate the fuel lines anywhere they pass near a hot component, like the exhaust system or transmission.*

*Replace the stock fuel pump with a high-capacity, high-pressure pump, and add a regulator set to the appropriate pressure close to carburetor.*

### Too Full

I have a 1982 6-cylinder Concord. When I fill the crankcase to the FULL mark on the dipstick, oil seeps out around the base of the cap where you add oil. I was told by a friend that this was a common thing that happens to this model car. Should I pour less oil into the engine to prevent this?

JOHNSON LAMBERT  
BROOKSVILLE, FL

*The seepage isn't caused by too much oil. Continue to fill the crankcase with oil to the appropriate level, or your oil-starved engine will grow old before its time. Replace the gasket in the oil filler cap to stop the seepage.*

### Shocking Story

Is there a recommended period of time or mileage as to when MacPherson struts on fwd cars should be replaced? My 45,000-mile Dodge Lancer just doesn't feel tight anymore—so I thought I needed new shocks up front.

Is it better to change the strut assembly, or just the shock? Or is the cost difference so great that the spring is reused? And should I have the front realigned?

CHUCK MIELKE  
RAHWAY, NJ

*Strut life is influenced greatly by driving style and the roughness of the roads you drive on. The area of New Jersey where you (and I) drive is pretty hard on suspensions because of bad pavement. Your 45,000 miles is well past the expected service life of even a premium shock under these conditions.*

*Some struts have a rebuildable or replaceable shock. Others replace the entire strut, except for the spring. Normally, the spring is reused, unless it's sagged or broken.*

*Many service manuals say that by scribing the positions of the alignment bolts prior to disassembly, you can reassemble the front end and still be in alignment. I disagree, and recommend a full camber/caster/toe-in alignment anytime the settings are disturbed.*

*Don't forget to replace the bump stops (which normally are included with a new shock) and to look carefully at the splash shield, top bearing, ball joints and tie rod ends.*

### Rim Of The World

I recently purchased a 1989 Mustang LX with the 5.0-liter V8 and GT suspension. It has 15x7 aluminum alloy wheels in 4-bolt pattern. Is there someplace I can order some steel wheels in 14- or 15-in. diameter? The salt spread on the roads here is pretty hard on aluminum wheels.

DARREN HAAS  
DARTMOUTH, WI

*You don't need to order new wheels from anywhere special. Trot over to the nearest junkyard—excuse me, they call themselves auto-parts recycling centers nowadays—and pick up some used rims. That 4-bolt Ford bolt pattern has been used for generations, and they'll undoubtedly have a stack of them as tall as a house.*

*This will set you back considerably less than new ones, even if you're the fastidious type and insist on having them sandblasted and painted at a body shop first.*

(Please turn to page 42)

### Superfunnel

Changing your oil is pretty easy: Warm up the car, crawl underneath with drain pan and a wrench, and remove the drain plug and filter. But on some cars, it's a really messy job, 'cause the oil stream runs right onto a frame rail. Then the filter usually leaks oil all over until the threads clear and you can turn it upright. This tends to leave oil running down into your armpit, and greasy stains all over the driveway.

To prevent this sort of irritation, try this tip sent in by Steven Smolen from Chicopee, Massachusetts: Recycle a plastic milk or bleach bottle by cutting the bottom off, making it a huge funnel. Use this funnel, with its built-in handle, to keep all the oil flowing into the drain pan. It's big enough to catch the filter, too.



# “Just another brake job? Not to the guy who owns this car. Not to me, either.”

*“You learn real fast in a GM dealership, behind every brake job there’s a person. Someone who depends on these wheels to get around town, go on vacations, take the kids to school. And that person brought their car to this dealership because they wanted these brakes done right. With genuine GM parts. The kind this General Motors car was designed to use.*

*“Just another brake job? There’s no such thing in my book.”*

*Stephen V. Thompson*

Stephen Thompson  
Mr. Goodwrench Service Technician  
Sycamore Chevrolet, Terre Haute, Indiana

Talk to Mr. Goodwrench and you learn very quickly, he’s a career technician. He takes pride in his GM factory training and the skills he brings to the job. So when you’ve got Mr. Goodwrench taking care of your car, you’ve got the freedom to go anywhere, anytime. And isn’t that what owning a car or truck is all about? Whether you drive a Chevrolet, Pontiac, Oldsmobile, Buick, Cadillac or GMC Truck, bring it to the man who knows it best...Mr. Goodwrench.

GM  
Parts

## Mr. Goodwrench

It’s not just a car...it’s your freedom.

## Turbogrinder

I own a 1987 Buick Regal Grand National. The rear axle makes a metal-to-metal grinding noise while backing up or turning a corner slowly. The car is under extended warranty, so I asked the dealer to look into it. He said there's nothing wrong, and that changing the gear lube should help. But with only 18,000 miles, how can this be possible?

RICHARD PEDDAR  
STERLING HEIGHTS, MI

*Limited-slip differentials have spring-loaded clutches inside them, to prevent one wheel from spinning uselessly when too much power is applied. Your GN is one of the few cars on the road today with a substantial excess of power, and the differential is set up very tight. This differential noise used to be common in the supercar era.*

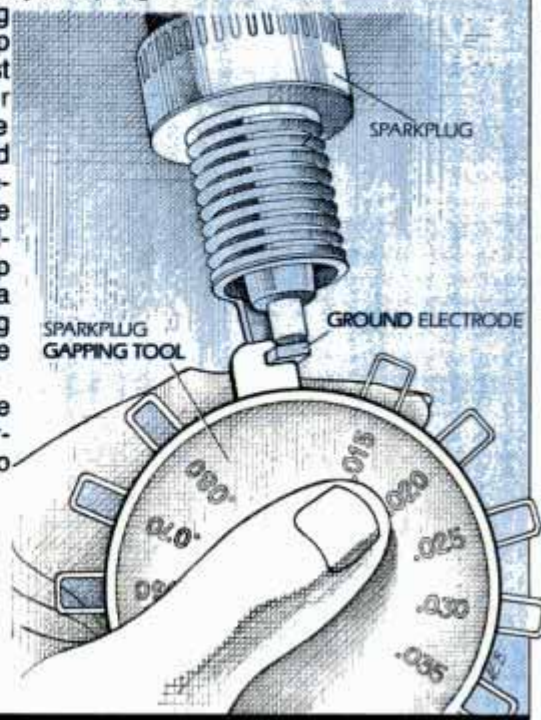
*Gear lube specified for LSD axles has a friction-modifier compound in it, to make this noise a little less obtrusive. Be sure the lube you use is specified for LSDs. The friction modifier is available separately as an additive as well, but I recommend changing the lube rather than just adding modifier. If you're really concerned about the health of your axle, have the lube you drain out checked by one of the oil analysis labs. For that*

## Real Hot Tip

Sparkplugs, if they're the right ones for your vehicle, are almost always correctly gapped when they come out of the box.

But if the gap is wrong—say the plug was dropped, or you're reinstalling used plugs and want to close up the gap a smidgeon—don't just tap them on the shop floor or bend them with needle-nose pliers. There's a hook-shaped gapping tool for that—just carefully bend the ground electrode until the gap is correct. (You already know that to check the gap properly, you need to use a round-wire sparkplug gapping tool, which will be more accurate than a flat feeler gauge.)

Many plugs are otherwise identical except for the difference in gap width, but don't try to use the wrong plug and regap it—the electrode won't be parallel to the center post, and you'll have misfiring problems and short plug life.



# Flushing With Water Just Doesn't Wash.



matter, it's pretty simple to remove the rear cover and inspect the differential.

## Piecemeal

I have a 1988 Cavalier with the 2.8 V6. The dealer has been messing around for months trying to cure a lumpy idle and stalling problem by replacing most of the fuel-injection system, one piece at a time. This has been most inconvenient, because I have to rent a car every time.

At the same time, he's made no progress in making the cruise control operate normally. It varies considerably in speed, and drops off-line completely at odd moments. I'm not too worried about the cruise control, but the stalling problem makes pulling out into traffic potentially dangerous.

ARTHUR KASTEN  
DES MOINES, IA

*I suspect both your problems are related to an intermittent vacuum leak, somewhere in the main vacuum fitting on the intake manifold, in the line that feeds the cruise control or its vacuum tank, or perhaps in one of the other lines that originate at the fitting.*

*If a simple inspection doesn't turn up the problem—which is probably a deteriorated rubber fitting or cracked nylon vacuum control line—try the traditional methods of chasing vacuum leaks.*

*Start by disconnecting the vacuum line that operates the cruise at the main fitting, and plugging the hole. If your idle returns to normal, you've isolated the problem. With the engine idling, spray WD-40 or a similar oil onto suspect connections. If idle quality changes momentarily, as the oil temporarily blocks the leak, you've found it.*

## Strained Relationship

I have a new 1988 Ford Ranger with a fuel-injected V6. What type of fuel filter can I install between the tank and engine?

ROBERT GREEN  
ALLEGAN, MI

*Use the part number that Ford recommends for your truck. Fuel-injected vehicles, unlike carbureted buggies of yesteryear, have really good filters, capable of picking up considerable amounts of dirt and moisture.*

*Don't try to splice in a filter intended for a carbureted vehicle. The flow rates and pressures are much higher in the lines to the fuel injection.*

PM

## DO YOU HAVE A CAR PROBLEM?

*Just ask Mike about it. Send your question to Car Clinic, Popular Mechanics, 224 West 57th St., New York, NY 10019. While letters cannot be answered individually, problems that are of general interest will be discussed in the column.*

## SERVICE TIPS

■ Some '86 and '87 Jeep Cherokees, Wagoneers, Comanches and Wranglers may exhibit repeated stalls when started from cold. This may be caused by a faulty throttle-body injector. TSB INJ TBI/G-9-87

■ Note that '86 and '87 Ford Rangers and Bronco IIs may experience throttle-plate sticking under conditions of high humidity and sub-freezing conditions. Adding a shroud and hot-air tube to the air induction assembly should cure this. TSB 87-2-31

■ High idle speeds, perhaps accompanied by a CHECK ENGINE light and a trouble code 35, experienced on '85-'87 Fieros with 6-cylinder engines may be caused by a fracture in the EGR pipe. TSB 87-6 (Gasoline)-23

■ Hyundai Excels may experience failure of the upper radiator tank seam because of insufficient clearance between the radiator and the radiator support. After repairing the seam, add a flat washer at all four attachment bolts. TSB Vol. 1 ENG006

# Prestone Super Flush does.



Deposits removed using Super Flush



Deposits removed using water alone

Super Flush your cooling system. Because Prestone® Super Flush cuts through 53% more oil, dirt and rust than draining and flushing with water alone. Super Flush power-cleans the clogged radiator passages that could destroy your cooling system and lead to possible engine breakdown.

And there's nothing to it. Just pour the Super Flush directly into your radiator. Simply run your engine and drain it. In no time, you'll have a clean cooling system that'll keep your engine humming.

And if you flush with Prestone Super Flush, refill your system with Prestone® Advanced Formula Anti Freeze and register, we'll guarantee your radiator for a full year.

So when it's time to flush, remember the right way to flush. Prestone Super Flush.

**B** FIRST BRANDS



# FREEWHEELING

BY TONY SWAN

## Red Rock Rookie

**W**HY IS THAT Bronco II poised on the edge of that precipice? Why are those people standing there watching this impending peril? What can that driver be thinking about?

Those are very good questions, and I *still* don't have truly rational answers for them—even though I was the driver.

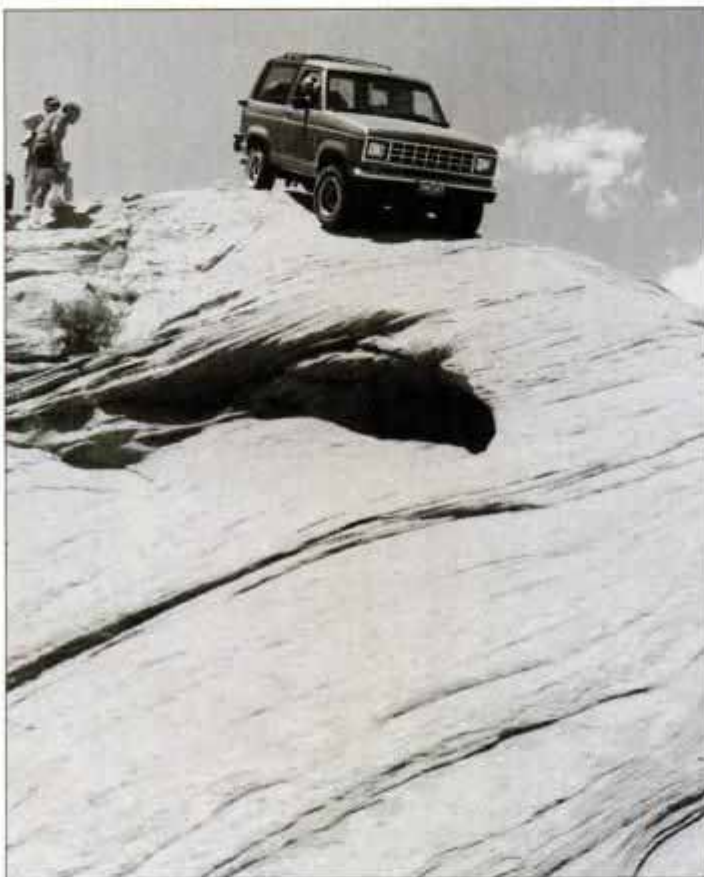
The occasion was a special preview staged by the Ford Motor Co. to showcase its 4-wheel-drive trucks for 1990. We were invited for a day of driving in the red rock country near Moab, in southeastern Utah.

This is an amazing part of the world, full of formations, shapes and colors that defy the imagination. There are a couple of spectacular National Parks in the immediate area, Arches and Canyonlands, as well as lots of rocky terrain that's open to recreational vehicles.

The territory chosen for the Ford show was just east of Moab, and virtually every inch of the route was laid out on bare, red-hued sandstone. Virtually all the formations in the area are sedimentary rock, laid down when southern Utah was at the bottom of a shallow sea. Slick-rock is what the locals call it, although its texturing afforded a good deal more grip than I expected.

I didn't have much time for marveling at the marvelous scenery, though. Once the drive began, I concentrated my full and undivided attention on the tricky business of keeping my vehicle upright.

We started the day by driving along the back of a long, narrow rock ridge, narrow enough that the wheels straddled its crown. The disconcerting part of this is that the design of most pickups and sport/utilities limits vi-



Cliff-hanging in southern Utah's eye-filling red rock country.

sion to the immediate front of the car. There's no slope to the hoodline, which means you can't see down very well, which means you're guessing to some extent at the placement of the front wheels.

I'd never really been particularly conscious of this trait until I started out across that narrow hogback, but by the end of the day it was indelibly etched into my consciousness. And I was most acutely aware of that bluff bow when it came time to negotiate steep downhills like the one you're seeing here. The sensation is about what you'd associate with driving the vehicle over the edge of an absolute vertical drop.

However, I should also note that by the time we reached this particular drop-

off, the steepest of the day, I'd also built up a good deal of confidence in the equipment. Ford's collection of 4-wheel-drive machinery handled all this rough stuff with ease, uphill, downhill, sidehill, sand wash, you name it.

Naturally, it helped that our trail guide gave us a demo run on all the particularly tricky bits. Seeing a difficult feat accomplished takes you a long way toward doing it yourself, and carried me over, up and down some pieces of terrain I would not have thought driveable.

(Just about the time I got used to the idea of driving around in this rockpile, we encountered some guys riding around on mountain bikes. Our guide told us the bicyclists are almost as common as SUVs out here. The

thought made me want to go directly to lunch.)

One note worth adding here is that tires make a substantial difference in this kind of environment. If you buy a sport/utility vehicle with off-road in mind, make sure the rubber matches the mission. The garden-variety tires that come as original equipment on most SUVs aren't equal to real dirty driving.

At any rate, I came away with a healthy respect for Ford's new truck collection and a desire to get back to southern Utah again soon. If you're shopping for new off-road adventures, this one ought to be high on the list.

### Buckle Up, Hollywood

Do you believe in seatbelts? We do. There's no question that seatbelts work, and that our national injury and fatality incidence would diminish substantially if everyone buckled up.

This is hardly news, even in the movie community. But when was the last time you saw an actor buckle up when he or she climbed into a car? The last one I can remember for sure is the bad guy clicking his lap belt just before the chase scene in "Bullit," which was made around 20 years ago.

Even in cop shows the actors jump in and drive off without fastening their belts, and they're never belted for in-car scenes.

Here's a chance for the film industry to do a little positive consciousness-raising for a change. We can't imagine that it would be either difficult or costly to write seatbelts into appropriate scenes, and it might just help erode some of the continued mindless resistance to their use. **FM**

# Save Gas, Save Engine with 'POLY'

**GUARANTEED LOWEST PRICE** (see details below)

The following introduces one of the most fully tested and proven gas saving, friction-reducing engine treatments ever to reach the market!

## The Secret is "Poly"

"Poly" is short for polytetrafluoroethylene (TFE), the slipperiest substance known to man. (1981 Guinness Book of World Records). Petrolon Corporation, makers of Slick 50, invented a way to permanently bind this slippery chemical to your engine with one treatment. Just one quart of Slick 50 can reduce engine friction, increase gas mileage and horsepower and reduce engine operating temperature, causing your oil and engine to last longer...plus it reduces metal wear, defraying costly overhauls.

## Years of Testing and Use Have Proved it True!

Slick 50 has been thoroughly tested in independent laboratories and out on the road:

The March/April 1982, p. 35 issue of "Consumer Digest" magazine stated, "Slick 50 does reduce engine heat and ordinary wear, and our informal tests indicate that it will improve gas mileage by about 2 or 3 miles per gallon."

One of the country's most respected research institutes reported applying a powerful ultrasonic cleaning process to a Slick 50 treated engine and were surprised at its permanence. "We actually expected the Petrolon Slick 50 TFE Resin coating to also be removed, but later found it was still there."

TUV, a German testing laboratory with credentials every bit as prestigious as our Underwriters Laboratories, tested Slick 50 in 1986. They found substantial increases in both gas mileage and horsepower. Their tests showed that these gains were due to a reduction in friction.

The Federal Aviation Administration has fully accepted a similar product for aircraft—Slick 50 Aircraft Piston Engine Treatment (F.A.R. #33.49). This FAA endurance test simulated 1400 hours of engine use.

The power technology laboratory at a leading southwestern university stated, "Slick 50 does increase horsepower and decrease fuel consumption in tests done at the university."

The Space Shuttle Columbia uses the chemical "poly" in its gears and bearings because it is the only chemical lubricant which can withstand the heat and corrosive elements of space.

Perhaps most dramatic of all is a torture test overseen by the Automotive Services Council for Pennsylvania and shown on WIVE television. Three cars with 75,000 to 129,000 miles on them were treated with Slick 50. Six months later the oil was drained from each vehicle, and the cars driven without the oil plugs for about a half hour. The water temperature never rose and the engines sustained no apparent damage.



## It's Easy to Treat Your Engine

A few minutes before oil and filter change, add the engine flush you get free with each order to clean out the engine. Let the engine idle for 5 minutes. Then drain the oil, change the filter and add the proper amount of oil, less one quart. Add one quart of Slick 50, drive for 30 minutes, and leave it in the crankcase for at least 3,000 miles. As the engine operates, the oil carries the "Poly" between the parts where it is burnished into the pores of the metal.

## Only One Treatment Necessary

It's permanent, so you do it only once, not each time you change oil. One quart of Slick 50 will treat all standard 4, 6 and 8-cylinder gasoline and diesel engines.

## Works with Most Oils

Slick 50 will work with all petroleum-based oils and all synthetics compatible with petroleum-based oils with the exception of graphite oils. However, once an engine is treated, you can go back to a graphite type if desired.

## 4 Ways Slick 50 Saves You Money

Your actual percentages may vary depending on your driving, vehicle condition, weather and geographic location, but no matter what your conditions, Slick 50 can:

1. Increase mileage
2. Increase horsepower (small economy cars and large RV's really need this)
3. Reduce operating temperatures, thus increasing the lubrication and life of the oil and engine.
4. Minimize or eliminate costly overhauls by reducing engine wear

Up to 90% of the engine wear on a car can be caused by lubrication starvation cars experience when first started before the oil begins to circulate. Slick 50 can eliminate this problem for less than the cost of two tanks of gas.

## Slick 50 Will Not Affect Your Warranty

Slick 50 is suspended in an excellent grade of petroleum oil which meets or exceeds every manufacturer's engine warranty requirements. In addition, this oil carries an American Petroleum Institute service classification SF-CC-CD.

## There's No Risk with Our Money Back Guarantee

Use Slick 50 for 3000 miles. If you don't notice an improvement in engine performance, return your invoice with a short note telling why, for a prompt full refund—no questions asked.

## Profit from Selling Slick 50 Yourself

Here's an opportunity to make handsome profits. Having such solid test results from major institutions make Slick 50 easier to sell than many other products. Free dealership information is sent upon request.

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# OLD HOUSE RESTORATION

BY BOB VILA

## Old House Moving

**I**T'S THE RIGHT house in the wrong place. That's often the problem when someone finds an old house ripe for restoration these days.

Perhaps rezoning of residential land to commercial property makes a neighborhood undesirable. Or maybe the area where the house originally sat just doesn't warrant the type of investment you'd have to make to restore the structure. Although it should be considered a last-resort answer to the problem, literally picking the house up and moving it—either whole or in pieces—may be the solution.

Of course, anytime a building can be restored on site it should be. Historically speaking, when you move a house you're taking it out of its natural context, so you lose the inherent character of the land and culture of the area. But sometimes moving a house is the only answer—and often it's a far better one than having the structure destroyed in the name of progress.

### Have house, will travel

Whether a house can be moved in its entirety comes down to one thing: Is there room to move it? So the starting point of every professional house-moving project is a map of the route the building must take to its new home. The obstacles the house will encounter on its trip, like bridges, narrow roadways and overhead wires, will determine whether or not a whole-house move is feasible. One must be sure beforehand that the width and height of the house will fit

*Contributing Editor Bob Vila was host of public television's "This Old House" for 10 years.*



Though expensive, moving an old house to a new site can greatly increase the value of the house.

along the entire path it will take.

The major deterrents of house moving these days are power and telephone lines. The cost of removing these to allow the height of the house to pass can be enormous. In some communities, local utilities charge \$1000 or more to move, then reconnect, main cables to make way for a house. Because of the cost factor involved here, you really can't move a house very far.

Tree limbs, too, can cause problems. If branches are in the way, a tree trimmer will have to be hired to make sure the structure can pass freely. Depending on where you live, you'll also need all types of permits or permissions be-

fore you can begin the move to ensure your home's journey won't be too disruptive to the community. These usually include approval from the police and fire departments that you won't be blocking emergency routes or disrupting traffic patterns, along with permits for an overweight and oversized vehicle, demolition and reconstruction.

The way a house is physically moved is surprisingly simple to understand. Holes are punched in the foundation and steel I beams inserted through them to support the building. Then the rest of the foundation is broken out, the house is jacked up, put on a special hydraulic dolly and literally rolled away. Once at

its new home, the house is positioned over the foundation footings. The steel beams are blocked up, elevating the structure, while the foundation walls are completed.

To give you some idea of what costs are involved in a project like this, expect to pay around \$15,000 to \$20,000 (depending on where you live, of course) to move an average 2-story frame house. This price is just for the physical act of moving the structure, it doesn't take into account the costs associated with moving wires, trimming tree branches and so on. The job should take about a week.

Moving a masonry house is more complicated. Since the

*(Please turn to page 49)*

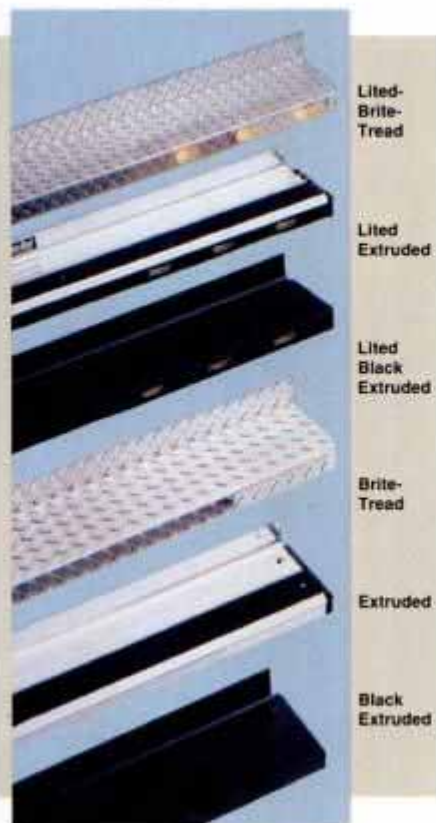
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**Reach new heights.**



structure is heavier, more steel beams must be used. There are also more limitations on its transport because of its weight, especially if you need to cross a bridge.

### A new old house

If an old house needs structural restoration, like new sills, a new foundation or repair of a major chimney mass in the basement, antique reconstruction may be the way to go. The old structure is carefully taken apart piece by piece and numbered, like a giant puzzle, then reconstructed again on its new site.

The major advantage to this type of house moving is that major structural repairs can be done while the house is being put back together. Since many parts of the house are upgraded during its reconstruction—without affecting its antique charm, of course—you really

also an expensive undertaking, but you eliminate the distance factor you encounter when trying to move a house in its entirety. Expect to pay from \$125 to \$200 per sq. ft., depending on the firm you choose, the detailing on the house, and the new location. This includes the cost of a new foundation, electricity, plumbing, appliances and so on. It does not include any site work, like adding a driveway or access road, necessary to make the land livable. When you consider that the cost of a new house might average \$100 per sq. ft., the antique better be pretty special.

Believe it or not, it only takes about two to three weeks for a work crew to totally dismantle, document and move a house. But it usually takes a good seven to 10 months to actually put the building back together again on its new site. Of course, a great deal of design and plan-

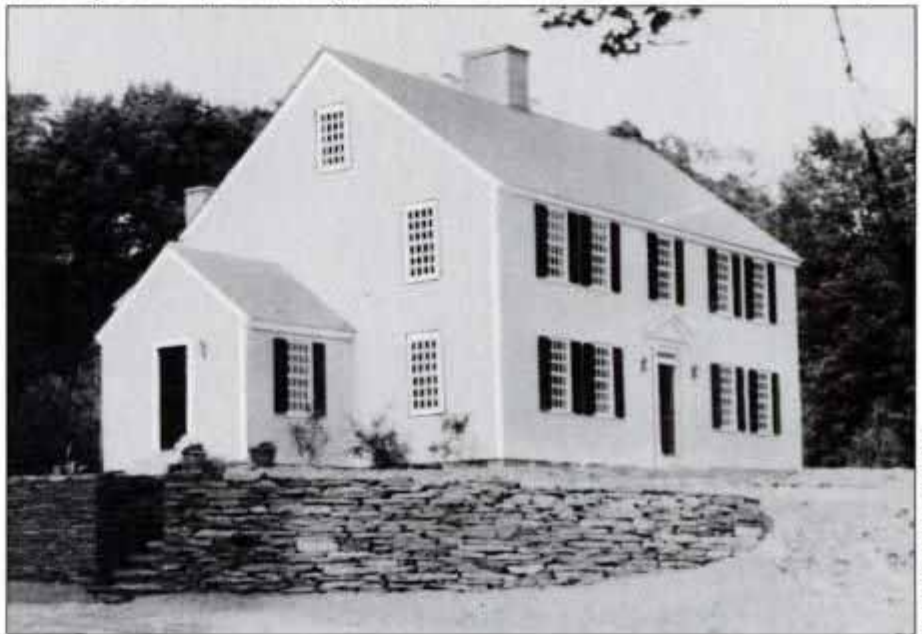


PHOTO BY DOUGLAS GEST

Houses can be dismantled and moved in parts, as this one, then reconstructed on a new site.

can have the best of both worlds in old-house living. Electrical and plumbing systems are new, eliminating the headaches of old wiring and pipes. New roofing and siding that simulate the old are also often used. Reproduction window sashes often replace old, leaky ones, and insulation can be added to meet today's standards.

Before the house is dismantled, photos and accurate measurements are taken to ensure it's put back together again the way it should be. Since many old homes have been renovated over the years, care is taken during the dismantling phase to note any changes that have been made. By studying the wear patterns of the floors, for example, it's easy to determine the location of old doorways. In this way, the building is brought back as close to its original state as possible.

Of course, antique reconstruction is

ning work is done before this, perhaps two to three months worth.

Finding the professionals to move an old building shouldn't be too difficult. Your telephone directory should have companies that specialize in this trade listed under "House And Building Movers." If you're interested in antique reconstruction, your local historical society may know folks who specialize in this type of work.

So, if you've found an old house that's perfect except for its location, it's heartening to know that you may be able to move it. If the building doesn't need major structural repair and there's room to accommodate it all along its route, moving the house in one piece may be the solution. If it needs major structural repair, antique reconstruction may be the answer. Either way, your restoration will still preserve a piece of the past—just in a new place.

PM

**W**hen it comes to pickups, some buyers set their sights higher. One look at the 1990 Sierra, and you'll see why that suits us at GMC Truck just fine.

Sierra is the full-size pickup born and bred to be nothing less than the best truck we can bring you. Able to go just about anywhere, with shift-on-the-fly four-wheel drive and the unmatched standard muscle and torque of the 4.3-liter Vortec V-6. Then stop just as surely with rear-wheel anti-lock brakes. There's even a new sport handling package available, with special low-profile tires and gas-charged Bilstein shocks.

Of course, Sierra's also big on comfort. And its advanced, aerodynamic styling is so far ahead of its competition, *4-Wheel & Off-Road* magazine said, "it is now the benchmark against which all other products are being measured."

The 1990 Sierra from GMC Truck. It's the one pickup every other truck on the road has to live up to.

For a catalog and the name of your nearest dealer, call 1-800-VALUE90 (1-800-825-8390).

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Union Made

Actor Portrayal

Thirty-one years is a long time to go without changing your pants. But according to Slim, when they're built as tough as Carhartt builds them, who wants to change.

Like all our Carhartt brown duck garments, our pants and jeans start out with one of the toughest natural fabrics known to man - 12 oz., 100% cotton duck. And of course, they're triple stitched at the main seams for more strength than the material itself.

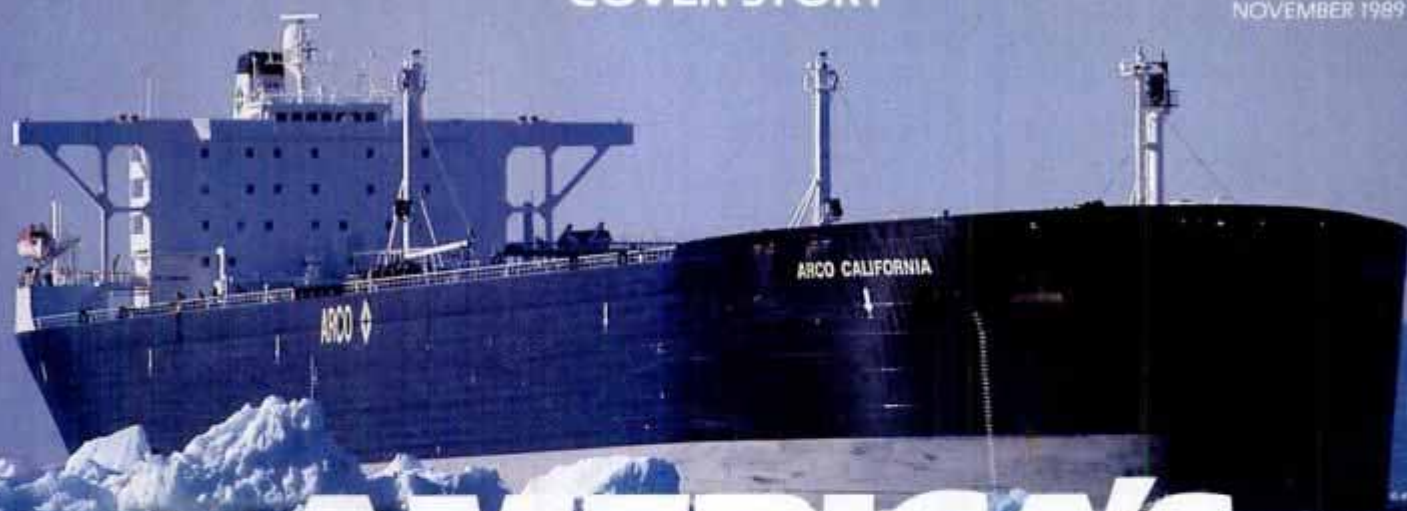
Plus, the longer you wash and wear them, the more comfortable they seem to get. And the same goes for our growing line of pants, shirts, jackets, overalls and hunting wear.

**Rugged as the men who wear them.™**

That's why Carhartt is Slim's brand. And after 31 years, he's not about to change. For your nearest Carhartt retailer, call 1-800-877-2757.







# AMERICA'S OIL TANKER MESS

Industry's failure to implement improvements in oil tanker design is a leading cause of current environmental disasters.

BY ABE DANE

**F**OUR MINUTES after midnight on March 24, miles off course and with an unlicensed and increasingly panicked third mate in command of the bridge, the full 246,000-ton weight of the supertanker *Exxon Valdez* focused itself on a pinnacle of rock. Penetrating  $\frac{3}{4}$ -in., high-tensile steel to a depth of 3 to 5 ft., the point carved along the ship's underside from the forepeak to just

ahead of the engine room, and brought the ship from a speed of 12 knots to a dead stop. A second, more crushing impact came moments later, when the ship pivoted and came to rest on a ledge. Eight of the 11 cargo tanks were ruptured, and oil surged out with such force that it burst to the surface in 3-ft.-high waves.

The first fully equipped cleanup team didn't arrive for 14 hours, 9 hours longer than was called for in contingency plans. In the chaotic days that followed, it became clear that Exxon, the Coast Guard and the Alyeska Pipeline Service Co. had nothing like the resources needed to combat the spill. It soon spread to the size of Rhode Island, and an Exxon official conceded, "We will never get



AP/WIRE PHOTO



AP/WIRE PHOTO

The wreck of the *Argo Merchant* off Nantucket (left) foreshadowed the grounding of *Exxon Valdez*, shown offloading cargo into smaller

vessel (right). Nosing through ice in Prince William Sound, the double-bottomed *Arco California* (top) represents a possible solution.

# AMERICA'S OIL TANKER MESS

back most of those 240,000 barrels."

Thus, Prince William Sound became an environmental Pearl Harbor. The damage was staggering, with cleanup costs likely to exceed \$1 billion, a \$150-million-a-year fishing industry threatened, and an enduring stain left on a part of the world that residents justly think of as God's country. Secretary of Transportation Samuel K. Skinner declared the spill to be "one of the worst environmental and economic disasters this nation has ever faced."

As if to drive the message home, three smaller but still serious spills occurred exactly three months after the *Valdez* accident. In one extraordinary weekend, spills of between 250,000 and 420,000 gallons each fouled the waters of Rhode Island, Delaware and Texas.

So far, investigations have laid responsibility for all of the accidents to mistakes by crewmen. But they have also raised disturbing questions about equipment and procedures.

## Six parts oil, one part steel

Modern tankers are uniquely fragile and unwieldy vessels. According to Lincoln Crane, chief of the Stability and Control Division of the Davidson Laboratory at the Stevens Institute of Technology, the idea in tanker design is "to get as much cargo as you can into as little steel as possible, and still have economical propulsion." The larger the ship, the simpler this task is to accomplish. As a result, over the past three decades the largest tankers have grown from vessels of no more than 121,000 tons into quarter-mile-long behemoths displacing 640,000 tons, and drawing up to 90 ft.

ULCCs, or Ultra Large Crude Car-

riers as these ships are called, require 3 miles and 20 minutes to stop from a top speed of 15 to 16 knots. To make matters worse, the low ratio of steel to cargo—1:6 in the case of the *Exxon Valdez*—makes them vulnerable to rupture at the gentlest brush with an unyielding object.

## The double-hull controversy

Of the safety measures now being considered, none has inspired more heated debate than a proposed requirement that a second layer of steel



First of three in a weekend, the *World Prodigy* spill coated the shores of Rhode Island.

be laid inside a ship's framework, resulting in either a double bottom or double hull (see illustrations opposite). Hardly an untried idea, twin skins of one kind or another are present on virtually all of the 60,000 merchant ships afloat—except for oil tankers.

Double hulls are already required on tankers carrying hazardous cargoes such as liquefied natural gas, and more than once have been credited with preventing disaster.

On July 1, 1979, the LNG tanker *El Paso Paul Keyser* steamed onto a rock ledge in the Strait of Gibraltar at a speed of 17 to 18 knots. Although the outer hull was torn open under four of



the six cargo tanks, the inner hull suffered only a minor dent, and none of the 95,000 cubic meters of highly volatile cargo escaped.

Experiences such as this are backed up by several studies. A 1975 Coast Guard analysis of 30 oil-tanker groundings concluded that double bottoms with a 2-meter separation between the layers would have prevented spills 96 percent of the time. Studies by Congress's Office of Technology Assessment, the National Transportation Safety Board and others provided supporting evidence.

In the wake of the 1976 wreck of the *Argo Merchant*, which introduced 7.6 million gallons of oil into the waters off Nantucket, President Carter proposed that double bottoms be required on all tankers over 20,000-tons dead weight (the weight of the ship's cargo alone). The measure was rejected, however, by a convention of maritime nations, and replaced by one calling for segregated ballast tanks (see illustration above). Set aside strictly for seawater ballast, carried to stabilize the ship when it is empty of oil, these tanks are placed so as to provide some protection against collision.

Justifying the move, the oil and shipping industries offered two basic objections to twin skins. First, they said, oil could leak into the void space between the inner and outer plating, forming a vapor that could explode. But, according to Arthur MacKenzie, who was on the OTA panel that studied tanker safety in the 1970s and now runs a casualty reporting service called the Tanker Advisory Center, there has not been one explosion attributed to a double hull or double bottom in the past 25 years, although some 530 tankers have them.

The industry also claimed that if the outer layer of a twin-skinned tanker were breached, water filling the void space could cause the ship to lose buoyancy and come harder aground, increasing the difficulty of salvage and possibly causing it to capsize.

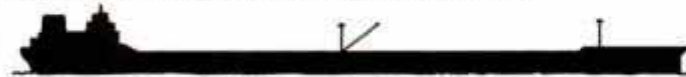
## OIL TANKER PROFILES



**EASTERN SUN**—Length: 641 ft. Capacity: 30,252 tons.



**TEXAS SUN**—Length: 752 ft. Capacity: 50,864 tons.



**MEDITERRANEAN SUN**—Length: 889 ft. Capacity: 134,835 tons.



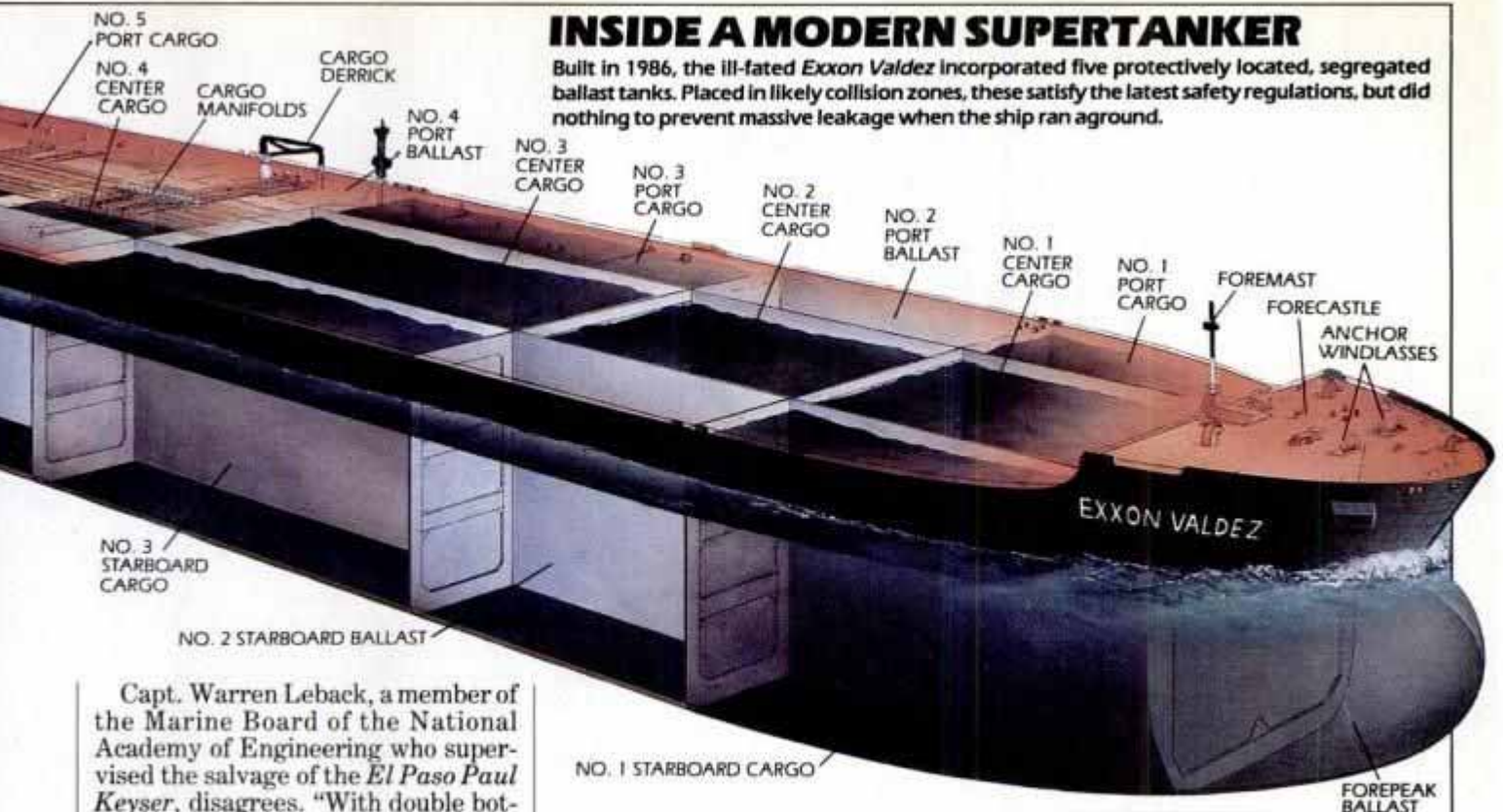
**ATLANTIC SUN**—Length: 1117 ft. Capacity: 255,850 tons.



**ESSO ATLANTIC**—Length: 1200 ft. Capacity: 508,731 tons.

## INSIDE A MODERN SUPERTANKER

Built in 1986, the ill-fated *Exxon Valdez* incorporated five protectively located, segregated ballast tanks. Placed in likely collision zones, these satisfy the latest safety regulations, but did nothing to prevent massive leakage when the ship ran aground.



Capt. Warren Leback, a member of the Marine Board of the National Academy of Engineering who supervised the salvage of the *El Paso Paul Keyser*, disagrees. "With double bottoms and wing ballast tanks, you're actually in a better position to start a salvage operation," he says, reasoning that having the vessel firmly aground at first makes it easier to work on. Then, when the vessel is ready to be floated, the compartments between the inner and outer hulls provide a space to blow compressed air into, without offloading.

Capt. J.H. Boyd, Navy Supervisor of Salvage from 1973 to 1976, puts it more succinctly. "I view the probability of a major salvage or pollution incident growing out of the grounding of a large single-bottom tanker an order of magnitude greater than that for a double-bottom tanker."

In April of this year, Sen. Brock Adams (D-Wash.) began a new attempt to require double plating. A version of his bill, approved in August, will require the Coast Guard to either produce regulations mandating the safeguard, or explain why it is not needed.



Initial grounding left a gash running from the *Valdez's* forepeak to her starboard slop tank. The 11 colored tanks were all holed. Darkened area was caved in when she came to rest.

### Charting the future

Of course, if ships could be prevented from running into things, there would be no need to armor them against impact. Over the past 10 years, devices have evolved that could make the taxing business of navigating a large ship less chancy.

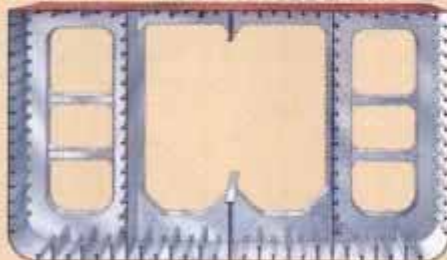
Among the most promising are systems known as electronic charts. These take the data from the navigational equipment already aboard most vessels, including loran, global positioning satellite receivers, depth sounders, radar and gyrocompasses, and integrate them with a computer database of digitized nautical charts.

The result is a single video readout that shows the ship's location and course with respect to the shoreline, bottom contours, buoys, markers and other ships. "It's a very, very powerful display," says Morton Rogoff, head of the Radio Technical Commission for Maritime Services.

Acknowledged to be the most thoroughly developed system of this kind, is one called the Precise Integrated Navigation System made by Offshore Systems of Vancouver. With the aid of radar reflectors placed on shore, the system is able to determine the ship's location to within 1 to 2 meters.

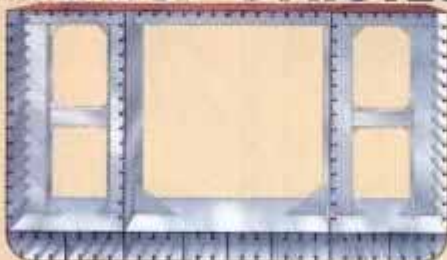
Now in use aboard a handful of Ca-

## BRACING FOR IMPACT—3 PROTECTION LEVELS



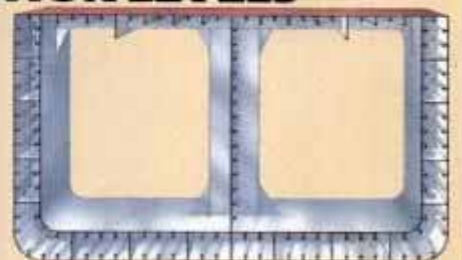
### SINGLE SKIN

Light, cheap and traditional, this design prevails despite longer tanker hulls.



### DOUBLE BOTTOM

Inner bottom adds strength, and contains oil if grounding breaches outer bottom.



### DOUBLE HULL

Required on hazardous chemical carriers, wraparound void space protects in crash.

# AMERICA'S OIL TANKER MESS

nadian Military and Coast Guard vessels, PINS has already shown its effectiveness in treacherous waters. Sylvain Lachance, fleet systems superintendent of operations in the CCG, notes that PINS has enabled icebreakers operating in the St. Lawrence to work day and night.

By comparison, even under relatively favorable conditions, the third mate of the *Valdez* was unsure of his position until it was too late to avoid Bligh Reef. Offshore Systems has demonstrated that a PINS system would have tripped numerous alarms before this point and shown how to steer clear of the obstacle.

Unfortunately, standards have not been agreed upon by the Coast Guard and the International Maritime Organization that would allow ships to operate on electronic charts without a marked paper chart to serve as backup documentation. According to Rogoff, provisional standards should be in place by 1991.

## The last line of defense

When all else has failed, the job of protecting the environment from oil falls to those who race against time to round it up and extract it from the water before it does too much damage. But, according to a report issued after the *Valdez* spill by the American Petroleum Institute, which represents oil interests, "The industry has neither the equipment nor the response personnel in place and ready to deal with catastrophic tanker spills."

Spill-cleanup technology has been the subject of relatively little re-



In oil-recovery mode, the hull of the oil-recovery vessel *Bottsland* gaps into a V to funnel oil toward ORAS equipment, which will separate it from water.

search in the U.S. since the 1970s. The tools used today are essentially those developed during that time—floating booms to contain oil, skimmer ships equipped with conveyors to lap it from the water's surface, oleophilic materials to absorb it, chemical dispersants to break up slicks and ignition techniques to burn them. Each has little impact on major spills.

After the *Valdez* spill, the American Petroleum Institute, promised to devote \$30-\$35 million to research on better techniques over the next five years. They will focus on dispersants, sorbents and gels that might be added to spills to mitigate their effects, shoreline cleanup techniques and basic research into the ways that oil affects the environment. They will also spend \$250 million setting up a nationwide rapid deployment cleanup force.

As far as current technologies go,

one of the most intriguing is a ship-board oil-separation unit developed by the West German company Jastram-Werke. Known as ORAS, for Oil Recovery And Separation, the device can turn the oil/water mixture skimmed from a slick into oil for storage, and 99.99 percent pure water for discharge. Without this equipment, skimmers must carry large amounts of water, requiring frequent interruptions in service for offloading.

The ORAS system uses what company president Claus Jastram calls "a variety of hydrodynamic tricks" to encourage natural separating forces such as gravity and cohesion. By forcing the oil/water mix through a labyrinth that exposes it to vacuum and carefully defined zones of turbulence, oil is forced to the surface.

A number of novel ship configurations have been experimented with to funnel oil toward the ORAS intakes, including a hull that splits into a V during recovery operations. One such vessel, the *Ecopemex* in service in the Gulf of Mexico, recently recovered 210,000 gallons of oil in 9 hours.

Whatever the equipment, however, preventing environmental damage once oil hits the water is an uncertain business at best. "No single system works well with all types of oil and in all sea states," says Ensign Roger Laferriere of the Coast Guard's Pollution Response Branch.

The real issue, then, comes back to this: Why are ships like the *Exxon Valdez*, one of just a tiny fraction of ships worldwide with single skins, allowed to travel through some of the most biologically vital waters in the world with such deadly cargo?

It's not for lack of an alternative. "We know how to make good, safe ships," says MacKenzie. "It's just a matter of seeing the need." The need, in the form of Prince William Sound's blackened shoreline, may at last be impossible to ignore.



Readout of electronic chart clearly shows inbound and outbound channels through Prince William Sound, and the errant course of the *Exxon Valdez* shortly before striking Bligh Reef.

# FUELS IN YOUR FUTURE

Against an ominous backdrop of global warming, tighter emissions controls and diminishing oil reserves, it's plain that tomorrow's cars will have to burn something else besides gasoline. But what?

BY MIKE KNEPPER; PM Photos by G Photo

**G**ASOLINE IS on its way out. Not in the next few years, probably not even in the next few decades, but little by little it will be phased out. This isn't really news. It's been apparent since the first gallon of gasoline was refined that the world's petroleum reserves were finite. But it took the first oil crisis of 1973 to spark the first really serious study of alternatives to gasoline, not only because of its ultimate depletion, but also to free us of our dependence on foreign energy sources. Research on workable alternatives has been going on ever since.

Today OPEC is no longer our primary worry.

Filthy air over metropolitan areas—and the global greenhouse effect—are of much more immediate concern, and once again developing an alternative to gasoline is on the front burner.

One of the biggest contributors to the brownish plague hanging over many cities is the fleet of older cars in the U.S. Current automobiles, especially those of the past few years,



## FUELS IN YOUR FUTURE

are remarkably benign polluters. A Ford researcher asserts that if all the vehicles in the country were 1989 or '90 models, we wouldn't have any regions out of compliance in carbon monoxide. But that isn't going to happen overnight. We can't legislate all the old vehicles off the road.

Meanwhile, America—and the world—must deal with the growing menace of global warming. This is a process that's been in progress since the dawn of the Industrial Age in the mid-19th century, when we began adding massive quantities of carbon dioxide, one of the major heat-trapping greenhouse gases, to the atmosphere. Other gases include methane, oxides of nitrogen and chlorofluorocarbons.

Although automobiles contribute only a small percentage to the greenhouse effect, many feel that the percentage should be reduced even more. Two ways of doing this are by reducing gasoline consumption—which is why we'll see a renewed tightening of Corporate Average Fuel Economy requirements—and by eliminating gasoline altogether.

With more than 100 cities in violation of clean-air requirements, coupled with a call from President Bush for the production of 500,000 alternative-fuel vehicles a year by 1997, deciding on a gasoline replacement has suddenly acquired a high priority.

Replacements do exist. There are several alternate sources of power available, including electricity. But not every one measures up to the criteria gasoline's replacement must meet. It must be easy to produce, readily available, affordable and environmentally sound. Here's a pro-and-con rundown of today's leading alternative fuel prospects.

### Ethanol

Better known as grain alcohol, ethanol begins as corn, but can be made from a variety of biological substances.

Gasohol, a blend of gasoline (90 percent) and ethanol (10 percent), has been sold for years in agricultural-intensive states. According to the Renewable Fuels Association, a Washington, D.C.-based lobby group, between 8.5 and 9 billion gallons of gasohol will be sold in 1989.

Because it has almost no petroleum reserves but an abundant biomass (primarily sugar cane), Brazil has been employing ethanol for its cars for almost a decade. Although there are

problems, the program shows that ethanol is viable as a broad-spectrum gasoline substitute.

Ethanol and methanol are both chemically active, so there is little difference in the equipment required to transport, store, dispense and make them work in a vehicle. Ethanol is not as toxic as methanol. But the drawback is its cost, from three to four times more than methanol.

### CNG

Compressed Natural Gas (CNG) has low volumetric energy density, so it would require very large in-car tanks to provide reasonable driving range.

## Energy Density Of Automotive Fuels

### British Thermal Units (BTUs) per gallon

Diesel Fuel	135,000
Gasoline	110-126,000*
Ethanol	75,000
Liquefied Natural Gas	73,500
Methanol	56,500
Liquid Hydrogen	34,000
Compressed Natural Gas (3000 psi)	29,000

\*Energy density of gasoline varies as a function of crude oil composition and distillation techniques.

Also, it would require an all-new infrastructure to handle it. Some 8000 vehicles in British Columbia are running on natural gas, with other programs being tested in California, Washington state and New York.

Natural gas would be a practical fuel for fleets that operate in a limited area and return to a central refueling site. It is an exceptionally clean fuel, in terms of tailpipe emissions, and is kind to engine internals.

### LPG

Liquefied Petroleum Gas stores at high pressure, although there is some infrastructure in place. An even bigger drawback to LPG is that it is primarily associated with natural gas and refinery processing and is 10 times more expensive than gasoline.

### Hydrogen

Hydrogen gas is easy—although expensive—to produce and burns with almost no harmful emissions. A hydrogen engine is not dramatically different, although performance is reduced. BMW and Mercedes are involved in research projects on hydrogen-fueled vehicles, and both have reported considerable success.

BMW's program uses hydrogen stored as a liquid, which provides the highest energy density, but also re-

quires a complex system to keep the liquid at -253° centigrade.

The Mercedes system stores hydrogen in the form of metal hydrides which release hydrogen gas when heated. Mercedes reports its test vehicles currently have an average range of 200 kilometers (124 miles).

Widespread use of hydrogen, either cryogenic or as hydrides, would require a new supply infrastructure.

### Electricity

The search for a practical electric car goes on in the U.S. In 1988 Congress appropriated \$14.1 million for R&D. Overseas, BMW and Mercedes-Benz continue electric vehicle development programs.

The problem with electric power continues to be limited range, low speed and the bulk of batteries, although there has been progress on the latter. Also, until nuclear or solar energy is used to handle recharging, electric cars will still be indirectly dependent on petroleum.

### Methanol

Of all the alternative fuel contenders, methyl alcohol, commonly known as wood alcohol, looks the most promising.

Methanol was once made from the distillation of wood, but is now more commonly synthesized from coal or natural gas (methane).

Some of the emissions from methanol are the same as gasoline: carbon monoxide, carbon dioxide and oxides of nitrogen (NOx).

However, the amount of carbon dioxide, a significant contributor to the greenhouse effect, is significantly lower for methanol, from 7 to 16 percent less. Unlike gasoline, methanol does not release unburned hydrocarbons, which are a critical constituent of surface ozone. Methanol is less reactive in the atmosphere.

Methanol combustion, on the other hand, produces aldehydes, primarily formaldehyde, which can be harmful. Some researchers think aldehydes could preclude methanol from widespread use. Others, however, say aldehyde emissions will be controlled.

There are no particulate emissions from methanol, so methanol engines stay quite clean inside. Because of this, methanol could be a substitute for petroleum-derived diesel fuel, an extremely high particulate polluter.

Methanol does not have the energy density of gasoline, so it takes twice as much to propel a car a given distance, although there's no penalty in output. Also, some researchers be-

lieve methanol's mpg rating can be improved by as much as 25 percent.

Though its energy density is low, methanol burns with high efficiency and has a high octane rating, which means it can be used in engines with higher compression ratios to produce output figures higher (about 20 percent) than gasoline. Methanol has been used in Indy cars for years.

But there are other problems. Methanol is highly toxic if ingested, and can enter the body through the skin. It has no odor and burns with no visible flame. It doesn't vaporize readily, which means difficult cold starting. Unlike gasoline, it can form a flammable mixture in the fuel tank. And methanol production generates carbon dioxide. From natural gas, the carbon dioxide production is approximately 10 percent less than gasoline's, but from coal, our main methanol feedstock, the carbon dioxide production is almost twice as great as that derived from gasoline.

Dr. Roberta J. Nichols, principal research engineer in Ford's Fuel Systems Department, says, "If you make methanol from coal, you have a concern for the overall carbon dioxide emissions. That's not a methanol problem, it's a coal problem. Will the U.S. use its coal resources? I believe the answer is yes. If it is, you have to address the carbon dioxide emissions associated with coal. Being a technical person, I have to believe technology will find a way to do just that, and in fact some progress is being made."

However, Dr. Nichols doesn't see carbon dioxide as the top concern.

"The number one open issue for methanol vehicles is the proper control of the aldehyde emissions," she says. "We just don't know how to reach the standard (in California) of 15 milligrams per mile yet. Currently we're at 30."

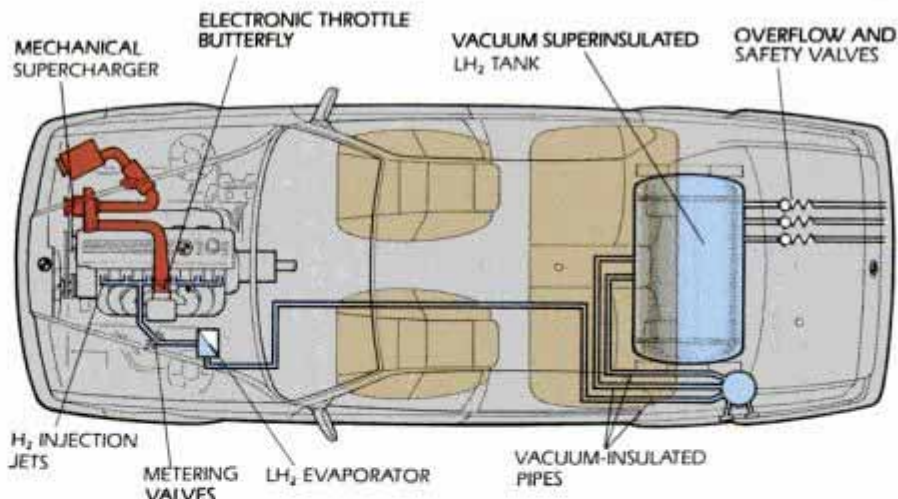
Dr. Nichols goes on to explain that the aldehyde emissions essentially occur—or are at their heaviest—in the first 2 minutes after start-up.

"The smaller we can make that window," she explains, "the smaller the emissions. After the catalyst warms up, it does an amazingly good job."

And that's with today's catalysts.

Bob Potter, project manager in Advanced Product Engineering at General Motors, says, "We must get the catalytic converter up to temperature very quickly. We can't preheat, because that would be too much draw on the battery when starting. One possible solution is to put the converter as close to the engine as possible, which is called a close-coupled converter."

Ford has had methanol-fueled cars running in a California program for



BMW's hydrogen-powered 735 has complex systems to handle highly explosive liquid hydrogen fuel (LH<sub>2</sub>) which is warmed to a gas (H<sub>2</sub>) for combustion.

many years, and has accumulated more than 23 million miles of experience with them. GM is involved in a similar program. But before we become a country of methanol-fueled cars, there must be an interim step.

"If you have only one dedicated methanol vehicle you want to operate in a normal way," Ford's Dr. Nichols points out, "you have to have a refueling infrastructure from coast to coast. The average customer does not want to worry where the next refueling station is going to be."

The answer, while that infrastructure is going into place, is vehicles capable of burning either 100 percent alcohol, 100 percent gasoline or any mixture of the two. Ford calls them Flexible Fuel Vehicles (FFVs), at GM they're Variable Fuel Vehicles (VFFVs), at Chrysler, Gasoline Tolerant Methanol Vehicles (GTMVs).

Here's the good news. As soon as you start adding methanol to the fuel mix, performance begins to increase. One of Chrysler's GTMVs is a Le Baron GTC convertible powered by a turbocharged, intercooled 2.2-liter 4-

cylinder engine with a slightly raised compression ratio. Its peak performance is on a mixture of 85 percent methanol and 15 percent gasoline, known as M85. On that mixture, horsepower is 175 and torque 205 lb.-ft. The standard engine, on 100 percent gasoline, produces 150 hp and 188 lb.-ft. of torque.

How does the engine know what it's being fed? Flex-fuel vehicles adjust to differentiations with a sensor in the fuel system that determines the amount of alcohol just before it enters the induction system. The device, which may be optical or electronic, continually monitors the fuel flowing past it. The information is fed to an on-board computer which makes instantaneous adjustments of spark timing and air/fuel ratio.

We may never have a 100-percent methanol fleet across the entire U.S. The more likely scenario is a gradual shift to M85-fueled vehicles. The addition of that small percentage of gasoline adds odor and a visible flame for safety reasons, and improves cold starting, while retaining the benefits.

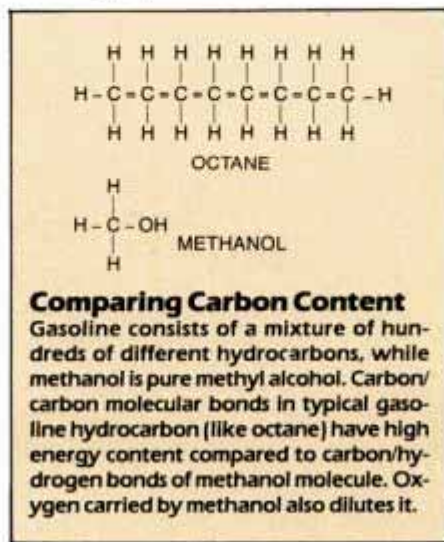
But there is a big difference between having FFVs in the showroom and FFVs on the street. The President's goals can only be realized if customers buy the cars he is calling for.

Ford Chairman Donald E. Petersen says plainly that "monetary incentives will be the key."

Monetary incentives will likely take the form of government subsidized rebates on an FFV, making it a better deal than a gasoline car, and a pump price lower than gasoline.

Right now, with its many advantages and few drawbacks, the fuel that will power future cars and trucks appears to be methanol. **PM**

See this month's Science column for info on advances in producing a cleaner gasoline.



O N L Y O N



*The one-of-a-kind Aston Martin Group C racer.  
Exclusive tires: Goodyear Eagle racing radials.*



*The \$275,000 limited edition Aston Martin Volante Zagato.  
Exclusive tires: Goodyear Eagle V speed-rated "Gatorback" street radials.*



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BECAUSE THERE REALLY IS A DIFFERENCE.





# COALAHOLICS

We test three state-of-the-art methanol-powered cars from Chevrolet, Ford and Chrysler.

BY MIKE ALLEN, Assistant Auto Editor; PM Photos by G Photo

**B**UILDING A CAR that runs, and runs well, on methyl alcohol (methanol) isn't particularly hard. Just look at any Indy 500 race car. Every one of those 220-mph racers burns pure methanol, which is made from coal. Some alcohol-powered dragsters are capable of 250 mph from a standing start in a quarter-mile.

Much as some of us would like to drive our race car to the office every day, these types of vehicles aren't a viable option for daily transportation.

But sheer go-power isn't the only appeal of this alternative to gasoline. It also burns cleaner than gasoline, making methanol very attractive from an environmental perspective.

California is considering proposals right now that would mandate that a good portion of the fleet vehicles sold in the Los Angeles Basin—an area with perhaps the nation's most serious smog problem—run on methanol. Fleet owners will have to install methanol pumps to service their own vehicles. What will happen a few years from now, when tightening clean-air standards force the rest of us to perhaps drive methanol-burners? The lack of methanol at the corner gas station makes privately owned alcohol burners useless for any out-of-



Under the hoods of the cars tested are all the familiar components, plus a fuel-line sensor to measure the proportion of methanol to gasoline fed to the engine. Sensor data allow engine computer to adjust to mixture.

town forays you may have planned.

In what seems to be a successful engineering move, the Detroit automakers are developing an alternative to the pure alky-burners—the flexible-fuel vehicle. There are remarkably few changes that are necessary to make a vehicle run on *either* ordinary unleaded pump gas or high-octane, cool-burning methanol—or any mixture of the two. Want to take a short jaunt to Palm Springs? It's farther than a single tank of go-juice will take you. But you can refuel at any garden-variety gas pump, and change back to methanol on your return.

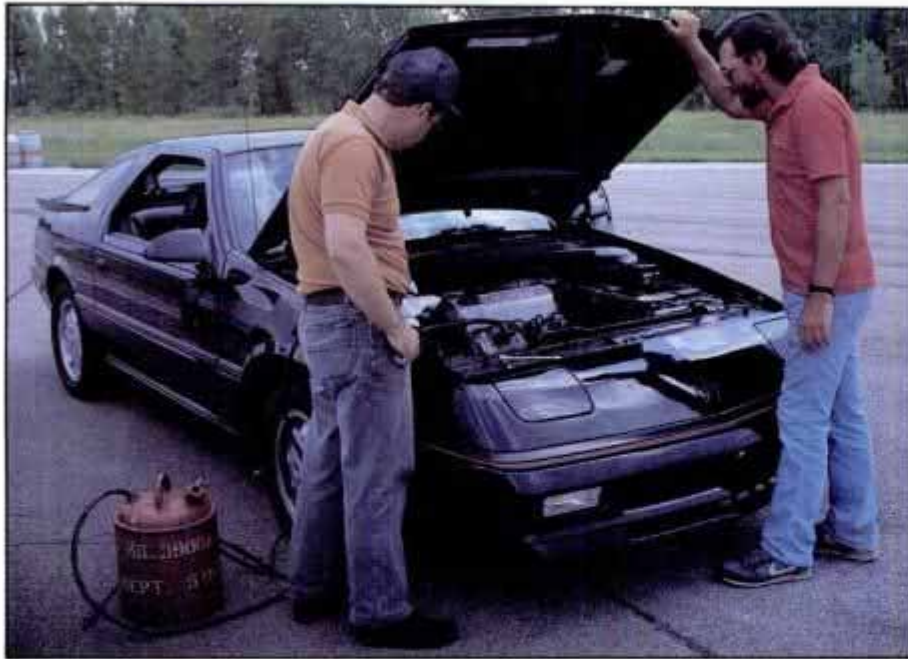
Actually, all of these vehicles are designed to run on a mixture of 85-percent methanol and 15-percent un-

leaded gas. There are two reasons for this. The first reason is safety. Methanol burns, during the daytime, with an absolutely clear, invisible flame. In the event of an accident or fire, what might otherwise seem to be a puddle of water on the street could actually be a blazing inferno. Adding 15-percent gasoline makes the fire bright enough to see. Secondly, methanol isn't as volatile as gas, and that makes cold startups difficult without the extra volatiles in the gas.

So how does a methanol-powered car run compared to a conventional gas burner? We wanted to know, too, so we gathered up three methanol-burning cars—one each from Chevrolet, Chrysler and Ford—and headed out to a test track.

In the case of all three of our test cars, the basic engine assembly is unchanged from their gasoline setup. Alcohol has a very high octane rating, and can run well in engines with very high compression ratios—16 or 18 to 1. But doing so would obviate the use of gasoline.

Alcohol is more chemically reactive than gasoline. All three cars use a stainless-steel fuel tank and lines, as alcohol peels the galvanizing off the inside of a conventional steel tank within a few months. Virtually any component that gets wet with fuel



## Ford FFV

Ford supplied us with a Taurus FFV, filled with M85, and a brand-new, identically equipped gasoline-powered Taurus. The new Taurus was destined for sled testing later, followed by a date with the crusher.

Taurus is a known quantity, with the 3.0-liter 6-cylinder engine providing good midrange power and not much excitement. Opening the hood reveals only a few subtle changes—like AeroQuip teflon/stainless-steel fuel lines. Ford uses a fuel sensor that employs optical principles—Methanol has a different index of refraction than gasoline, and a beam of light passed through a wedge-shaped cavity will bend differently. Measure the bend, and you know the proportion of gas to methanol.

Aside from the usual invisible methanol-tolerant parts, and the labels on the doors, the only tipoff is the methanol-concentration meter on the dashboard, which constantly reads out the percentage of methanol.

The only really unique component on the FFV is the sensor in the fuel line that tells the f.i. computer the proportion of methanol to gasoline. The computer itself is basically the same, with some additional chips and considerably different software.

These engines still rely on catalytic converters for emissions control. Methanol is a very clean-burning fuel, but there are some emissions, in the form of aldehydes, that present-day converters aren't designed to handle. Apparently the FFV was off its feed on the warm, windy day we tested. The stock gasoline Taurus we tested back-to-back was a few tenths faster

needs to be rated for methanol use. Many plastic and rubber parts either swell up or crack when bathed in methanol instead of gas.

The fuel injectors are replaced with high-flow versions, because it takes roughly twice as much volume of alcohol as gasoline to make about the same power. But despite the fact that methanol has only half as much energy per gallon as gasoline, it definitely can push you right along if you burn it fast enough.

Internal combustion engines are limited in horsepower by the amount of air they can suck in, not how much fuel. Methanol has a very high heat of vaporization—it gets cold as it evaporates, and that makes for a colder, denser intake charge into the cylinders. That means more air and, as a

Daytona was tested on M85 and then later on gasoline by draining and refilling tank. Hood graphics might as well go on an Indy car or alcohol dragster.



result, more horsepower. Combined with its high-octane antiknock qualities, that translates into anywhere from at least 10 to 25 percent more horsepower from a given engine configuration.

## Hydrogen-Powered BMW



**L**IKE THE OTHER vehicles on these pages, BMW's dual-fueled vehicle runs on gasoline when it needs to. But unlike the others, there's a healthy dose of aerospace, high-tech, high-dollar gee-whiz under the skin of an ordinary BMW 735i. Open the trunk, and try to squeeze your overnight case in next to the 100-liter liquid hydrogen tank. Vacuum-superinsulated, this tank isn't noticeably cold to the touch. But it does use up most of the trunk.

Underhood, there's a lot of extra plumbing, including hoses from the LH<sub>2</sub> tank, water lines to the system that warms the hydrogen to a gaseous state from its -250° F

storage, as well as an added-on belt-driven supercharger. The blower is necessary to restore some of the performance lost to hydrogen's low heat content.

Inside, there are several properly inscrutable computer-looking panels and boxes, and a lot of extra wiring. Obviously, this is a working engineering test prototype. Systems that aren't obvious include refueling valves, and sensors that detect potentially explosive hydrogen inside the trunk or interior and automatically open the windows and trunk. No smoking is permitted, for obvious reasons.

How did it drive? In a nutshell, not very well. The blower restores some of the lost power, but not much. The German-speaking test driver delegated to squire me around (BMW felt the car was too valuable for performance testing, or even to be driven by journalists) rowed the automatic trans mercilessly up and down the gears, trying to stay in the narrow powerband. His success was diluted by a lot of lean backfires and considerable stumbling.

With limited range, potentially hazardous refueling, a gas tank that evaporates bone dry in only a few days, BMW still has a lot of work to make hydrogen a viable option.

—Mike Allen

## COALAHOLICS



FFV Taurus was slower than gas-powered Taurus, although tests show 6-hp gain to 162 hp using 85-percent methanol/15-percent gasoline.

and felt even stronger, especially off the line. Best times were achieved when we could spin the front tires loose by holding the car with the brake. That's common with fwd cars, but the FFV's engine was too weak to spin anything. Dr. Roberta Peters, Ford's FFV guru, was surprised at the results, as their own testing shows the FFV to do as expected, and run slightly faster than gasoline-powered vehicles.

Driveability was excellent. No stumbles, backfires, surging or other complaints. Dr. Peters claims that even on M85 they've licked the cold-start problem down to -20° F. "It's all a matter of knowing where and when to add fuel."

### Chevrolet Variable Fuel Corsica

Chevrolet uses a different method for determining the concentration of methanol/gasoline. The sensor is essentially a large box with two plates separated by fuel. Electrically, a pair of plates separated by an insulator is a capacitor, and because the insulating properties (dielectric constant) of gasoline differ from methanol, the capacitor's value varies proportionally to the mixture's concentration.

Aside from the exterior and underhood graphics, there are no tipoffs to the differences between the M85-powered car and the gasoline twin we tested. Unlike the Taurus, the 2.8-liter V6-powered Corsica generates some satisfying wheelspin off the line,

and plenty of power right up to the redline. Best times were again achieved by holding the car with the brake to stall speed, about 3000 rpm, leaving the trans in Drive and letting it shift itself at 6000.

GM engineers admit that cold starting is a problem at this stage of development, with reliable starting below 40° F still not achieved.

### Dodge Daytona Turbo GTMV

GTMV (Gasoline Tolerant Methanol-powered Vehicle) stands for Chrysler taking the position that methanol-powered cars will spend most of their lives drinking alcohol, with only occasional trips to the petroleum well. Like the other vehicles, the engine itself is purely production, with only changes to the engine control systems and the fuel-wetted parts of the fuel system.

Chrysler also uses an optical sensor to measure the proportion of methanol to gas, and has a small readout in the speedo mirroring that percentage. The sandwich-sized sensor is remarkably unimpressive to look at, and like the other vehicles we tested, there's not a trace of Star Wars under the hood. The engineering changes are all buried inside the fuel-injection system, and its software. Cold starting? "It's under development."

Catering to the tastes of curious automotive journalists, Chrysler used the decidedly sporty Daytona Turbo, with 2.5-liter intercooled 4-cylinder turbo and 5-speed transmis-

sion for an engineering testbed. Turbo Daytonas are pretty quick little boxes running on plain unleaded, and we were looking forward to a chance to wring out this one. The plan, because of the lack of a readily available twin car, was to run times on M85, drain the tank, refuel with gasoline and repeat the testing.

A last minute change of plans switched our testing from Michigan International Speedway to Chrysler's Chelsea Proving Grounds. Unfortunately, the extra road mileage brought the level of M85 in the tank down to the fuel-starvation point before we completed the first tests. And the nearest methanol was, who knows where? Proving that the concept of a flexible-fueled vehicle is a good one, we simply continued testing on gasoline. The performance numbers you see here are supplied by Chrysler, from a different day of testing, and we find them very believable. The turbo motor undoubtedly finds high-octane, cool-burning alcohol to its liking, making the 4-cylinder Daytona accelerate briskly.

### The Future

Is there a methanol-powered car in your future? Maybe. Should you be worried? Probably not. There are a few engineering wrinkles to work out, minor things like cold starts and long-term longevity of the fuel system. But rest assured that by the time these cars come to market, those will be non-issues. **FM**

### TEST RESULTS—GASOLINE VS. METHANOL

MANUFACTURER/MODEL	FUEL	ACCELERATION 0-60 mph (sec.)	ACCELERATION ¼ MILE (sec. @ mph)
<b>Chevrolet Corsica</b>	Gasoline	9.43	17.40 @ 79.70
<b>Chevrolet Variable Fuel Corsica</b>	M85	9.17	17.10 @ 81.60
<b>Dodge Daytona Turbo GTMV</b>	Gasoline	8.56	15.56 @ 86.10
<b>Dodge Daytona Turbo GTMV</b>	M85	7.80	15.01 @ 91.00
<b>Ford Taurus</b>	Gasoline	9.72	17.45 @ 80.40
<b>Ford Flexible Fueled Vehicle</b>	M85	10.34	18.27 @ 77.00

## COMPARISON TEST

# TALE OF THE TAPES

How do the new 100-minute audio cassettes perform compared to the shorter-length 90-minute variety? Our tape shootout tells all.

BY STEPHEN A. BOOTH, Electronics Editor, and  
FRANK C. BARR, President, Advanced Product Evaluation Laboratory

**T**HE AUDIO CASSETTE, formally named the Compact Cassette, has come a long way in the quarter-century since its birth. Now, at age 25, it's getting longer—and better, according to tests conducted by POPULAR MECHANICS and the Advanced Product Evaluation Laboratory.

The cassette today is the most popular medium for music recording, but this wasn't always so. Its inventor, N. V. Philips of the Netherlands, originally perceived the format as a dictation-quality

medium for low-fidelity voice recordings—and little more. At the time, open-reel recording tape reigned supreme, for some very good technical reasons.

The tape on the large reels meas-

ured ¼ in. wide and ran at speeds as high as 15 in. per second. Compared to this, the diminutive cassette's tape measured 1<sup>5</sup>/<sub>100</sub> in. across and rolled at a slow 1<sup>7</sup>/<sub>8</sub> ips. By today's standards, the magnetic pigment on all tapes was limited in its ability to accommodate a musical signal. To do so with high fidelity, it was necessary to move a large volume of tape past the deck's recording heads.

This accounts for the width and speed of open-reel tape recording. Under the stress of musical signals, the narrow, slow cassette



# TALE OF THE TAPES

tape couldn't bear the load. It quickly became saturated, thereby distorting the sound. Even the shell and tiny reels were suspect. Compared to open reels, cassette reels tended to wobble and run unevenly, further distorting the recorded sound.

## Ongoing improvements

Despite its early limitations, the cassette was a born winner. Because it was small, it was mobile—opening the way for car-stereo systems, boomboxes and Walkman-type portables that travel better than open-reels and phonograph records. Given the impetus of high-volume sales, blank-tape manufacturers began to improve every aspect of the cassette's operation.

Today, it is virtually perfect—a mini-replica of the nearly extinct open-reel system. Shells and reels operate smoothly and reliably, causing no audible variations in musical pitch. The magnetic pigments coated on the tapes are retentive enough to record strong and demanding musical signals, even at the slow 1 7/8-ips speed.

The pigments, in fact, have become so good that they can be applied in thinner and thinner layers, with no loss in sound quality. For some time, the 60-minute cassette (called a C-60,

with 30 minutes of recording capacity per side) was the practical limit. Then, the arrival of thinner, stronger base films made the C-90 possible. Coating and base were reduced to fit 50 percent more tape in the shell, with no appreciable loss in fidelity.

Now, ongoing improvements in magnetics and materials have resulted in the C-100, and even 110- and 120-minute audio cassettes. In recent months, five tape manufacturers have introduced longer lengths, and other companies are sure to follow. Credit the digital audio Compact Disc for precipitating the "silly millimeter longer" campaign. C-60s and C-90s offer adequate capacity for recording the average LP phonograph record, but CDs contain more playing time.

## Slaying a myth

Although the longer tapes are a boon to music lovers, they also have the potential to create confusion. Extra length cassettes have been available for years—and virtually every equipment manufacturer has cautioned against their use in high-fidelity recorders and players. These existing C-120s and C-180s are designed for dictation purposes, where their superthin coatings and base films provide adequate fidelity for voice recording. Sound quality aside, their very thinness might pose handling problems—breaks, jams and snarls.

This would be especially troublesome in car-stereo tape players, where the cassette is drawn into the unit and not accessible, thereby creating a potentially expensive repair bill.

Although the new, longer cassettes are designed for high-fidelity recording, it is likely that home recordists would be rightfully wary of using them after years of warnings about longer tapes. Accordingly, POPULAR MECHANICS decided to test the C-100s against their C-90 equivalents for both recording quality and handling characteristics.

The results from the Advanced Product Evaluation Laboratory (APEL) are encouraging—in fact, superlative. Magnetically and physically, the longer cassettes perform as well as their shorter versions and, in some cases, better.

APEL tested every longer length tape on the market—in all, 12 tape formulations from five brands: BASF, Denon, Maxell, Memorex and TDK. For each formulation (for example, BASF Ferro Extra I), the C-90 and the longer version were tested.

The cassettes represent every tape type—I, II and IV. These Roman numerals are a standard designation, decreed by the International Electrotechnical Commission (IEC), for a tape's magnetic formulation, recording bias and equalization.

Type I tapes use a ferric oxide for-

## LAB TESTS

BRAND/LENGTH	MAGNETIC PROPERTIES		PHYSICAL PROPERTIES					OTHER Flutter (%)
	Coercivity (Oersteds)	Retentivity (Gauss)	Tensile Strength (Lbs.)		Thickness (Mils)			
			5% Elongation	Breaking	Base	Coat	Total	
<b>TYPE I TAPES</b>								
BASF Ferro Extra I/90	391	1615	1.14	1.93	.27	.16	.43	.15
BASF Ferro Extra I/100	388	1618	1.10	2.29	.26	.15	.41 (A)	.14
TDK AR/90	350	1754	1.00	1.94	.27	.19	.46	.14
TDK AR/100	352	1780	1.13	2.14	.23	.18	.41 (A)	.15
<b>TYPE II TAPES</b>								
BASF Chrome Extra II/90	615	1521	1.19	2.19	.26	.18	.44	.15
BASF Chrome Extra II/100	608	1474	1.06	2.24	.25	.17	.42 (A)	.14
Denon HD6/90	716	1415	1.26	2.07	.25	.21	.46	.14
Denon HD6/100	746	1718	1.06	1.94	.24	.20	.44 (A)	.15
Denon HD8/90	790	2583	1.10	2.21	.27	.16	.43	.13
Denon HD8/100	800	2599	1.09	2.20	.27	.16	.43 (B)	.14
Maxell XLII/90	733	1550	1.16	1.95	.25	.19	.44	.15
Maxell XLII/100	736	1566	1.16	1.93	.23	.16	.39 (A)	.14
Maxell XLII-S/90	763	1460	1.08	2.01	.25	.20	.45	.14
Maxell XLII-S/100	765	1515	1.05	1.94	.23	.15	.38 (A)	.14
Memorex HBS-II/90	753	1398	1.31	2.42	.27	.17	.44	.15
Memorex HBS-II/100	725	1535	1.16	1.56	.25	.17	.42 (C)	.14
TDK SA/90	720	1522	1.14	2.30	.25	.19	.44	.16
TDK SA/100	718	1522	1.09	1.84	.23	.19	.42 (C)	.17
<b>TYPE IV TAPES</b>								
Denon HD-M/90	1249	2813	1.09	2.19	.27	.18	.45	.15
Denon HD-M/100	1236	2750	1.08	2.20	.26	.17	.43 (A)	.14
Maxell MX/90	1242	2690	1.44	2.70	.29	.17	.46	.13
Maxell MX/100	1243	2860	1.37	2.54	.26	.14	.40 (A)	.12
TDK MA/90	1221	3045	1.04	1.98	.27	.13	.40	.15
TDK MA/110	1224	2813	1.12	1.74	.23	.14	.37 (D)	.15

Compared to the shorter length (A) has thinner base and coating; (B) has same base and coating; (C) has thinner base, same coating; (D) has thinner base, thicker coating but is thinner overall. Note that Denon HD6/100 and Memorex HBS-II/100 use different magnetic formulations than their 90-minute versions.

mulation, normal bias and 120-microsecond (120- $\mu$ s) equalization. *Bias* is the amount of current needed to create a magnetic pattern on the tape. *Equalization* is a manipulation of the audio signal to ensure uniform output at all frequencies. Type II tapes use a chromium dioxide material, or some equivalent. These materials require 70-microsecond EQ and a higher bias current to magnetize them. This is why they're sometimes called high-bias tapes. Type IV cassettes use a pure iron pigment that requires the highest bias current of all. They're popularly called metal tapes and use 70- $\mu$ s EQ.

### Reading the charts

For the record, the main difference among the types is their background noise level (the hiss) and their ability to record high-frequency (treble) sounds. As you'll see from the accompanying charts, Type II tape is the quietest, with the highest signal-to-noise (S/N) ratios. Generally, maximum output level (MOL) and saturation output level (SOL) at high frequencies improve with the tape-type numeral. This is also true of dynamic range—a measure of how well a tape records sounds between the loudest and softest parts of the music

(the greater the number in decibels, or dB, the better). Though Type II doesn't seem much higher than Type I on the MOL and SOL charts, in practice, treble frequencies sound more pronounced against Type II's quieter background. This shows up on the dynamic range charts.

Any type of tape may be used for any type of recording. But expensive Type IV tape, which has the highest MOLs and SOLs, is best used for demanding material, including live music. Types I and II can be used interchangeably, though the quieter high-bias tapes work best for classical music with its frequent soft passages.

According to the APEL tests, all of the C-90s and their longer versions are excellent tapes. There is virtually no difference between the short and longer tapes in S/N, MOL, SOL, dynamic range and frequency response (the latter measures of how accurately the tape reproduces the original signal). Differences of 1.5 dB or less are virtually inaudible, and therefore insignificant.

### Rough 'n' ready

The C-100s (and TDK's MA-110) fared just as well as the C-90s in magnetic properties—and in APEL's physical torture-tests. Coercivity and retentivity, respectively, measure the tape's ability to accommodate and retain a magnetic signal. In both categories, the C-90s and longer tapes

have parity—despite the use of thinner coatings (measured in mils, or thousandths of an inch) on some of the longer tapes. And despite the use of thinner base films on some of the longer tapes, they're not much more delicate than C-90s. Tensile strength, measured as the pounds of force needed to stretch the tape 5 percent and to break it (a standard IEC test), is excellent for the long tapes.

In APEL's other torture-tests, the C-100s proved no different in performance than the shorter lengths. These trials included freezing for 24 hours at -10° F and baking for a day at 160°—climatic conditions that might exist in a parked automobile. A more severe trial was the vibration test, in which the cassettes were shaken up, down and sideways 20 times per second for 30 minutes—movement much more violent than anything that would be encountered when driving or jogging. After each of these trials, the C-100s and C-90s showed the same magnetic and physical properties as before. Flutter—minute variations in tape travel that distort musical pitch—was an entirely insignificant fraction of 1 percent.

The bottom line is that you'll find no significant sound-quality difference between C-90s and their lengthier brethren—and little difference in price. There's nothing to lose, including those last few minutes of your favorite highway tunes. **FM**

## LAB TESTS

BRAND/LENGTH	S/N RATIO (dBA)	MAXIMUM OUTPUT LEVEL (dB)			SATURATION OUTPUT LEVEL (dB)		DYNAMIC RANGE (dB)			FREQUENCY RESPONSE (dB)
		50 Hz	315 Hz	1KHz	10KHz	16KHz	315 Hz	1KHz	10KHz	315 Hz—16KHz
<b>TYPE I TAPES</b>										
BASF Ferro Extra I/90	54.0	-0.9	+2.8	+2.8	-7.2	-15.3	56.8	56.8	46.8	+0.2/-0.1
BASF Ferro Extra I/100	53.1	-0.5	+3.3	+3.5	-7.0	-15.1	56.4	56.6	46.1	+0.2/ 0.0
TDK AR/90	55.6	+3.2	+6.4	+5.1	-6.4	-14.0	61.9	60.5	49.1	+0.1/ 0.0
TDK AR/100	55.7	+2.8	+5.3	+4.1	-6.8	-14.6	60.9	59.7	48.9	+0.1/-0.1
<b>TYPE II TAPES</b>										
BASF Chrome Extra II/90	60.2	-1.7	+2.2	+0.5	-8.6	-15.5	62.6	60.8	51.6	+0.1/-0.1
BASF Chrome Extra II/100	60.3	-1.9	+2.2	+0.4	-8.7	-15.7	62.5	60.7	51.6	+0.1/-0.2
Denon HD6/90	58.9	-2.8	+0.7	-0.2	-8.7	-15.4	59.6	58.7	50.2	0.0/-0.4
Denon HD6/100	59.0	-1.9	+2.0	+1.0	-6.9	-13.8	61.0	60.0	52.1	+0.2/-0.1
Denon HD8/90	55.5	-0.6	+3.1	+2.1	-4.8	-10.8	58.6	57.6	50.7	0.0/-1.3
Denon HD8/100	55.5	-1.1	+2.1	+0.9	-5.1	-11.1	58.0	56.7	50.7	0.0/-1.0
Maxell XLII/90	59.0	-3.4	+1.2	+0.2	-8.3	-15.1	60.2	59.2	50.7	0.0/-0.1
Maxell XLII/100	59.1	-2.9	+1.0	+0.4	-8.3	-15.2	60.1	59.4	50.8	+0.1/-0.1
Maxell XLII-S/90	60.3	-3.3	+0.1	-0.4	-8.3	-14.8	60.5	59.8	52.1	0.0/-0.4
Maxell XLII-S/100	60.2	-3.3	0.0	-0.5	-8.4	-14.6	60.2	59.7	51.8	+0.1/-0.3
Memorex HBS-II/90	59.3	-3.0	+0.5	+0.4	-8.1	-14.6	59.8	59.7	51.2	0.0/-0.2
Memorex HBS-II/100	59.2	-3.5	+0.6	0.0	-8.5	-15.1	59.9	59.2	50.7	0.0/-0.2
TDK SA/90	60.6	-1.4	+2.3	+1.3	-7.9	-15.1	62.9	61.9	52.7	0.0/-0.1
TDK SA/100	60.8	-2.1	+1.4	+0.5	-8.0	-14.5	62.2	61.3	52.8	+0.1/-0.1
<b>TYPE IV TAPES</b>										
Denon HD-M/90	58.5	+1.6	+5.7	+4.7	-4.8	-7.4	64.2	63.2	53.7	+0.2/-0.1
Denon HD-M/100	58.5	+1.6	+5.8	+5.1	-5.1	-7.0	64.3	63.6	53.4	+0.2/-0.1
Maxell MX/90	58.3	+1.2	+4.9	+4.1	-4.5	-6.4	63.2	62.4	53.8	+0.1/-0.1
Maxell MX/100	58.3	+1.1	+5.1	+5.0	-4.4	-6.2	63.4	63.3	53.8	+0.4/-0.1
TDK MA/90	58.3	+1.9	+5.9	+6.1	-4.6	-6.7	64.2	64.4	53.7	+0.4/ 0.0
TDK MA/110	58.4	+2.0	+5.8	+6.1	-4.4	-6.9	64.2	64.4	54.0	+0.4/ 0.0

# Quality is Job 1.

## **Profile in quality #3: Prevention.**

*Ford Motor Company believes in prevention. Beginning with the prototype stage, we test models of our Fords, Mercurys and Lincolns on a gruelling "roller road" shaker machine. While this is going on, our engineers are listening for possible squeaks and rattles with highly sensitive stethoscopes (much like your doctor uses). By doing this, we can help engineer squeaks and rattles out, before you ever get in. When quality is job 1—you don't do it any other way.*

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Our goal is to build the highest quality cars  
and trucks in the world.**



*Buckle up—together we can save lives.*

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CHEVROLET C1500 454 SS

# POWER TRUCKIN'

The pickup and sport/utility vehicle boom hits the '90s with more muscle and more variety.

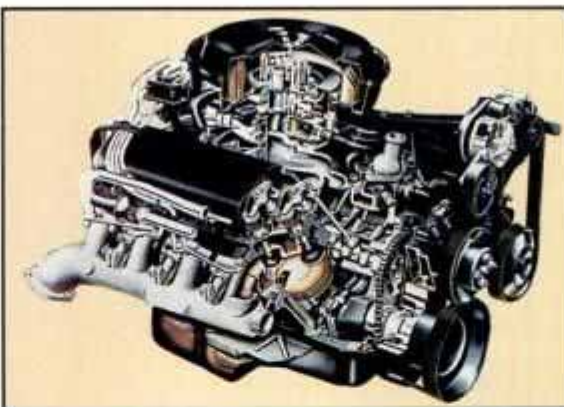
BY TONY SWAN, Automotive Editor, and JIM DUNNE, Detroit Editor

**A**MAZING, ISN'T IT? With the boom in the compact pickup and sport/utility marketplace, America is going truckin' as never before.

Eager to capitalize on this phenomenon, the light-truck industry, both domestic and imported, is responding with even greater model variety for the 1990 model year.

The choices range from unabashed big-inch honkers like the Chevy 454 SS full-size pickup pictured above to the superversatile club cab pickups and 4-door sport/utilities. But through it all, there's a consistent emphasis on power, with new engines coming into some model families and other established powerplants getting wholesale performance tweaks and upgrades.

Our make-by-make rundown of 1990 new truck news follows. We are omitting vans and minivans from this roundup, but watch for a major minivan comparison test in an upcoming issue.



Chevy's 454-cu.-in. big-block V8 gives the C1500 pickup 230 hp and 385 lb.-ft. of torque.

## Chevrolet

The bow-tie boys steal the 1990 show with the biggest—literally—power news in the business. If you've been yearning for a return to the stump-pulling, tow-anything days of yesteryear, well, yesteryear is here. The stylish C1500 454 SS and its no-nonsense Work Truck counterpart, both members of Chevy's full-size C/K series, include the good old big-block

454-cu.-in. V8—230 hp and 385 lb.-ft. of torque—as standard equipment.

The SS also includes a performance handling package, plus coolers for engine and transmission oil, a heavy-duty radiator and locking differential, as well as a lengthy list of comfort and convenience features worthy of a luxury car.

Though a good deal more spartan in terms of creature comforts and trim, the Work Truck, available in either 2- or 4-wheel drive, boasts a Gross Vehicle Weight Rating of 5600 pounds, which adds up to a 1711-pound payload in 2-wheel-drive models.

Chevy is also offering a heavy-duty version of its 4.3-liter V6, slightly detuned to better withstand prolonged operation under heavy loads at low speeds.

There are also standard and heavy-duty versions of the General Motors 6.2-liter V8 diesel, plus 5.0- and 5.7-liter gas V8s, giving Chevrolet trucks as broad and varied a range of power-



**DODGE RAM 150S CLUB CAB**

train offerings as any manufacturer in the business.

Over in the compact camp, a new Getrag-designed 5-speed manual transmission is available for 4.3-liter V6-powered S-10 pickups and S-10 Blazers. Built by GM's Hydramatic subsidiary, the new Hydramatic 290 5-speed will also be available with Chevy's 2.8-liter V6, but this package will be offered only for 1990. Also, the 4.3 V6 is now standard equipment on all Blazer models.

The improvements to Chevy's various compact light-truck entries also apply to their counterparts from GMC, the S-15 Pickup and S-15 Jimmy sport/utility.

Chevy's jaunty little Suzuki-supplied Geo Tracker sport/utility, a newcomer for the 1989 model year, is another entry with more power available for 1990, thanks to the addition of Chevy's 2.8-liter V6 in 4-wheel-drive models.

## Dodge

Chrysler Corp.'s official truck division is concerning itself in 1990 more with interior volume than with muscle. Dodge achieved something that was truly unique in this area last year with the introduction of the industry's only convertible pickup truck, and follows up for the coming year with new club cab versions of its Ram and Dakota models.

The full-size Ram series club cab comes on either a 133-in. wheelbase or a new extended 149-in. version. The short wheelbase is available in 2-wheel drive only, and cargo box length is limited to 6½ ft. The longer wheelbase includes two models with 4-wheel-drive availability, and an 8-ft. cargo box is standard.

Ram series pickups will again be offered with three different engine options—a 125-hp 3.9-liter V6, a 170-



**DODGE DAKOTA SPORT CLUB CAB**

hp 5.2-liter V8 and a 5.9-liter (360-cu.-in.) V8 rated at 190 hp. Also, a new heavy-duty 4-speed overdrive transmission has been added to the power-train mix.

The Dakota club cab is available in either base (124-in. wheelbase) or Sport (131-in. wheelbase) configuration, with the longer wheelbase new to the lineup this year. For 1990, the club cab models will be 2-wheel drive only.

Interior trim changes include 40/20/40 split bench seats for the club cabs, as well as some new colors. The two engine offerings for the Dakota line will be strictly carryover—a 117-horsepower 2.5-liter Four and 125-horsepower 3.9-liter V6.

Dodge's Mitsubishi-supplied small-truck line, the Ram 50 series, does get a power upgrade for 1990 with the availability of Mitsubishi's excellent 3.0-liter V6 engine. Among other performance improvements, the 143-hp Six increases trailer towing capacity to a respectable 3500 pounds.

However, the V6 engine option is available only with 4-wheel drive. The base engine continues to be a 2.6-liter Four.

As a consequence of the increased U.S. tariff on 2-door sport/utility vehicles, Dodge is dropping the Mitsubi-

shi-supplied Raider from its truck lineup for 1990.

## Jeep

It's a year of refinements for the Jeep division, with a number of subtle engineering updates scheduled for the Wrangler/Cherokee/Wagoneer/Comanche lineup.

Among the more interesting technical touches are new composite front brake rotors using cast-iron friction surfaces mated to stamped steel centers. The sandwich construction saves weight—about 3 pounds—and is expected to improve braking efficiency.

Jeep has also improved its ability to meet the unexpectedly intense demand for its new-in-'89 Cherokee 4-wheel antilock braking system. This option was an industry first for a full-time 4-wheel-drive vehicle.

## Range Rover

Having addressed the go-power issue last year by increasing the displacement of its aluminum-alloy V8 engine (from 3.5 to 3.9 liters and 178 horsepower), Range Rover adds improved stopping capability to its full-time 4wd luxury sport/utility package for the coming year with a new 4-wheel antilock braking system.

Range Rover has also improved the efficiency of its 4-wheel disc system with the addition of vented front brake rotors.

Fuel economy has been improved by 1 mpg, to 13 city, 16 highway, and there are a number of adjustments to interior and exterior trim, including recontoured seating.

## Nissan

Although we were unable to obtain photos of this entry by press time—introduction is scheduled for very late fall—we know that Nissan's major light-truck news for 1990 is the addition of a new 4-door Pathfinder to its popular sport/utility range.

Riding on the basic 104.3-in. pickup chassis, the newcomer is 171.9 in. overall, and Nissan is claiming the biggest interior volume dimensions of any 4-door sport/utility currently available.

Nissan has found another 10 hp in its smooth 3.0-liter V6 engine, raising maximum output to 155 hp. This will be the only engine offered for the Pathfinder.

Optional equipment that will be available on the new Pathfinder includes rear disc brakes, driver-adjustable shock absorbers, a limited-slip differential for 4-wheel-drive models and bigger 31x10.5R15 tires.

The 4-door Pathfinders will be offered in both 2- and 4wd editions, while 2-door Pathfinders will be 4x4 only.

Nissan's range of **Hardbody pickups**, 14 models strong for 1990, also benefits by the improved 3.0-liter V6 output, as well as a new 2.4-liter 12-valve Four.

This will be the Hardbody base powerplant and is basically the same engine used in Nissan's 240SX sport coupe, rated at 130 hp—a 24-hp improvement over the 4-cylinder available in 1989 Hardbodies.

Like the Pathfinders, the Nissan pickups also receive a more aerodynamic front-end appearance update for the new model year.



Ford's new 4.0-liter V6 brings much-needed muscle to both Ranger and Bronco II lineups.

## Ford

With a complete redesign of the Bronco II (the new model will be called the Explorer) still a year away from production, Ford's big light truck news for 1990 is a new 4.0-liter V6 engine, offered as an option for Ranger series compact pickups.

Built by Ford of Germany, the new V6, a 60° design, is an expanded and updated version of Ford's current 2.9-liter V6, and is rated 160 hp with 240 lb.-ft. of torque, compared to 170 lb.-ft. for the 2.9. Technical features of the new engine include a single serpentine accessory drive belt, distri-

butorless ignition and hydraulic roller lifters.

Ford will continue to offer the basic 100-hp 2.3-liter Four and 140-hp 2.9-liter V6 engines in 1990 Rangers, but the 2.9 will be the only engine available in Bronco II models during their final year on the market.

In another powertrain upgrade, Ford is replacing its old C-6 automatic transmission (full-size Broncos and F-series pickups) with a new electronically controlled 4-speed automatic. The new transmission will mate up to Ford's 4.9-liter V6 and 5.8-liter V8 engines.

The engine control computers for both engines include new self-diagnostic capabilities for 1990.

## Toyota

Like Nissan, Toyota's major news this year is an addition to its sport/utility line, the 4-door 4Runner. Toyota introduced the 4-door edition several months ago in 2- and 4-wheel-drive versions.

A 2-door edition of the new 4Runner will also be offered, but only as an upscale 4x4 model, due to the extra tariff on 2-door imports.

In addition to the new 4-door bodywork and a modest facelift, the 4Runner line will get a little more horsepower from its optional 3.0-liter V6, 150 versus 145 in 1989. The base engine continues to be Toyota's 2.4-liter 116-hp Four.

Other mechanical upgrades include a new independent rear suspension system, from the pickup series introduced last year, antilock braking system for the rear wheels, and optional 31x10.5 tires.

Available on both 2- and 4-wheel-drive models, the antilock system functions only when the vehicle is operating in 2wd. In 4wd operation, a proportioning valve sends most of the braking power to the front wheels, to prevent rear-wheel lockup. An inter-



## POWER TRUCKIN'



MITSUBISHI MIGHTY MAX

esting technical aspect of the design is that it operates off the power steering pump, rather than engine vacuum.

The Toyota pickup line, which underwent extensive revision last year, also gets the new antilock feature but is otherwise unchanged.

### Isuzu

Forget about the Roman numerals that used to be part of the official name for Isuzu's Trooper II sport/utility vehicle. For 1990, it's simply called the **Trooper**, with a number of different model designations—S, XS, LS and RS.

Aside from a number of small trim changes that go with the model shuffles, that's about the only news on the Trooper front. Isuzu's other sport/utility line, the smaller **Amigo**, gets the option of Chevrolet's 2.8-liter V6 engine with 4wd models. This engine is also available in the Trooper, whose base powerplant continues to be Isu-

zu's 120-hp 2.6-liter Four. Amigo's base engine is a 96-hp 2.3-liter Four.

On the pickup front, Isuzu's lineup, which got a thorough redesign last year, is unchanged save for the addition of a rear antilock brake system as standard equipment on all models. The ABS feature switches off when the truck is in 4-wheel drive.

### Suzuki

Although it has lost some of its Southern California cult-car allure, Suzuki's **Samurai** returns once again to hold down the least expensive end of the sport/utility market. You can't get a dirt-capable vehicle for less.

The Samurai's fuel-injection system has been overhauled for 1990, yielding a small gain in horsepower (66 versus 64) and a bigger gain in all around driveability.

Suzuki's **Sidekick**, which is known as the Geo Tracker in Chevrolet showrooms, returns for its second

season on the SUV market virtually unchanged.

### Mitsubishi

Although there are no sheetmetal revisions to Mitsubishi's pickups or Montero sport/utility vehicles, there are a couple of noteworthy powertrain upgrades.

Topping the list is the availability of Mitsubishi's smooth 143-hp 3.0-liter V6 in 4wd pickups, replacing the venerable 2.6-liter Four. Base powerplant for the pickup family is now a 116-hp 2.4-liter Four, replacing the previous 2.0-liter Four.

About the only cosmetic change to any of the Mitsubishi trucks is a black-out grille for the Mighty Max pickup package.

The 3.0-liter V6 is also the sole powerplant for the Monteros. Mitsubishi has dropped the 2.6-liter Four from the lineup.

### Mazda

Having topped the J.D. Power light-truck Consumer Satisfaction Index (CSI) for three straight years, Mazda plans no major changes for 1990. The only noteworthy mechanical upgrade is the addition of an antilock rear brake system as standard equipment on all models.

Mazda is also adding a new trim level—LE-5—which makes three models available in either 2- or 4-wheel drive. The two engine offerings—an 85-horsepower 2.2-liter engine and a 121-horsepower 12-valve 2.6 with balance shafts—are the same as '89. **PM**

## Laforza: Beauty And The Beast

**U**NTIL RECENTLY, if you wanted power, prestige and luxury in a vehicle with real off-road capability, there was only one choice. But with the recent arrival of the Laforza, a leather-lined muscle-ute, Range Rover finally seems to have some competition.

Developed by American enthusiasts, the Laforza—which means strength, force or power in Italian—is built around Ford's torque (270 lb.-ft.) 5.0-liter (302-cu.-in.) V8, mated to a 4-speed overdrive automatic transmission and Chrysler viscous-coupled transfer case with limited slip and 3.9 to 1 final drive.

Suspension is independent double wishbones and coil springs at the front, with a live axle at the rear and Bilstein shocks all around, and the turning circle is under 30 ft.

Although the company is based in Hayward, California, Laforzas begin life at the Pininfarina works in Turin, Italy. Pininfarina makes the Laforza's rolling chassis, its 18-gauge galvanized steel bodywork and luxurious interior furnishings.



LAFORZA

From Turin, the vehicles are shipped to C&C, in Michigan for powertrain installation.

With its 106.2-in. wheelbase, 179.9-in. overall length, and blocky 79.0-in. width, the Laforza offers exceptional interior volume. There's seating for adult-sized people front and back, with excellent leg, head and elbow room.

Ride quality is excellent, on-road or off, and the Laforza's capabilities as a real dirt-going 4wd machine seem to be competitive.

There's also plenty of low-end grunt for stump-climbing, boulder-hopping and trailer-towing. However, Laforza's substantial curb weight—5250 pounds—offsets the advantage of V8 torque to some degree, making acceleration a somewhat deliberate process. The manufacturers plan to cure this by making Ford's 351-cu.-in. V8 standard later this year.

One area where Laforza doesn't have to play catch-up is price. At \$43,850 per copy, this new luxu-ute runs second only to the \$130,000 Lamborghini LM002. —Barry Brazier

PHOTO BY BARRY BRAZIER

# WOODWORKING GUIDE

# HAND WORK

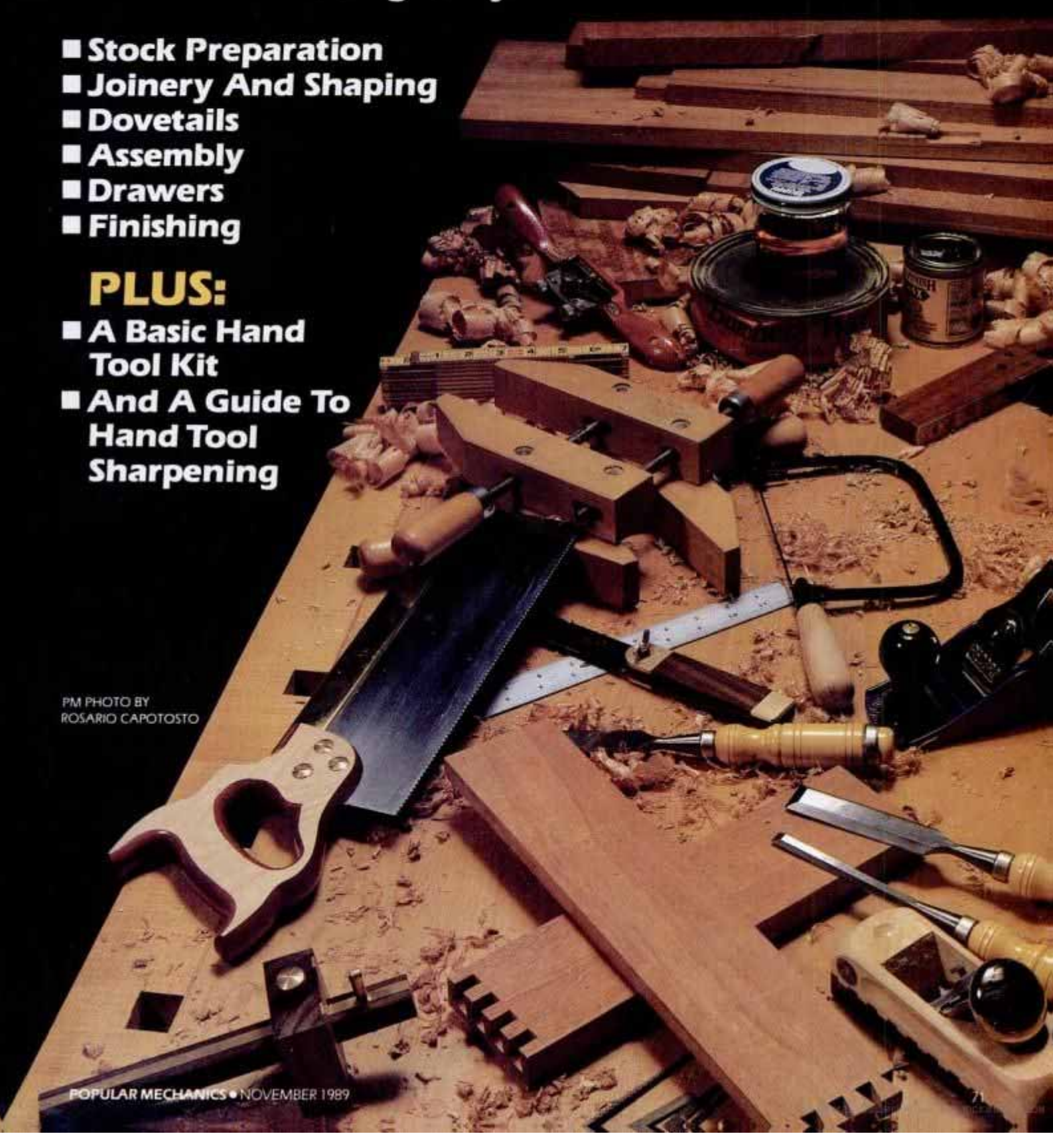
How To Craft Elegant Furniture  
Using Only Hand Tools

- Stock Preparation
- Joinery And Shaping
- Dovetails
- Assembly
- Drawers
- Finishing

## PLUS:

- A Basic Hand Tool Kit
- And A Guide To Hand Tool Sharpening

PM PHOTO BY  
ROSARIO CAPOTOSTO





# HAND BUILT

**B**UILT BY HAND. You've heard the term being used to promote everything from kitchen cabinets to automobiles. It denotes a finished product that has intrinsic value, some intangible quality that no machine-made product can ever claim, no matter how well fit and finished.

A handmade object, after all, embodies certain elements that are the very antithesis of machine production. It represents an investment in both time and effort that far exceeds the requirements of machine-assisted work. More importantly, it demands a keen eye and steady hand—a level of skill that's constantly evolving in search of perfection.

Of course, woodworkers of yesterday knew nothing of routers and radial-arm saws and had no choice but to carry on the time-honored techniques of those who went before them. The basic skills were not only unquestioned, but considered common knowledge—simply a part of everyday life. Today's woodworker can choose whether to do the job by hand or power. The difference lies not in the finished product, but in the process. And, it's the dedication to the process—making the effort, taking the time and developing the skills—that makes doing it by hand a satisfying and rewarding experience.

This year, we've dedicated our entire Woodworking Guide to making things the traditional way—without power tools. The centerpiece of our efforts is this elegant mahogany secretary. Based on designs from the 18th century, it's a classic example of the woodworker's art and incorporates typical joinery and molding details common to handcrafted work of this period.

The entire project, from cutting the rough-sawn wood to applying the last coat of wax, is explained in detail in the following sections. Each section is devoted to a specific phase of construction.

Woodworking that spans the centuries in style and execution.

BY THOMAS KLENCK, Associate Home and Shop Editor

Stock Preparation (page 75) deals with crosscutting and ripping lumber to size, then hand-planing it to the correct thickness—a subject all but ignored in today's world of store-bought, planed lumber.

Next comes Joinery And Shaping (page 81). Here the components are trimmed to exact size and the dadoes, grooves, rabbets and mortise-and-tenon joints are cut. This section also explains how to plane a quarter-round molding and how to cut traditional beaded, tongue-and-groove paneling.

Color Photos: J.R. Rost  
Technical Art: Eugene Thompson  
Photo Styling: Gabe Hemick

Perhaps the most revered woodworking joint is the dovetail, and we've devoted an entire section to its layout and cutting (Dovetails, page 87). Once the dovetails are fit, you can move on to Assembly (page 89). And, for a complete description of how the drawers are made and fit, including how to fashion half-blind dovetail joints, see Drawer Making (page 93).

Because old mahogany pieces were invariably stained dark and polished to a warm glow, our section on Finishing (page 95) covers the complete procedure from staining and grain filling to varnishing and waxing.

The drawing and materials list on the following page describes each component of the secretary in detail and illustrates how they go together. Details of the back panel assembly, case dovetails and drawer dovetails are found in the sections on Joinery And Shaping, Dovetails and Drawer Making, respectively.

Of course, one of the beauties of working by hand is that the tools are simple. You may already own many of the basic ones and, other than dusting them off, all they'll require is a freshly honed edge for great performance. The Cutting Edge (page 107) explains how to keep your tools tuned up so they literally sing through the wood.

The complete toolkit that we used to build the secretary is described in Tools Of The Trade (page 99). Along with a few commonplace tools, our kit will enable you to produce work that rivals that of the best-equipped power-tool shop.

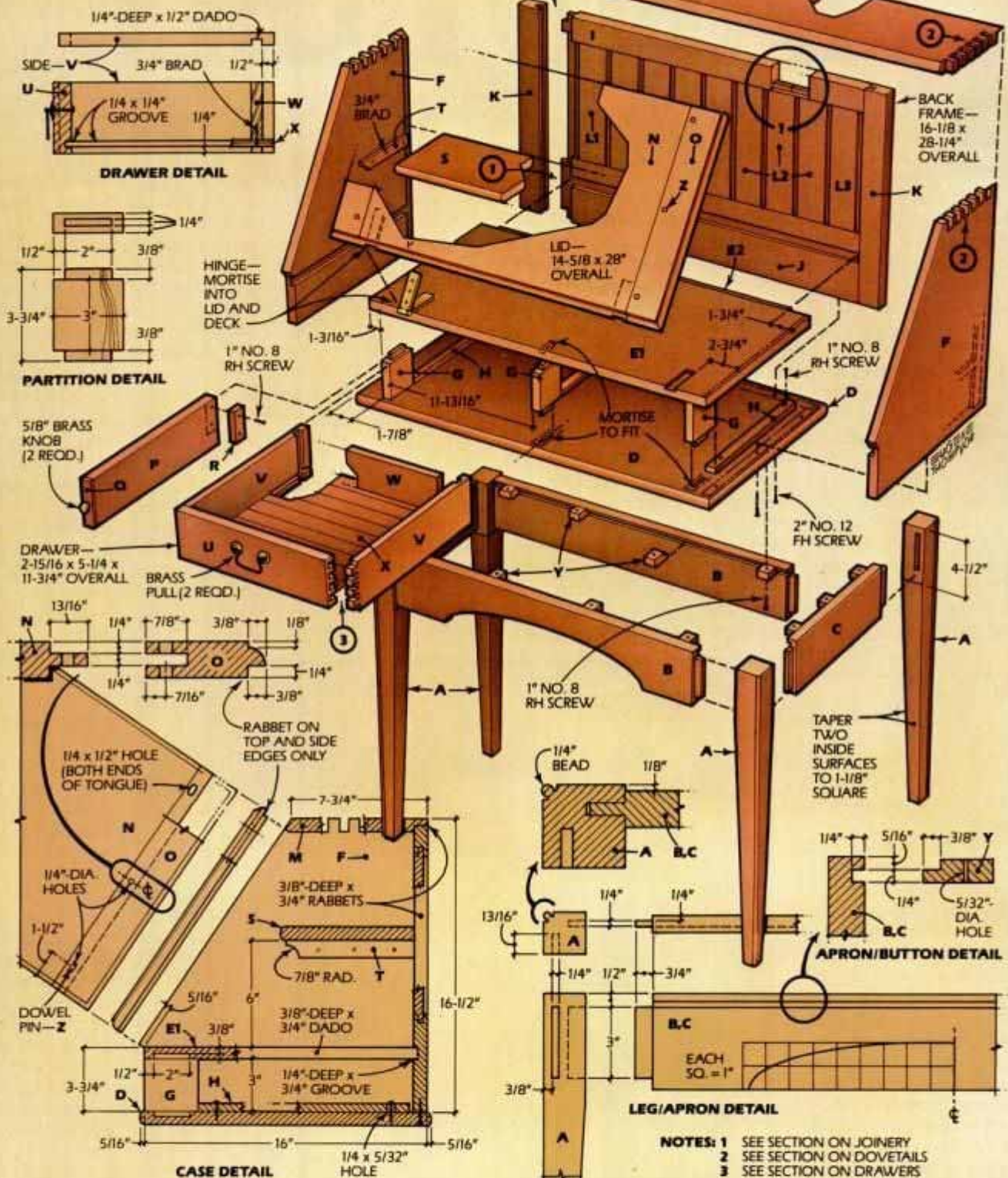
Certainly, you don't have to complete this project entirely with hand tools. If you do, however, we can guarantee that the finished piece will be a source of pride and enjoyment for years to come.

And, you'll have gained more than just a beautiful piece of furniture. Your skills will have increased, and both your eye and your cutting edges will be a good deal sharper.



**SECRETARY**

16-3/4" DEEP x 29-5/8" WIDE x 43-1/4" HIGH



**NOTES:** 1 SEE SECTION ON JOINERY  
 2 SEE SECTION ON DOVETAILS  
 3 SEE SECTION ON DRAWERS

**MATERIALS LIST—SECRETARY**

Key	No.	Size and description (use)
A	4	1 1/2 x 1 1/2 x 26\" mahogany (leg)
B	2	3/4 x 4 x 27\" mahogany (long apron)
C	2	3/4 x 4 x 14\" mahogany (short apron)
D	1	3/4 x 16 1/2 x 29 1/2\" mahogany (base)
E1	1	3/4 x 15 x 28 1/2\" mahogany (deck)
E2	1	1/2 x 3/4 x 24 1/2\" mahogany (filler)
F	2	3/4 x 16 1/2 x 16 1/2\" mahogany (side)
G	3	3/4 x 3 x 3 3/4\" mahogany (partition)
H	3	1/2 x 3/4 x 12\" mahogany (guide)
I	1	3/4 x 1 1/2 x 26 1/2\" mahogany (rail)
J	1	3/4 x 5 1/2 x 26 1/2\" mahogany (rail)
K	2	3/4 x 1 1/2 x 16 1/2\" mahogany (stile)
L1	1	1/2 x 3 1/2 x 10 1/4\" mahogany (panel)
L2	7	1/2 x 3 x 10 1/4\" mahogany (panel)
L3	1	1/2 x 8 3/16 x 10 1/4\" mahogany (panel)
M	1	1/2 x 8 1/4 x 29\" mahogany (top)
N	1	1/2 x 14 1/2 x 24 1/2\" mahogany (lid)
O	2	3/4 x 2 1/2 x 14 1/2\" mahogany (cap)
P	2	3/4 x 2 1/2 x 14 1/2\" mahogany (slide)
Q	2	1/2 x 3/4 x 2 1/2\" mahogany (trim)
R	2	1/2 x 3/4 x 2 1/2\" mahogany (stop)
S	1	3/4 x 7 1/2 x 27 1/2\" mahogany (shelf)
T	2	3/4 x 1 x 7 1/2\" mahogany (cleat)
U	2	3/4 x 2 1/2 x 11 1/4\" mahogany (drawer front)
V	4	1/2 x 2 1/2 x 15\" mahogany (drawer side)
W	2	1/2 x 2 7/16 x 11 1/4\" mahogany (drawer back)
X	2	3/4 x 11 1/4 x 14 1/2\" mahogany (drawer bottom)
Y	14	1/2 x 1 x 1 1/2\" mahogany (button)
Z	6	3/4\"-dia. x 3/4\" dowel (pin)

**Misc.:** 2\" No. 12 fh screws (10 reqd.), 1\" No. 8 rh screws (26 reqd.), Drawer pulls (No. A34.01), knobs (No. A39.03) and hinges (No. D21.02) available from Garrett Wade, 161 Avenue of the Americas, New York, NY 10013. Behlen's finishing supplies: Medium Red Mahogany Solar-Lux Stain and Retarder, Pore-O-Pac Paste Wood Filler, 4-HR Rubbing Varnish (gloss).



# STOCK PREPARATION

Getting rough-sawn lumber straight, square and smooth—the quiet way.

TEXT AND PHOTOS BY ROSARIO CAPOTOSTO, Contributing Editor

**T**HE CABINETMAKER of 200 years ago would indeed be intrigued by the lumberyard of today. And, there's a good chance that one of the many surprises would be the availability of planed or dressed lumber—wood that comes ready to be cut and assembled like the parts of a kit. Of course, we've come to take this for granted. Why use rough-sawn wood when the lumber mill can both saw and plane it quickly and efficiently?

Well, our time-traveling craftsman, along with many of today's professionals, might offer a few reasons. First, starting with rough-sawn wood gives you more wood to work with. Full 1-in.-thick lumber is often capable of a  $\frac{3}{8}$ -in.-dressed thickness, or it can be resawn and planed to produce bookmatched boards  $\frac{3}{8}$  in. thick each.

And, although store-bought planed lumber may be flat and straight when it's milled, it's rarely so by the time it reaches your shop. A  $\frac{3}{4}$ -in.-thick board may end up only  $\frac{5}{8}$  in. thick or less before you're done jointing and planing the faces. Starting with rough stock ensures that your wood will be true—at the thickness you want.

Of course, you can buy the machinery to do the work. And, if you have a few thousand dollars to spend, a jointer and planer are, without a doubt, worthwhile investments. However, we're about to show you that an ordinary hand plane will do the job as well—and maybe better.

## Buying the wood

We used kiln-dried, rough-sawn Honduras mahogany to build our secretary. This wood can vary in color and grain pattern from one piece to the next, and buying it in the rough takes



a trained eye to ensure that all of your stock is compatible. If at all possible, select the wood yourself and, if your dealer doesn't object, use a small block plane or sharp knife to discreetly check the actual color of the wood.

Another good test for stock consistency is by judging the weights of several equal-size boards. If one is significantly heavier or lighter, chances are that this piece will have a different finished appearance.

Most of the components for the secretary are made from  $\frac{1}{4}$  (1-in.-thick) rough-sawn stock that you'll hand plane to  $\frac{3}{4}$  in. Of course, you can vary the finished thicknesses if you like, but bear in mind that other dimensions—given in the materials list on page 74—may have to be adjusted.

The back panel boards and drawer sides and backs are  $\frac{1}{2}$  in. thick. These

parts are economically made by resawing  $\frac{3}{4}$  stock and hand planing to the exact thickness. If it's available,  $\frac{5}{8}$  lumber should be used for the legs. Otherwise, leg blanks can be made by gluing together thinner stock.

## About planes and saws

Planes come in a variety of sizes. As the length increases, the plane's ability to flatten out irregularities in the wood increases. The advantage in owning several is that you'll not only have the right length on hand, but you can set up each plane for a specific job. (For proper plane adjustment and sharpening, see [The Cutting Edge](#), page 107).

We built our secretary with two planes: a No. 04 smooth plane and a No. 05 jack plane. Sharpen the smooth plane cutter so its edge is

straight and then slightly round the corners. When set for a fine cut, this plane is capable of producing glass-like surfaces that require only minimal attention before finishing.

It pays to have an extra cutter for the jack plane. Sharpen one with a slightly rounded edge to make preliminary stock removal fast and easy. Keep the other cutter straight for edge jointing and preparing surfaces for smoothing.

We used a 10-pt. crosscut saw and a 5½-pt. ripsaw for all preliminary cutting. While they may not be as fast as your power saw, when sharp, they'll cut faster than you might expect. For rough cutting, use the longest saws

that you can easily handle—you'll spend less time going up and down for each inch of cut.

### Thickening the stock

Begin by cutting the ¼ stock about 2 in. oversize in length for all the ¾-in.-thick parts (Photo 1). The secretary side panels, base, deck and lid are each made by gluing three boards edge to edge. These boards are planed 1/16 to 1/8 in. thicker than the finished ¾-in. dimension and will receive a final surfacing after they're assembled. Rip all stock oversize in width.

Select the first piece to be thickened and plane the edges straight and smooth with the jack plane. While

it's impossible to get the edges perfectly square with the rough, unplaned faces, try to get as close as you can (Photo 2).

Then, use a straightedge to mark a planing guideline on one of the edges and begin planing the entire surface down to the line (Photo 3). Check your progress frequently by laying a straightedge both lengthwise and across the board.

Before you reach the guideline, lay two long, straight sticks across the board—one at each end. These are called winding sticks and are used to detect a twist or "wind" in the planed surface. Sight down the board with your eye level, and in line, with the



**1** Mark the rough lumber and cut with a sharp crosscut saw. Cut each piece square and oversize to allow for trimming.



**2** Plane both edges of each board straight and relatively square. Longer jack plane trues the rough, irregular edges quickly.



**3** Plane the entire surface flat and to guideline marked on one edge. Check frequently with straightedge and winding sticks.



**4** After planing edges square to completed face, use a marking gauge to scribe finished thickness on both edges of the board.



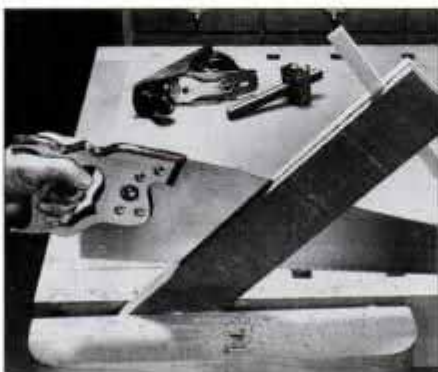
**5** Sharp pencil makes scribed line visible. To remove remaining stock quickly, use rounded cutter adjusted for coarse cut.



**6** Begin second surface by planing diagonally starting at one corner and working across. Then, plane opposite diagonal.



**7** Check the surface frequently for flatness. After planing diagonals, plane with the grain and finish with smooth plane.



**8** The ½-in.-thick stock is prepared by resawing ¾ lumber with a sharp, coarse ripsaw. Then, hand plane wood as before.



**9** Wide panels are made by edge gluing narrower boards. Plan to assemble panels with grain of each board in same direction.

# Who needs a Campbell Hausfeld® Air Compressor? Let's have a show of hands.



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**CAMPBELL HAUSFELD** 

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©Campbell Hausfeld 1989

winding sticks. If they're not parallel, plane the high corner and recheck.

After you're satisfied that the surface is straight in both dimensions and doesn't twist, use a sharp, finely set smooth plane to finish the job.

Plane the edges square to the finished surface. Set your marking gauge to the finished board thickness and scribe a line parallel to the surface on both edges to create the planing guidelines for the opposite surface (Photo 4). If you find the scribed lines difficult to see, use a sharp pencil to darken them (Photo 5).

Resecure the stock in your vise, the rough side up. Adjust the mouth opening on your jack plane for a

coarse cut and, if possible, use a cutter with a rounded cutting edge for fastest stock removal. Beginning at one corner, plane diagonally across the board progressing to the opposite corner. Then, plane the opposite diagonal in the same way (Photo 6). As you approach the scribed guidelines, plane along the length of the board with a more finely set straight-edged cutter and use a straightedge to check flatness across the grain (Photo 7). When you've just reached the line on both edges and the surface is flat, split the line by planing with a sharp, finely set smooth plane.

After the  $\frac{1}{4}$  stock has been thick-

ened, crosscut all pieces—except the panel components—just to the outside of the finished-length lines to allow for finish planing. Use a sharp rip saw to resaw  $\frac{1}{4}$  stock for the  $\frac{1}{2}$ -in.-thick components (Photo 8) and plane these in the same way. The leg stock should be planed to  $1\frac{1}{4} \times 3\frac{3}{4}$  in. When ripped in half at a later stage, each piece will yield two legs.

### Edge jointing and gluing

Mark the grain direction on each board to be edge glued. Group each set of boards that comprises a panel so that the grain direction is the same and then mark the boards so they won't be mixed up (Photo 9).

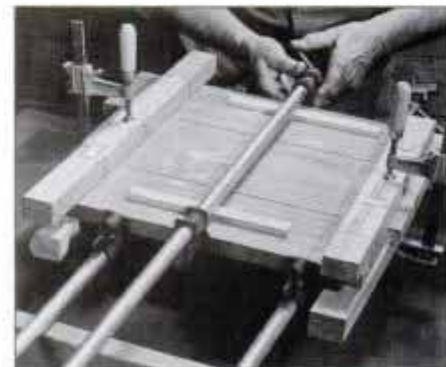
To prepare the edges for a perfect



**10** Joint mating edges by folding adjacent boards together and planing both at once. Plane a perfectly straight edge.



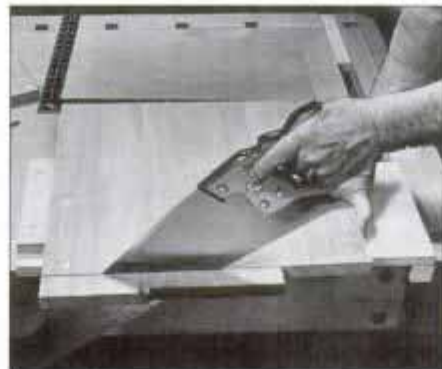
**11** Set pipe clamps on 2x4s and apply glue to board edges. Prepare four straight pieces for clamping across panel ends.



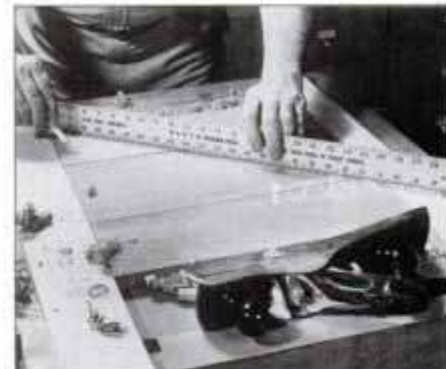
**12** After applying gentle clamping pressure on waxed crosspieces, fully tighten clamps. Remove excess glue after it sets.



**13** A large steel square is used to mark crosscutting lines square to edge. Lines indicate exact finished length of piece.



**14** Hold stock in bench hook and crosscut to the outside of each line. Hand pressure and sawing direction keep stock in place.



**15** Check assembled panel with straightedge as final surfacing progresses. Mark high spots with chalk for good visibility.



**16** Fine diagonal cuts remove excess where necessary. When first side is true, flip panel over and plane other side parallel.



**17** Use a smooth plane, with the grain, to finish. Keep the cutter sharp and set plane to produce the finest possible shavings.



**18** A shooting board makes end grain trimming simple. Note small chamfer on end which keeps end grain from splitting.



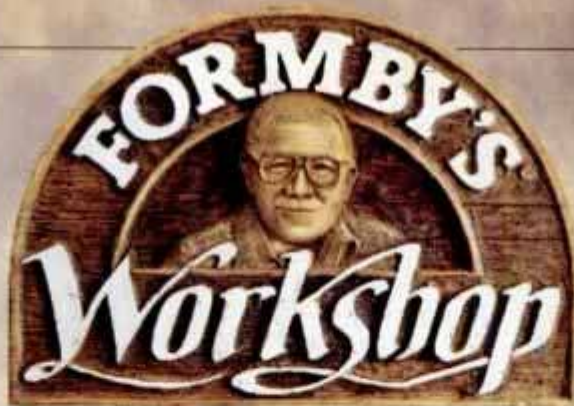
**"Formby's® Conditioning Furniture Refinisher helped me dress up my dresser."**

Ellen Whitehead, software designer, told us, "I've always treasured my antique dresser."



So when she wanted to bring back its original beauty, she looked to Formby's Conditioning Furniture Refinisher.

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Every day, thousands of people are finding that with Formby's products it's easier than ever to make their wood beautiful.

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After all, we've learned a lot about wood in 3 generations. And nobody loves wood more than we do or does more to help you care for yours.



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Gerard Burrell, teacher, says this beautiful Victorian chair had been in his family for generations.

And he wanted to protect its beauty and make it last so future generations could appreciate it.

That's why he used Formby's® Poly Finish.

States Gerard, "I'm glad I found Formby's Poly Finish, because normally when you brush an ordinary polyurethane on wood it ends up with that artificial plastic look."

Luckily for Gerard, he came to Formby's for hand-rubbed polyurethane protection that's easy-to-use, looks good and can stand up to a lot.



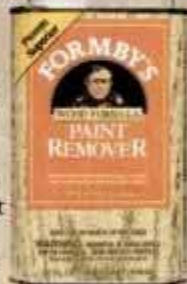
**"I had something to get off my chest—three layers of paint."**



Meet Dennis Lane, police officer. Dennis declares, "My chest was wearing the layered look in paint. But I knew deep down there was beautiful wood, so I took its coats off easily, without sanding."

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joint, first pick up two adjacent boards and fold them together as if there was a hinge at the mating edges. Secure these pieces together in your vise so the edges are flush.

With a perfectly straight cutter, plane both edges at once until they're straight (Photo 10). When the two slabs are unfolded and held together, any deviation from square on one board is compensated for on the other. If you see any light coming through the joint, the edges aren't straight and must be planed again.

When the edges are ready, prepare four straight crosspieces for clamping in pairs at each end of the first panel to keep it flat. Wax these crosspieces to keep them from being glued to the

panel. Apply glue to the mating edges of the panel components and lightly draw them together with three pipe clamps. Use C-clamps to gently hold the crosspieces in place and then, firmly tighten the pipe clamps (Photos 11 and 12). Check that the assembly is free from twist, let the glue set, and glue up the remaining panels in the same way.

Crosscut each panel to the outside of the finished outline to allow for finish planing and leave them oversized in width (Photos 13 and 14). Secure each panel in bench dogs or use a bench hook to hold them in place for the final surfacing. Check each side for flatness and twist then plane to finished thickness (Photos 15, 16 and 17).

**Trimming length and width**

With all of the stock surfaced, begin trimming to the exact size by planing the ends smooth, straight and square. First, double check that one long edge of each piece is straight and square and then plane if necessary. Mark the finished width line parallel to this edge and plane a small chamfer at one end on the waste side of the line. Then, plane this end by moving the plane toward the chamfer. A shooting board (which is described below in the sidebar) guides the plane straight and square as shown (Photo 18). Repeat the process on the other end to bring the piece to the exact same length. Finally, plane along the grain to the finished width line. **PM**

**Basic Hand Tool Jigs**

**A**LTHOUGH TRADITIONAL hand tools do require more effort and skill to master, there's no reason not to take advantage of jigs and guides to help make the job easier and faster. The three shown here will be useful for your work throughout this project.

Because many woodworking operations only exert a force in one direction (such as sawing and planing) your work doesn't always have to be secured in a vise. A bench hook is a wide board with one cross cleat at the top of the board at one end, and another underneath at the opposite end. To use it, place the bench hook on your workbench so the bottom cleat rests against the edge of the work surface. Place your stock against the top cleat and you're ready to surface plane or crosscut with complete stability.

The dimensions shown provide a bench hook that's scaled to suit the sizes of the secondary components. However, the bench hook's construction is so simple, it's easy to build a few in various sizes to handle a wide range of work. For planing thin stock, you can simply reduce the thickness of the top cross cleat.

To avoid cutting through the top cleat when crosscutting, the top cleat is shorter than the width of the bench hook base. Place the crosscut space on the right for righthand sawing, or on the left for lefthand sawing.

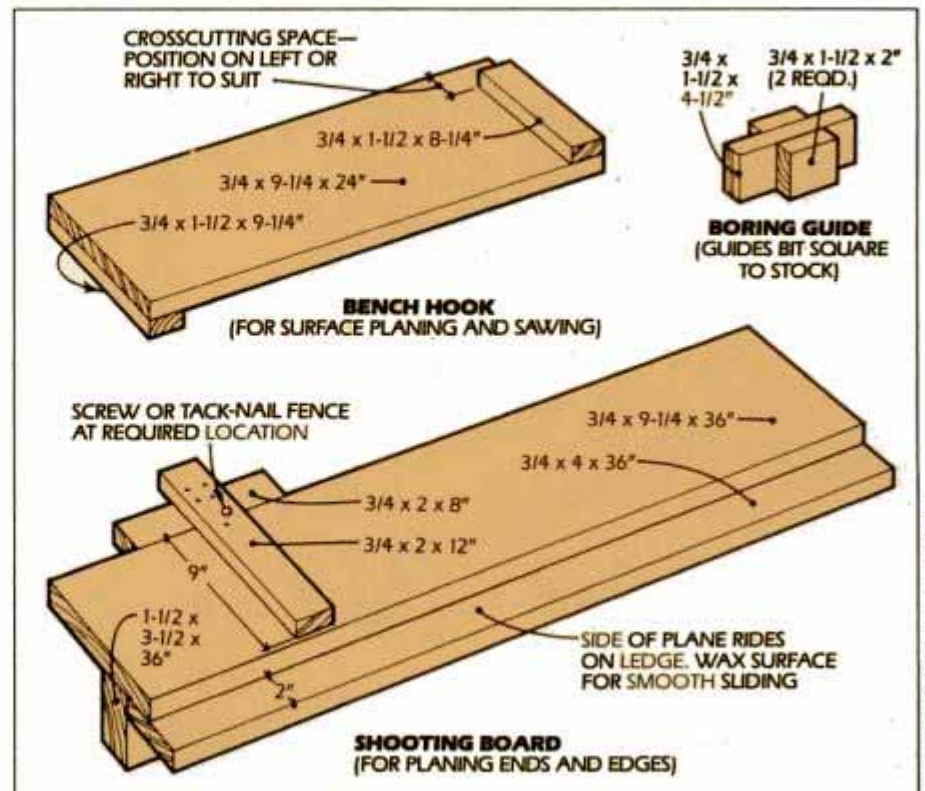
Planing a board edge straight and square is one of the most basic woodworking operations. However, while the long bed of the plane helps to ensure that the edge is cut straight, holding the plane at the correct angle is strictly a matter of hand control. To maintain a consistent planing angle, traditional woodworkers rely on a shooting board. This shopmade device is comprised of a wide top board

that holds your work and an overhanging ledge underneath on which the side of your plane rides. Both pieces are secured to a 2x4 rail for holding the shooting board in your vise. We used a T-square guide to hold the work squarely in place. This can be screwed or temporarily nailed in place and repositioned to suit the job. Allow the work to protrude slightly over the edge and guide a finely set plane on its side along the ledge. Fine tune the lateral adjustment lever to get a perfectly square cut.

To plane several parts to precisely the same width, install a cleat along the length of the shooting board at the appropriate distance from the edge.

Then, secure the crossfence to suit the stock length. Hold the stock firmly against the cleat and the fence and trim the edge until the plane stops cutting. Miteres and other angled trimming jobs can be handled with equal precision by simply securing cleats at the appropriate positions.

If you can saw to a square line, you can bore perpendicular holes with the boring guide shown. Simply make good, square cuts on the two side blocks then glue them to the center stock and double-check that the ends and edges are square. To use, clamp the guide to your work and keep the drill bit against an inside corner as you bore the hole.



PM ILLUSTRATION BY EUGENE THOMPSON

# JOINERY AND SHAPING

How to handcraft the details that stand the test of time.

TEXT AND PHOTOS BY  
ROSARIO CAPOTOSTO,  
Contributing Editor

**F**OR SOME, cutting a joint by hand will always be a waste of time. You'll find these people pursuing their favorite pastime in classic power-tool garb—ear protection, respirator and a pair of goggles or a face mask. Bent over a screaming 2-hp router with a high-priced carbide bit—that you have to send away to be resharpened—these folks will steadfastly maintain that there's no other way to produce accurate joints quickly and easily.

And, they're right. Power tools, with their built-in precision, have made woodworking accessible to any and all who are interested. The trouble is, they've become so popular, that many woodworkers have forgotten, or never learned, that hand tools will do the job equally as well, with a minimum of fuss and a great deal of personal satisfaction.

However, a handmade joint doesn't just happen. Your hand—and entire body for that matter—requires a little practical training to perform its part of the work. If you're trying a new joint or unfamiliar tool, practice a few times before moving to the actual project. Go for accuracy first—speed will come with time.

The joinery and shaping details in our secretary are made with ordinary chisels and planes and a couple of tools that might not look that familiar. One of these unfamiliar tools is a rabbet plane. It has open sides to allow the blade to cut into a corner and a fence for guiding the tool against the stock edge.

We also use a combination plane that's capable of cutting grooves, dados and beads which are nothing more than small half rounds. (For more information on these tools, see [Tools Of The Trade, page 99](#)).



## Secretary Joinery

To cut cross-grain dados in the case sides, the combination plane has two spurs—one on each rail—that score the wood just before it's cut to prevent splintering. Install a straight-edged cutter in the plane that matches the dado width. If the dado must be slightly wider than an available cutter, plan to make two passes with a narrower cutter. Sharpen the spurs and install them so the points protrude equally below the rail. Then, set the plane's fence to position the cut the correct distance away from the case lower edge as shown on the drawing on page 74. It helps to install a scrap block at the end of the cut to prevent splintering (Photo 2).

When the dados are done, lay out the angled side cut and the overhang at the front edges as shown. Use a

backsaw to trim the short front edges to the tops of the dados and a cross-cut saw to cut the long angled edge to the outside of the line (Photo 3).

Install a side panel in the shooting board for trimming the sloped edge. Scrap blocks hold it in place and ensure that the second piece will be cut exactly the same way. Then, plane the edge (Photo 4). Finish removing the waste that creates the front edge overhang and clean up with a sharp chisel. (For more information on the shooting board, see page 80).

The rounded edges of the base panel are first cut on the end grain. Clamp scrap pieces flush with the ends of the end grain to prevent splintering and plane equal bevels along each side of the edge to start the rounding. Then, progressively plane off the corners until a uniform rounded edge appears

(Photo 5). After all the edges are done, smooth with sandpaper.

If you haven't done it yet, cut and plane the small partitions to exact size and mark the tenons with a marking gauge and square. Cut the tenons with a backsaw and trim if necessary with a sharp chisel.

Lay out the mortises for joining the partitions to the base and deck as shown. Bore a series of holes at each mortise location to remove most of the waste and follow by trimming square with a chisel (Photo 6).

Finally, cut the shelf cleats to exact size and shape the quarter-round cut-out with a coping saw and sand smooth. Trim the shelf to width

rounding the edge as shown, but leaving it oversize in length to be fitted after the case is assembled.

### The back panel

First, cut and plane the back panel frame components to size. (The complete panel details are illustrated on page 86). It's a good idea to make the frame components slightly wider than their finished dimension—the frame can always be trimmed to fit during assembly. Install a 1/4-in. cutter in the combination plane, set the fence to produce a centered groove in the edge of each piece and plane the 1/2-in.-deep grooves. Keep the plane's fence on the same side (inside or outside) of each

part to ensure that a slightly off-centered groove will line up when the frame is assembled. Then, cut the wider groove along the bottom rail that accepts the deck. Note that the spurs should be in the retracted position for cuts with the grain.

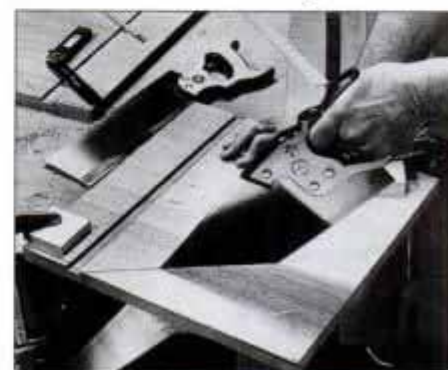
Use a square and knife to mark the tenon lengths on each rail and set your marking gauge to scribe the tenon width so it's aligned with the grooves. You can remove the waste with a backsaw and chisel or use a rabbet plane as we did. Set the plane's spur for a cross-grain cut and position the fence so the spur aligns with the tenon shoulder (Photo 7). A wide auxiliary fence attached to the regular fence



**1** Closeup shows spur in position for cross-grain cutting. Rabbet plane (shown) has single spur, combination plane has two.



**2** Cut dado using combination plane with spurs set for cross-grain work. Fence guides cut. Wide cuts may require two passes.



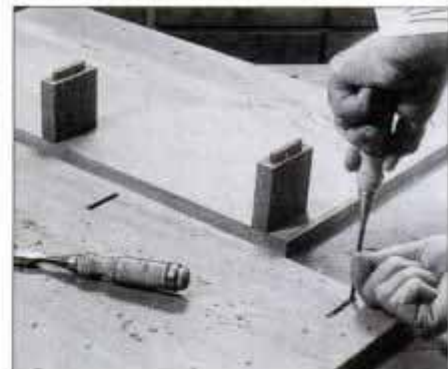
**3** Cut angled edge with crosscut saw. Begin near the dado and cut to top edge to reduce splintering on bottom of cut.



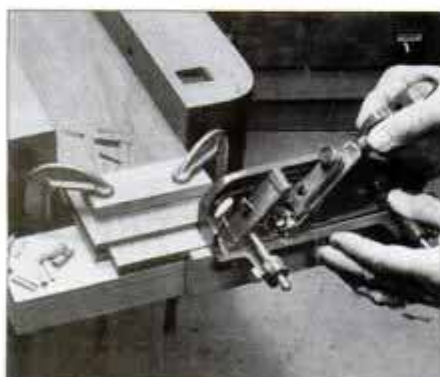
**4** Tack-nail cleats to shooting board to hold stock for planing sloped edge. Make sure plane is sharp and finely set.



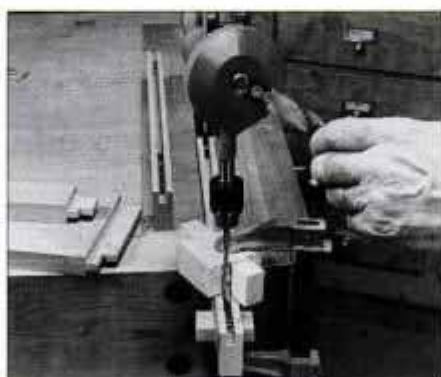
**5** Plane rounded base edge on end grain first. Scrap stock clamped at ends prevents splintering. Then, plane long grain edges.



**6** Mortise deck and base for partitions by first boring holes to remove most of the waste. Trim square with a sharp chisel.



**7** Cut back frame tenons with rabbet plane. Auxiliary fence rides on supporting block to help guide plane squarely.



**8** Start corresponding mortises by boring a series of holes. Align drill bit with groove and inside corner of boring guide.



**9** Use a sharp, 1/4-in. chisel to remove remaining waste from mortises. Note that width of mortise is determined by groove.



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and a thick, square board clamped under the work helps to ensure good plane alignment.

Using the grooves in the frame stiles as guides, bore a series of closely spaced holes at the mortise locations to remove most of the waste. A boring guide block (shown on page 80) helps to keep the bit square and aligned with the groove (Photo 8). Finish the mortises with a sharp chisel (Photo 9).

The 1/2-in.-thick stock that you've planed for the back tongue-and-groove panels should now be cut squarely to length and planed to exact width. Note that the two outer panels (L1 and L3) are of a different width.

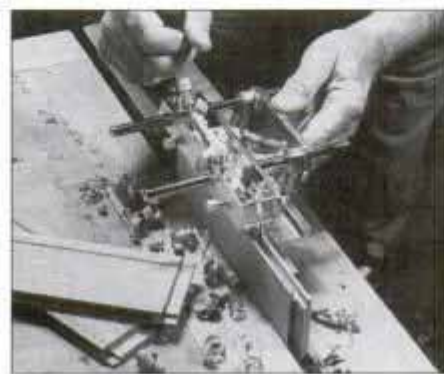


**10** After the back panels are cut to length and their ends rabbeted, cut 1/4-in. bead with combination plane.

Use the rabbet plane with the spur in position for cross-grain work to cut the 1/4-in.-deep  $\times$  1/2-in.-wide rabbets on both ends of each board.

Then, install a 1/4-in. beading cutter in the combination plane and set the fence for cutting the beads in the center panels (L2) as shown in the drawing on page 86. Readjust the fence appropriately for beading the two outer panels (Photo 10).

Next, cut the panel tongues by planing rabbets on each face with the rabbet plane. Use the depth stop on the plane to ensure that all the tongues will be the same. Install a 1/4-in. straight cutter in the combination plane and cut the grooves (Photo 11).



**11** Cut centered 1/2-in.-deep grooves in tongue-and-groove panels with combination plane and 1/4-in.-wide cutter.

### Making the lid

Our secretary lid features bread-board construction—the end grain of the wide central panel is capped with narrow stock. This reduces the amount of end grain showing, provides some resistance to cupping, and gives the top a finished look.

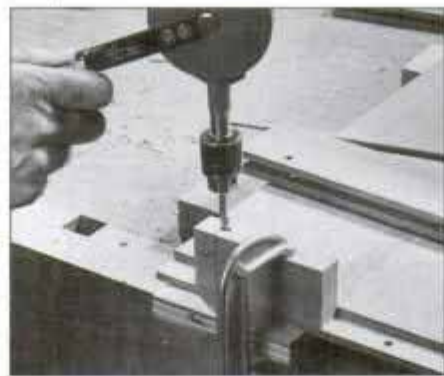
With all three components trimmed to exact size, set your rabbet plane for cross-grain cutting and position the depth stop and fence for a 1/4-in.-deep  $\times$  1 3/16-in.-wide cut. Plane each end from both faces to produce the tongues. Cut the corresponding 3/8-in.-deep groove in the capping pieces with the combination plane and 1/4-in. cutter (Photo 12). Although our Stan-



**12** After cutting lid panel tongues with rabbet plane, use combination plane to cut matching grooves in capping pieces.



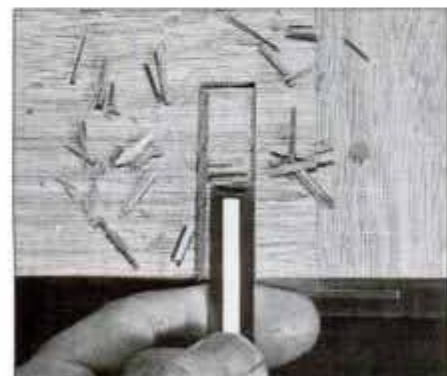
**13** Clamp end capping pieces tightly to panel and bore holes for pins. Boring guide helps keep bit square to work surface.



**14** Elongate corner holes by boring adjacent holes and cleaning up with chisel. Guide block keeps bit from wandering.



**15** Finish lid by planing quarter round. Start with 1/8-in.-deep rabbet. Chamfer uniformly and progressively round corner.



**16** Lay out and cut hinge mortises on lid after fitting hinges in case deck. Align lid carefully and cut mortises with sharp chisel.



**17** Lay out front apron curve and saw to line with a bow saw. Remove saw marks with sandpaper and curved sanding block.



**18** Install a 1/4-in. bead cutter in the combination plane and cut a half round from both surfaces for the 3/4-round molding.

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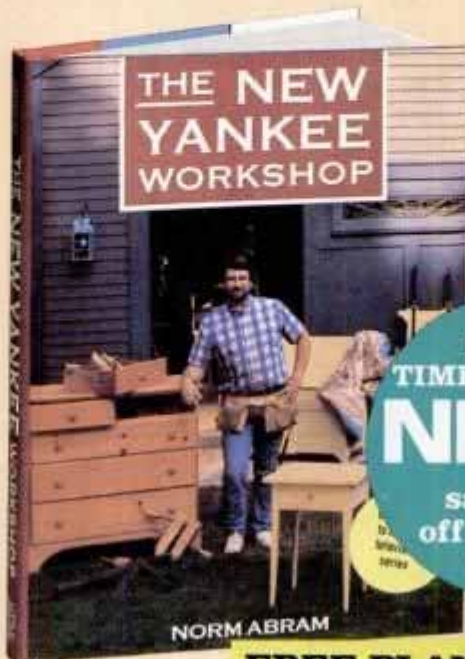
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ley plane has depth-of-cut capacity of only  $\frac{3}{4}$  in., simply advancing the cutter in gradual steps permits cutting the deeper groove.

Tightly clamp the end caps to the panel and mark the three pin locations on both ends. You can make your own  $\frac{1}{4}$ -in.-dia. mahogany pins by using the combination plane and  $\frac{1}{4}$ -in. beading cutter. Simply plane from both faces of a board until the half rounds meet.

After boring the initial holes (Photo 13), remove the caps and elongate the four outside holes by boring additional holes to either side and cleaning up with a chisel (Photo 14). Apply a little glue to the bottom surface holes of the end caps to keep the pins secure and drive the pins in from the top of the assembled lid. Trim them flush with a sharp chisel.

The quarter-round molding is started by first cutting a  $\frac{1}{8}$ -in.-deep  $\times$   $\frac{3}{8}$ -in.-wide rabbet around the entire perimeter. Start with the long edges. First plane the end grain of the capping pieces, with the spur projecting. Once the rabbet is started at the end grain, you can retract the spur and complete the rabbets. Then, uniformly chamfer the edges and progressively remove the high corners to achieve the quarter round (Photo 15).

After sanding the molding lay out the hinge positions on the case deck and cut the hinge mortises. With the hinges resting in place, carefully align the lid, then mark and cut the mortises in the lid (Photo 16).

**Base and legs**

Trim the stock for the aprons to exact size and cut the tenons to the dimensions shown. The curved cutout on the front apron is made with a bow saw. Although primitive looking, this tool cuts much faster than a coping saw and, with practice, is capable of handling a wide range of cutting chores. First, make a template of one half of the front apron curve. Then, trace the full curve on the actual stock and cut with the bow saw (Photo 17). Smooth the cut with sandpaper and curved sanding blocks. Finish the aprons by planing the  $\frac{1}{4}$ -in. groove for the buttons as shown.

Secure a slightly oversize length of the  $1\frac{3}{4} \times 3\frac{3}{4}$ -in. leg stock in your vise in preparation for cutting the  $\frac{3}{4}$ -round corner trim. With a  $\frac{1}{4}$ -in. beading cutter installed, adjust the combination plane fence to cut a half round that's tangent to the leg stock surface.

Plane the bead first on the face of the stock until the flat on top just disappears ( $\frac{1}{8}$  in. deep). Then, working

from the edge of the board, plane another bead that's aligned with, but offset 90° to the first to produce the  $\frac{3}{4}$  round (Photo 18).

Plane the same molding on the diagonally opposed corner and saw the board in half to yield two legs. Make the remaining two legs in the same way.

Mark the tapers on each leg and saw outside this line. Install a  $\frac{1}{2}$ -in.-thick strip on the shooting board ledge to raise the plane so it's cen-

tered on the thicker leg stock and plane the taper smooth (Photo 19). Finish the legs by cutting the mortises as described above.

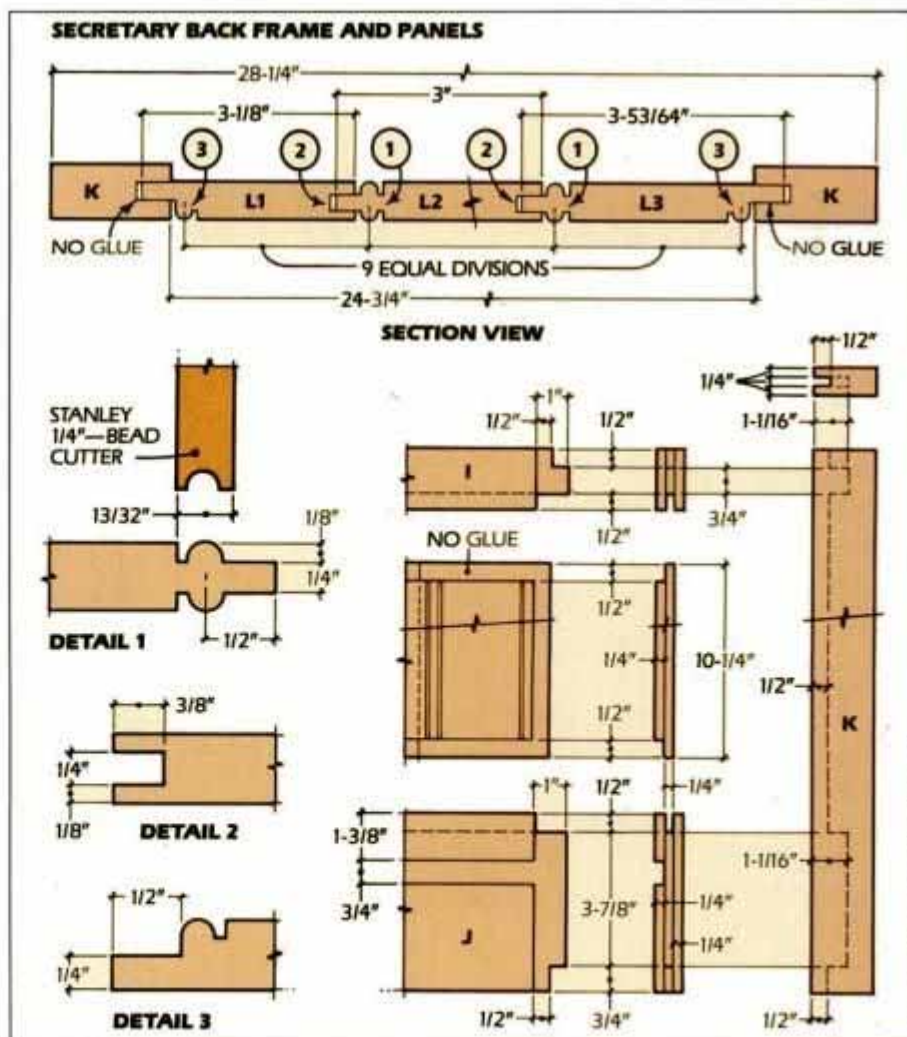
Prepare the buttons for securing the base assembly to the case by cutting a  $\frac{1}{4}$ -in.-deep  $\times$   $\frac{3}{8}$ -in.-wide cross-grain rabbet in  $\frac{1}{2}$ -in.-thick stock. Cut off this rabbeted end— $1\frac{1}{2}$  in. from the board end—and saw this piece into 1-in.-wide segments (Photo 20). Repeat this procedure until you have all 14 buttons. **PM**



19 Use shooting board to plane the taper smooth. Place  $\frac{1}{2}$ -in.-thick strip under plane to center plane on stock.



20 Cut case-to-base attaching buttons by first rabbeting  $\frac{1}{2}$ -in. stock. Saw off rabbeted end and cut into 1-in.-wide segments.



See page 74 for part dimensions.

PM ILLUSTRATION BY EUGENE THOMPSON

# DOVETAILS

The classic joint for beauty and strength. And, it's easier to make than you may think.

TEXT AND PHOTOS BY  
ROSARIO CAPOTOSTO,  
Contributing Editor

**W**HILE ANY well-fit joint looks good, the dovetail is the only one that's so eye catching it's often included as much for its aesthetic value as its superb utility. It not only creates an exciting visual rhythm along the corner of a case, but it defines a mechanical union in a way that we instinctively relate to. Like two hands folded together, the dovetail is synonymous with unity and compatibility.

Aesthetics aside, however, this joint is first and foremost a structural union. And traditionally, even in work where the joinery would be hidden or the piece was to be veneered, two boards meeting at their ends met in dovetails.

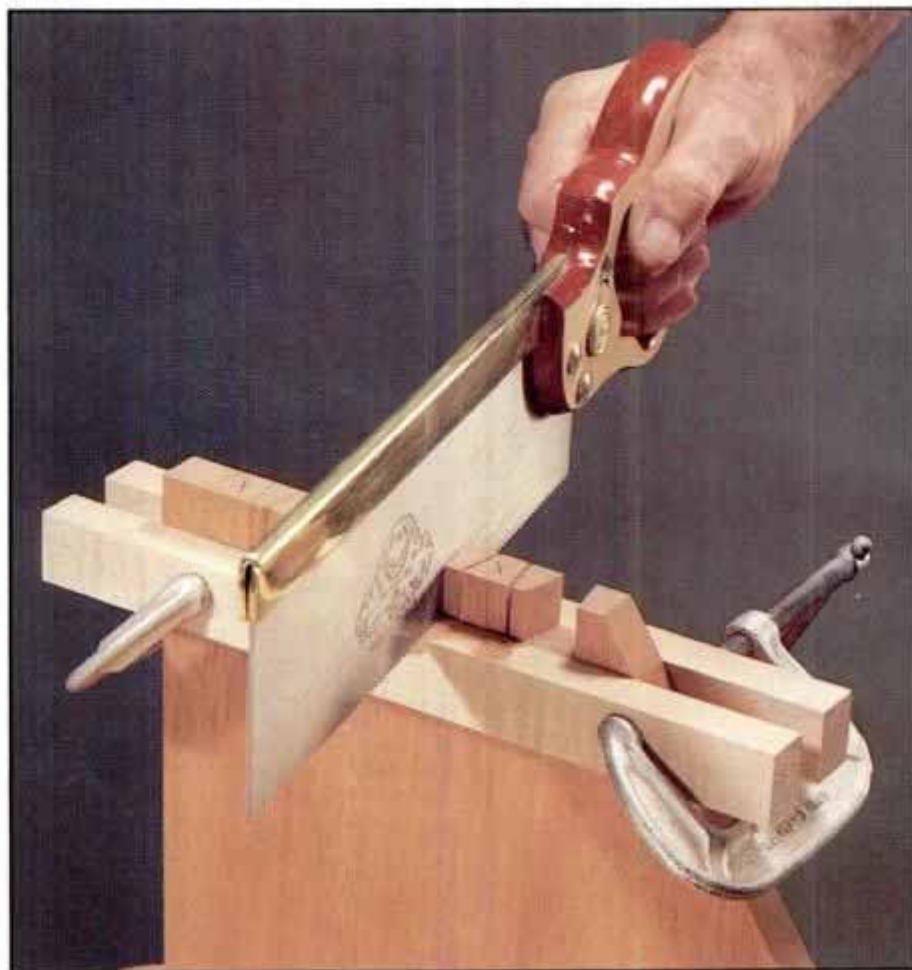
Our secretary features open dovetails at the case top, and half-blind dovetails (see page 94) in the drawers. While cutting each type is slightly different, the layout procedure is essentially the same.

In any dovetail joint, one board has notches—called tails—that are seen as tapered when viewed from the face of the board. And, the adjoining board has complementary fingers—called pins—that are seen as tapered when viewed from the end of the board. If you can lay out these parts accurately and cut to a line, you can make a dovetail joint.

## Cutting the pins

We began our case dovetails with the pins—the half of the joint on the case sides. First set your marking gauge to scribe the pin base line on the inside and outside of both case sides. This dimension should be slightly more than the thickness of the top to allow for flush trimming later. Then, mark the pin spacing on the top edge as shown in the drawing (page 88).

Use a protractor to set your bevel gauge to 78°, which is about a 1 to 5 slope. Align the bevel gauge with the



spacing marks and scribe the cutting lines with a sharp knife (Photo 1). Use a square to carry these cutting lines to the base line on the inside and outside faces of the panel. Mark the sections to be removed with an X.

Next, clamp two hardwood strips flush with the base line on either side to act as a depth stop for sawing. Secure the workpiece in your vise and follow the cutlines to the base line with a backsaw (Photo 2). Make sure that you cut on the waste side of the lines. Experienced woodworkers regularly cut right to the line, splitting it so no further trimming is necessary. However, if you're hesitant, cut slightly inside the waste side of the line—you can trim to the line later with a chisel.

To remove the waste between the pins, first clamp the workpiece to the bench with a guide strip on top and aligned with the base line. Press a chisel—bevel side out—vertically against the guide strip and strike the chisel moderately with a mallet.

Then, place the chisel—bevel up—on the top edge of the board and remove the first layer of waste (Photo 3).

Proceed in this manner for the remaining cutouts until you've removed about two-thirds of the waste from each notch. Then, flip the board over and, using the same techniques, finish the job from the other side. Resecure the stock in your vise and finish trim all faces where necessary.

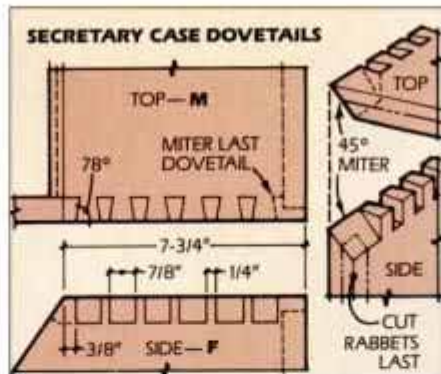
Note that the rear dovetail section is mitered to allow the rabbet that houses the back panel to be easily cut. Before cutting the miter, use the pins on each side as patterns for the tails on the case top. Because each side will be slightly different, make sure that you have the pieces marked properly so they're not mixed up.

## Cutting the tails

Begin work on the case top by marking the base lines for the tails in the same way that you marked them for the pins. Lay the top board upside down and stand the panel in place so

the backs of the pins are aligned with the base line. Use a very sharp pencil or knife to trace the cutting lines (Photo 4). Then, carry the cutlines squarely across the board end. Mark each waste section with an X.

Clamp depth-stop strips at the base line in the same way that you did when cutting the pins and saw to the waste side of the line. It helps to hold the stock in the vise so that one set of lines are vertical—it's easier to hold the saw consistently in this position while one side of each dovetail is cut. Then, shift the stock to make the other cuts in the same way (Photo 5). Remove most of the waste with a coping saw (Photo 6). Finish by trimming to the

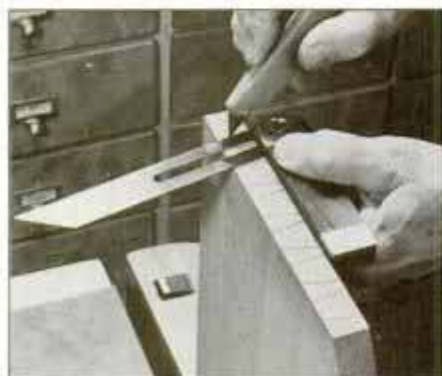


See page 74 for part dimensions.

base line with a sharp chisel (Photo 7). Work from both faces to the middle to avoid splitting the wood.

After the tails have been cut at both ends of the top, mark the miters using the base line as your reference point. Saw to the waste side of the line with a backsaw and trim with a chisel (Photo 8). Then, test fit the joints (Photo 9). The finished joint should only require light tapping with a mallet to bring the pieces together. Mark the front edge of the case top board at both ends to indicate the proper location of the edge bevel that's required. Connect these end marks with a straight line. Then, separate the components and plane the edge to this line.

Finish the sides and the top by planing the rabbet that accepts the rear panel assembly. **PM**



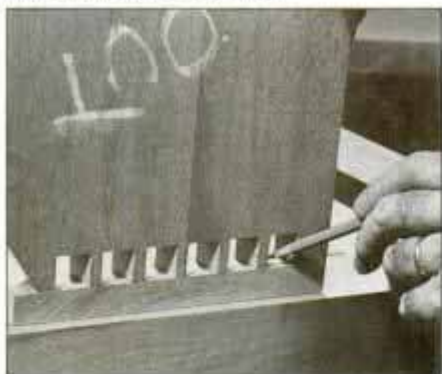
**1** After scribing base lines and spacing, use a bevel gauge and knife to mark pins. Carry lines squarely to base line.



**2** Clamp guide strips to the board, aligned with base line, to act as depth stops. Make cuts on waste side of line.



**3** Remove dovetail waste gradually. Use a chisel to chop vertically from above and then horizontally from the board end.



**4** Using the side panel pins as a template, trace the cutlines on the top. Keep side panel aligned with base line on top piece.



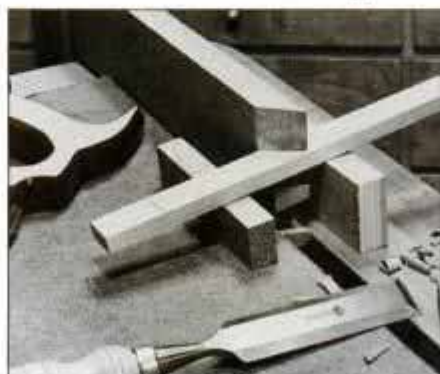
**5** After marking cutlines, use a backsaw to cut to waste side of line. Tilting board in vise allows saw to be held vertically.



**6** Remove most of the remaining waste with a coping saw. Don't cut too close to base line to avoid overcutting.



**7** Finish base line trimming with a sharp chisel. Guide strip clamped over workpiece helps keep cut square and on uniform line.



**8** After marking miter on rear dovetail section of each joint half, saw squarely to the line and trim with a chisel.



**9** Test fit dovetails. Joint should require only light tapping to bring pieces together. Trim where necessary with sharp chisel.

# ASSEMBLY

All that's come before is preparation. Now is the time to build.

TEXT AND PHOTOS BY  
ROSARIO CAPOTOSTO,  
Contributing Editor

**H**ERE'S WHERE THE adrenalin starts to flow. All the patient, painstaking cutting, planing and fitting lead to this one moment—assembly. However, don't lose your concentration now. Putting it all together must be planned so that everything goes like clockwork.

## Surface preparation

First check to see that all surfaces of each component are smoothed to your satisfaction. Many woodworkers feel that a final pass with a very sharp, finely set smooth plane is all that's required. The faint planing marks that remain—sensed by touch rather than seen—actually enhance the hand-crafted quality of the work.

If you wish to eliminate all indications of hand planing, a scraper is the best tool for the job. The long edge of this single steel plate is sharpened and curled over to form a hook that cuts or shaves a surface smooth. To use the scraper, hold it firmly in both hands and bend it slightly so that the sharp corners won't gouge the wood. Then, push it over the surface at a slight angle with moderate pressure (Photo 1). Work uniformly across the surface to avoid dishing. (See [The Cutting Edge, page 107](#), for information on sharpening the scraper).

You can also sand all the surfaces. Starting with 120-grit paper, move through each finer grade until you reach 320 grit. Sand with the grain and use a sanding block to maintain a flat surface.

We used hide glue on our secretary because it sets slowly and provides ample time to assemble and adjust the components. White or yellow carpenter's glue can also be used. With these glues, however, be prepared to move quickly—the glue can easily set up before the joints are fully engaged.

Begin by gluing a slightly oversized trim piece to the front of each sliding



lid support piece as shown in the drawing. When the glue has dried, plane its edges flush to the surrounding surfaces. Then, glue and trim the back deck strip (E2 on the drawing, page 74) to the deck.

## Assembling back and base

Dry assemble the rear panel frame and tongue-and-groove pieces to check for fit. There should be enough play between each piece so they can be spaced evenly while still allowing gaps in the stile grooves for expansion (Photo 2). If everything fits properly, apply glue sparingly to the tenons and mortises and clamp. Check for square by measuring the diagonals. While the individual panels can be left free floating, you can also apply a small amount of glue at each tongue-and-groove joint. When the back is assembled and before the glue sets, adjust the panel spacing to be uniform. Don't, however, glue the individual pieces to the frame.

Check each apron-to-leg mortise-

and-tenon joint for a good fit, apply glue and clamp the assembly together (Photo 3). Measure the diagonals to check for square. Use winding sticks laid on opposite aprons to check for twist, or simply lay the inverted assembly on a flat surface. If the top frame isn't flat, loosen the clamps and adjust the assembly.

Lay the base panel upside down and place the inverted leg assembly in position. Mark and bore the holes for securing the buttons and install them to ensure that everything fits (Photo 4). Then, remove the base panel.

## Checking case joinery

Next, dry assemble the case as a final check for fit. First, install the partitions in the base mortises. Then, fit the sides to the deck and lay this sub-assembly in place on the base, making sure to engage the partition top tenons in their mortises on the underside of the deck. Temporarily hold the pieces together with pipe clamps that run from side to side. Use small wood-

en pads between the clamps and the wood to prevent marring the surface.

Then, engage the dovetail joints, and double-check that the case is square. Fit the back panel assembly in the side and top rabbets, then trim where necessary for a good fit. Carefully lean the case on its back and mark and bore the screw pilot holes for securing the base to the sides.

**Final assembly**

With the dry run complete and all components fitting, disassemble the case and secure the drawer guide

strips to the base with screws (Photo 5). Note that the rear screwhole is elongated and there is a gap between the end of each guide strip and the back frame to allow the entire case to expand and contract with changes in humidity. Then, bore the screwholes for securing the stop blocks to the sliding supports but don't attach the blocks—these will be installed later.

Apply glue to the mortise-and-tenon joints that hold the partitions to the base and deck, and to the groove in the back panel lower rail. Assemble these components. Apply glue to the

side dados and rabbets and install the sides (Photo 6). Then, carefully brush glue into the dovetail mating



**1** A properly sharpened scraper does an excellent job of smoothing surfaces and removing slight ridges left by planing.



**2** Dry assemble the back first to check for good fits and proper panel spacing. Then, apply glue to frame joints and clamp.



**3** Test fit leg mortise-and-tenon joints. Use pipe clamps to glue assembly together and check for square by measuring diagonals.



**4** Bore the holes in the base for securing the buttons. Install buttons to ensure that components fit properly and then remove.

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SmartLevel is like no other professional level available today. SmartLevel actually calculates and displays the exact incline of any surface. For the first time, you can take precise measurements from dead level to plumb — and be assured that every reading will be precisely accurate.

With this one dependable tool, you can set concrete forms, drainage lines, door frames, the pitch of a roof, kitchen cabinets — even a radial arm saw. You will work faster and smarter, because measurements will be quick, exact, and precisely accurate.

### Measure Any Slope Four Ways

SmartLevel can measure the slope of any surface four ways — in degrees, percent of slope, rise and run in inches per foot, and as a simulated bubble. And you can adjust the accuracy of the reading from 1/2 degrees for rough work, to 1/10 degrees for a critical fit.

The precise number of degrees is available instantly on a large liquid crystal display (LCD). It's easy to see from above or below, even in direct sunlight.

### Rebalance By Pushing A Button

Bubble levels can be knocked out of balance, but not SmartLevel. Just push a button to reset the internal leveling sensor. In a matter of seconds, it's leveled as good as new. No delays, no mistakes, no guesses — just incredibly consistent accuracy, everytime.

SmartLevel is a dramatic advance over the conventional bubble level. As you might expect, the idea came from a Silicon Valley

engineer, who first made his living as a trained carpenter. His work reflects the "state of the art" in the use of microelectronics and tool design.

### Electronics: The Big Difference

SmartLevel's advanced digital electronics consist of a patented micro-calculator and gravity leveling sensor, housed in a tough polycarbonate module. That's the heart of the system. And what a difference over the old bubble!

Just four large buttons control the functions: on/off, leveling modes, sensitivity, and leveling reset. The LCD provides a clear digital readout of all functions. And the whole system runs on one standard 9-volt alkaline battery. It's that simple.

SmartLevel is a real "knockabout" tool. The sturdy 6-inch Sensor Module is weather-resistant, and truly rugged. Being tossed around or rained upon won't faze SmartLevel.

### A Major Advance In Rail Design

The sleek aircraft aluminum and teak rail introduces the latest improvements in tool design. It is beautifully balanced and easy to handle, due to the unique triangular shape and broadened base. The teak complements the strong aluminum frame, and was chosen especially for its strength, durability, and

ruggedness to withstand all weather conditions. And glove-size handholds afford a comfortable, sure grip. The rail is available in three different lengths to suit almost every job situation.

### Who Should Own SmartLevel

Contractor	Homeowner	Builder
Carpenter	Job Inspector	Engineer
Roofer	Architect	Machinist
Mason	Remodeler	Teacher
Plumber	Cabinetmaker	Hobbyist

### A Great Level at a Great Value

Each SmartLevel is composed of the Sensor Module and any one of the three rail lengths, which are sold as individual components and may be ordered in any combination. The Sensor Module locks into any handhold of the 2-, 4-, or 6-foot rail. It can be easily moved from one size rail to another size, or may be used alone as a torpedo level.

The SmartLevel is not available through any store, but exclusively through Wedge Innovations. Act now, and take advantage of our special introductory price while supplies last.



SmartLevel's advanced digital electronics consist of a patented micro-calculator and gravity leveling sensor, housed in a tough polycarbonate module.

SmartLevel Sensor Module **\$79.95**

2' rail only **\$25.00**

4' rail only **\$50.00**

6' rail only **\$75.00**

### Money-Back Guarantee

Try SmartLevel for 30 days. If you are not completely satisfied, you may return it for a full refund. SmartLevel also carries a one-year warranty for defects in materials and workmanship. That's our solid guarantee.

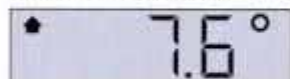
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7:30 am to 5:00 pm PST Monday - Friday  
Please mention number K9PM



### SmartLevel Reads Angles Four Ways — Instantly



**Degrees of Slope:** Useful for installing counter-tops, for critical carpentry, for setting doors, for job inspections.



**Percent of Slope:** Necessary for measuring deck slopes, for setting drainage lines, for masonry and landscaping grades. SmartLevel ends tedious transit work.



**Inches Per Foot:** An exact calculation of "rise and run" of a slope — useful in setting pitch of a roof, stairways and many carpentry jobs.



**Bubble Display:** SmartLevel simulates the conventional bubble for checking standard level or plumb measurements.

The sensor module is interchangeable between all rails.

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<b>SmartLevel System</b>				
Sensor module w/2' teak rail	SMTR2		\$104.95	\$
Sensor module w/4' teak rail	SMTR4		\$129.95	\$
Sensor module w/6' teak rail	SMTR6		\$154.95	\$
<b>Additional Components</b>				
Sensor module only	SM		\$79.95	\$
2' teak rail only	TR2		\$25.00	\$
4' teak rail only	TR4		\$50.00	\$
6' teak rail only	TR6		\$75.00	\$

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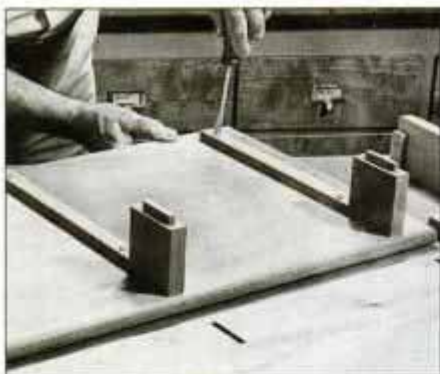
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## WOODWORKING GUIDE



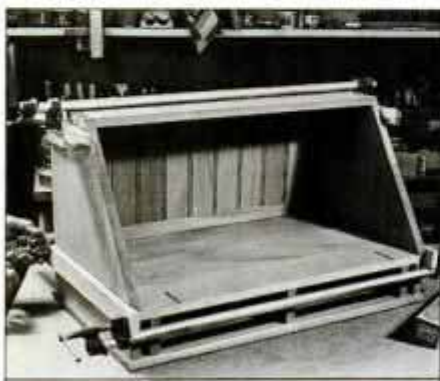
**5** Start case assembly by installing guide strips behind partitions. Rear screwhole is elongated to allow wood movement.



**6** After applying glue and joining back panel to deck/base assembly, apply glue to the side rabbets and dados and join sides.



**7** Spread glue sparingly on dovetail mating surfaces and install top. Hide glue has long open time needed for easy assembly.



**8** Clamp the case with pipe clamps until the glue is dry. Then, install the screws that secure the base panel firmly to side panels.



**9** When the glue has dried, use a sharp, finely set smooth plane to shave the protruding dovetail ends flush to the surfaces.

surfaces and along the top rabbet and install the top (Photo 7). Clamp the entire case together (Photo 8), let the glue dry and install the screws that secure the base to the sides.

Use a sharp, finely set smooth plane to trim the tail and pin ends of the dovetail joints flush to the surfaces (Photo 9). Prepare for shelf installation by boring pilot holes for the nails that hold the shelf cleats. However, don't install the cleats until the finish has been applied to all the components. Similarly, don't secure the case to the leg assembly to facilitate final finishing.

FM

# DRAWER MAKING

Light, strong and well fit, any good drawer is a project in itself.

TEXT AND PHOTOS BY  
ROSARIO CAPOTOSTO,  
Contributing Editor

**W**E'VE LEFT drawer making for last because it's simply easier to fit the drawers to the case than the other way around. Also, drawers are actually small, complete projects in themselves. They feature most of the techniques described thus far and demand careful joinery that will highlight and enhance the entire finished piece.

Like the case and leg assembly, each drawer is produced in three stages: stock preparation, joinery and assembly. It's a good idea to double-check the actual drawer openings on the case rather than rely solely on the drawing. It's also best to dimension the drawers for a tight fit and plane them to size after they're assembled.

## Preparing components

Begin by preparing the stock for each drawer bottom. Because the bottoms are comprised of narrow edge-glued stock, it's best to make these parts first. While the glue is drying, you can go on to the other components.

To make the 1/4-in.-thick drawer bottoms, first, hand plane both surfaces of 1-in. rough stock to achieve the maximum thickness possible—plane only until the surfaces are parallel. Then, resaw the stock to produce thin boards each having one planed side and one rough side. We started with 1 1/2-in.-wide stock to make the resawing easier. If you use wider boards, you'll need fewer pieces to make up each bottom.

After resawing enough wood for both bottoms, cut the pieces oversize in length. Lay the pieces together keeping the single planed surface face up and the grain direction consistent. Mark each piece so you'll remember the way they go together and joint the



mating edges in the manner described in the section on stock preparation (page 75). Then, edge glue the pieces together, being sure to keep the planed surfaces flush.

After the glue has dried, remove the clamps and smooth the planed side of the bottoms to remove any ridges at the joints. Then, use your marking gauge to scribe the finished planing line for the rough side. Remove most of the waste with a coarse-set plane and finish to exactly 1/4 in. thick with a smooth plane (Photo 1). When both bottoms have been planed to the proper thickness, cut them squarely to exact size.

Prepare the stock for the drawer back and sides by resawing 3/4 stock and planing the faces to achieve the finished 1/2 in. thickness. Plane 1/4 stock to 3/4 in. for the fronts. Pay par-

ticular attention to choosing pieces with attractive grain patterns and suitable color for the drawer fronts. Then, rip and plane the stock squarely to size. However, leave the fronts slightly oversize in length to allow the end grain to be trimmed flush with the sides after assembly.

## Cutting the dovetails

Begin cutting the blind dovetail joints by laying out the tails on the drawer sides. Follow the dimensions given in the drawing (page 94). First, mark the base line on both faces exactly 1/2 in. from the end. Then, mark the dovetail spacing and lay out the dovetails with a bevel gauge.

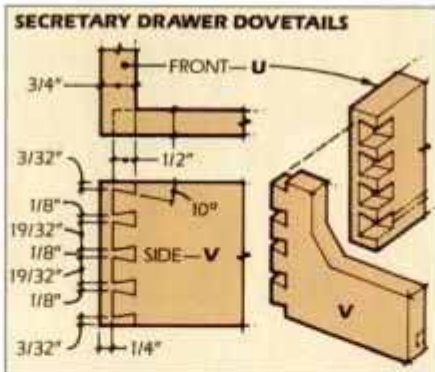
Saw the angled dovetail faces so the cut splits the line with the kerf falling on the waste side of the line. Remove most of the waste with a coping saw

and finish trimming to the base line with a sharp chisel. Be sure to cut from both faces toward the center to avoid splitting the wood. Also, mark the sides and fronts in the way they'll be assembled so the pieces won't be mixed up later.

Secure a drawer front in your vise so its inside surface faces toward the bench. Then, clamp a short piece of scrap stock to the inside face of the drawer side so its edge is aligned with the base line of the dovetails. Position the drawer side on the end of the drawer front so the scrap block rests against the inside surface of the drawer front.

Scribe the dovetail outlines on the drawer front end with a sharp knife (Photo 2). Then, mark the base line that indicates where the blind dovetails stop, on the back of the drawer front. This line should be located so it corresponds to the thickness of the side and the amount that the drawer front is oversize in length. Keep in mind that this base line determines the actual width of the drawer. The excess at the ends of the drawer front will be trimmed flush after assembly. Once the base line is marked, use a square to carry the dovetail cutlines down to the base line.

Mark the waste sections and begin cutting the pins with a backsaw held diagonally (Photo 3). Then, with the board clamped flat to your bench,



See page 74 for part dimensions.

make vertical chisel cuts first, followed by paring chisel cuts from the end to remove the remaining waste as shown (Photo 4).

Once you've reached the bottom line, carefully trim all pin faces exactly to the line. Then test fit the joint by gently tapping it together. Be careful when you separate the joint—hold the side in the vise and tap the joint so the pieces come apart squarely.

**Dadoes and grooves**

After all the half-blind dovetails have been cut and fit, make the dadoes that accept the drawer backs. While you could use the combination plane for this operation, the narrow width of the sides makes it practical to simply saw each dado edge and remove the waste with a chisel. Mark the cutlines squarely with a knife, hold the stock

in the bench hook and use a backsaw to make the cuts.

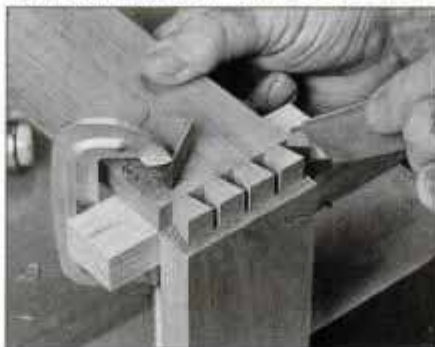
Cut the grooves for the drawer bottoms with the combination plane and 1/4-in. straight cutter. Start with the drawer fronts and align the fence so the groove will pass through the bottom dovetail cavity. This is important as it keeps the groove from being visible on the outside of the joint. Set the depth stop on the plane for a 1/4-in.-deep groove. Secure the stock flush to the edge of a scrap board to give the plane's fence a surface to ride against. After the fronts are done, groove the side pieces in the same way (Photo 5).

Trim the drawer backs to exact size as shown in the drawing. Double-check their length to ensure that the drawer will be parallel and assemble the drawer front, sides and back with glue (Photo 6). Install a few brads to hold the back in place and clamp the dovetail joint. Test for square and let the glue dry. Then, slide the finished bottom panels in place and secure to the bottom edge of the back with 3/4-in. brads. Leave a small space between the front edge of the drawer bottom and bottom of the groove in the drawer front for wood movement.

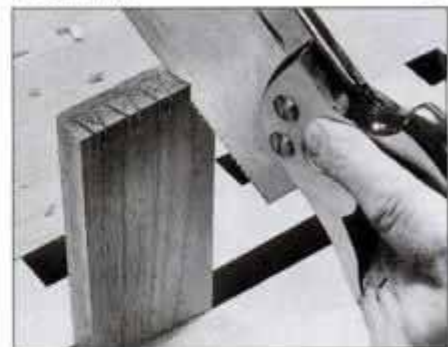
Use a sharp, smooth plane to trim the drawer front ends flush with the sides and test fit the drawer in the case. If the fit is a little tight, carefully plane the sides and edges where it is necessary. **FM**



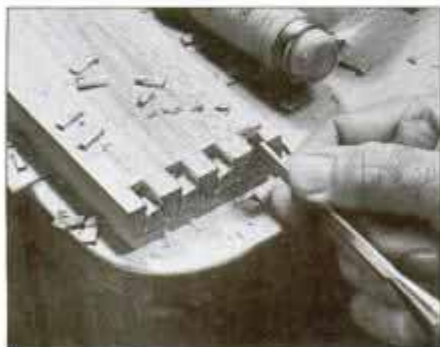
1 After the glue has dried on the edge-joined bottom panels, hand plane both surfaces so the panel is uniformly 1/4 in. thick.



2 Use a guide block clamped to drawer side at the base line to align dovetail joint for tracing. Mark tails with sharp knife.



3 After marking waste areas, begin cutting pins with a backsaw. Hold saw diagonally and avoid cutting through baseline.



4 Remove waste by first cutting down with chisel along base line and then paring in from the end edge of the drawer front.



5 Cut grooves with combination plane. Start with drawer fronts aligning groove with dovetail cavity. Then, groove sides.



6 Apply glue to the dovetail joints and back dado. Then clamp the front, sides and back square and install bottom panel.

# FINISHING

It's not done until it's finished. Take the time to do it right.

TEXT AND PHOTOS BY  
ROSARIO CAPOTOSTO,  
Contributing Editor

**I**N KEEPING WITH the traditional style and execution of our colonial secretary, we've chosen to stain the mahogany dark—just the way it looked in days gone by. And, we've topped it off with a traditional, hand-rubbed clear varnish finish.

Start the job right by cleaning the shop completely. Remove the lid, shelf, shelf cleats and sliding supports if installed. Take out the drawers and separate the leg assembly from the case. Vacuum the work and wipe the surfaces with a naphtha-dampened cloth to remove all traces of dust.

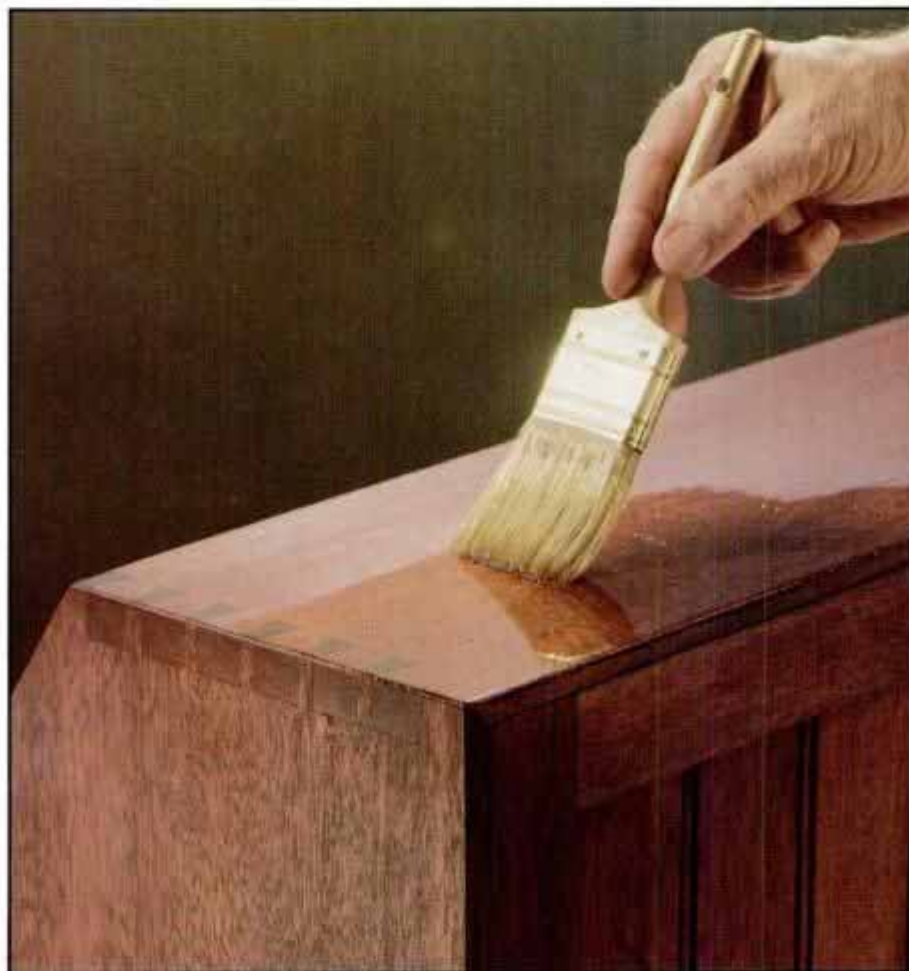
To work on both sides of the lid, tack nails in each hinge mortise and wedge two thin nails (filed to a flat point) in the joint seams at the opposite edge to act as temporary legs. Work on the nail side first. Then turn over the lid and work on the other side.

## Staining

We used Behlen's Medium Red Mahogany Solar-Lux stain. This is a nongrain-raising aniline-dye stain of great clarity. It can be sprayed on or brushed on. However, its fast-drying characteristics are less desirable in brush application and Behlen's Solar-Lux Retarder should be added to slow the drying rate.

We used a ratio of 1 part retarder to 6 parts stain. (Note: Aniline stains are applied before grain filling. If you use a pigment stain, apply grain filler first. Always follow manufacturer's instructions.)

Apply the stain to one section at a time and wipe away the excess before proceeding to the next section (Photo 1). For a darker color, reapply the stain after the first coat is dry. After letting the final application of stain dry overnight, apply a thin coat of shellac (6 parts alcohol to 1 part 3-pound-cut white shellac) to seal the stain and provide a good base for the grain filler. Allow this coat to dry at least 4 hours. Also, apply several



coats of the shellac to all unexposed surfaces to act as a moisture seal.

## Grain filling

Mahogany is an open-pore wood that requires a grain filler to create a smooth and flat surface for the varnish. We used Behlen's Pore-O-Pac Paste Wood Filler which must be thinned 1 part naphtha to 1 part filler to obtain the correct brushing consistency. While it's available in several wood tones, we used natural (light beige) and added burnt umber Japan color to obtain a compatible shade.

Apply the filler in the direction of the grain using a stiff brush (Photo 2). Wipe the filler with a coarse cloth such as burlap as soon as the filler has lost its wet look. Wipe across the grain to remove the excess and finish by wiping with the grain using a soft cloth (Photo 3). Avoid applying the filler over too large an area. If it dries too much, it will be difficult to remove. Because the filler is difficult to wipe away in intricately molded

areas, we chose to leave the beaded tongue-and-groove panels unfilled.

Let the filler dry for 24 hours. Then, check the surface for any residual deposits of filler. You can remove any excess by very light sanding with 220-grit sandpaper. Wipe off the dust and seal with another thin coat of shellac (Photo 4). Gently sand with 220-grit paper once the shellac is dry.

## Varnishing

We used Behlen's 4-HR Rubbing Varnish for our hand-rubbed gloss finish. It's a good idea to pour the varnish into a clean can with a stiff wire installed across the opening. The wire allows you to easily wipe excess varnish from your brush without the foaming that can cause bubbles on the finished surface. Use a good quality bristle brush and dip it into the varnish about  $\frac{3}{4}$  of the bristle length. Then, wipe the brush gently against the wire to remove excess varnish.

On broad surfaces, apply several brush-wide stripes—with the grain

—placing the stripes about a brush width apart (Photo 5). Then, without filling the brush with new varnish, brush across the grain to spread and level the coating (Photo 6).

Next, wipe the brush slowly over the wire to remove excess. Hold the brush almost vertically and let only the tips of the bristles touch the surface while making continuous light strokes with the grain (Photo 7). Called tipping-off, this process further levels and smooths the coating and removes any bubbles.

### Subsequent coats

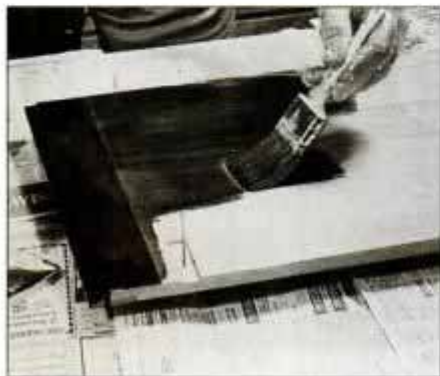
With the first coat of varnish dry, sand it very lightly with 220-grit

paper backed with a rubber sanding block—just enough to scuff the surface. Then wipe off all dust with a naphtha-dampened cloth.

Apply a second coat of varnish in the same way as the first. When it's dry, wet sand the surface with 400-grit, waterproof silicon-carbide abrasive paper backed with the rubber sanding block (Photo 8). The aim of wet sanding is to eliminate imperfections in the coating. Dip the sandpaper in a dish of water frequently and sand with the grain. Occasionally wipe the work with a cloth to inspect the surface. When only a few shiny low spots appear, scuff these areas with 4/0 steel wool.

Apply a third coat of varnish and repeat the wet sanding. Always be careful to avoid cutting through the finish. Stop sanding when the surface is flat and apply a fourth coat of varnish.

When the last coat is dry, wet sand with 600-grit paper and clean the surface. The final step involves using a very fine abrasive powder called rottenstone. Sprinkle the rottenstone on the surface, add water and then rub lightly with a felt pad following the grain direction. When the desired gloss is achieved, wipe the surface clean. Finish the entire job with a thin coat of paste wax applied with a water-dampened cloth (Photo 9). Allow to dry and buff with a soft cloth. **FM**



**1** Apply stain to one section at a time and wipe away excess. Nails act as legs for supporting the lid when staining other side.



**2** Paste wood filler is applied with stiff brush in direction of grain. Japan color is added to filler to match color of stain.



**3** When filler dries and dulls, wipe away excess with burlap. Work across grain to fill pores and then wipe with grain.



**4** Thin, wash coat of shellac is used after stain and filler to seal surfaces. Lightly sand when dry. Also, shellac unexposed areas.



**5** Apply varnish with grain in stripes about one brush width apart. Brush slowly to flow varnish on with minimal bubbling.



**6** Without adding new varnish, brush across grain for even coat. Always use an extralight stroke when leaving edge.



**7** After wiping brush slowly across wire, hold it vertically and stroke lightly with grain, barely touching surface.



**8** The second and succeeding coats of varnish are wet sanded with 400-grit silicon-carbide paper and firm rubber block.



**9** After polishing with rottenstone and water, apply paste wax. Let wax dry for 20 minutes, then buff with a soft cloth.



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# TOOLS OF THE TRADE

All the essentials for making furniture with hand tools.

BY THOMAS KLENCK,  
Associate Home  
And Shop Editor



**W**HILE traditional hand tools may be simple, the cabinet-makers who used them were certainly not under-equipped. One record from the mid-18th century recommends the following as a basic tool kit: 68 planes; 7 saws plus broad ax, adz and hatchet; 28 assorted chisels; 3 hammers and mallet; spokeshave, drawknife,

boring tools and stones plus a wide range of marking and measuring tools and shop accessories. And, this was a *basic* kit.

Fortunately, not every job requires such a complete collection. The tools that we used to build our traditional secretary were assembled specifically for this project. We've taken it for granted that you already have a workbench, clamps,

tape measure, hammer and all the little things that most shops are likely to have.

Most of the tools shown are available from mail-order woodworking suppliers and retail outlets. All of the tools are also available from Garrett Wade, 161 Avenue of the Americas, New York, NY 10013. The prices and stock numbers given are based on their latest catalog.

How-to videotapes  
available from

**Popular  
Mechanics**

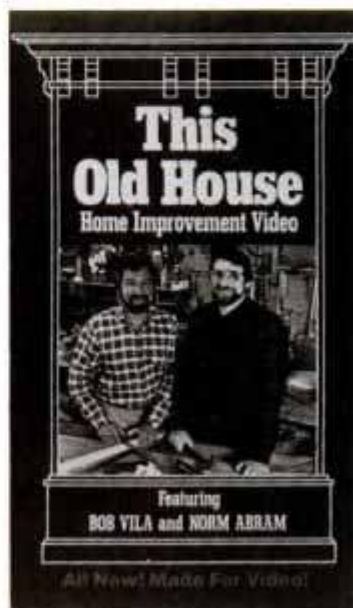
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If you're new to doing your own auto repair or want the perfect gift for someone who just bought a car, this one-hour tape of 20 common repairs is for you. *Last Chance Garage* shows you ways to save money and do the job right, from oil and filter replacement to flushing a radiator to lubricating the suspension. All procedures are clearly explained and demonstrated, and a clever on-screen numbering system lets you quickly fast-forward to any topic. You'll even learn how to change your alternator and replace shock absorbers. (VM-1002—\$24.95)



Based on the award-winning public television series of the same name, *This Old House* shows you in 60 minutes how easily you can do home repairs. As on their television program, hosts Bob Vila, a regular PM contributor, and Norm Abram skillfully demonstrate projects you can do. The setting is a typical house in need of basic repairs and enhancements. Among the 14 topics: trimming a door, fixing a faucet, glazing a window and installing track lighting. Even advanced projects will seem easy, such as building a deck, installing a brick patio and refinishing a floor. With the cost of home repairs and improvements these days, you'll save a lot by doing them yourself. (VM-1001—\$24.95)

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in every four homes will be burglarized.  
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Because these tools are traditional (or modern versions based on original designs), you can often find used examples at a fraction of the new-tool cost. You may have to spend some time refurbishing your finds, but you'll be rewarded with a collection that's both historically interesting and useful.

And don't forget, woodworkers didn't always go to the store or leaf through a catalog when they needed a particular item—they often simply made the tool themselves. While it's difficult to find a blacksmith in most communities today, you can buy plane irons and books such as *How To Make Wooden Planes* (Garrett Wade No. 49L01.01) that will help you finish the job.

Keep in mind that few woodworkers will ever admit to having a truly complete toolkit. There's always one more special chisel or plane that would simply be nice to have around. The following selection is a starting point rather than an inclusive presentation. Once you've begun working with hand tools, undoubtedly you'll discover a host of useful additions that suit your particular needs and the

kinds of projects that you make.

**1. Chisels**—While other specialized types of chisels are available, the bevel-edged chisel is the basic tool for both general surface paring and heavy stock removal. The ones that we've chosen feature a socket blade/handle joint and a ferrule at the top so they'll stand up to mallet work. The set shown comes in a wood case and includes six chisels ranging from 1/4 in. wide to 1 in. wide. It costs about \$50 (No. 07T01.01). As your hand-tool skills and requirements grow, square-sided mortising chisels and light-duty paring chisels are available in a range of sizes.

**2. Steel rule**—For everything from drawing straight lines to laying out dovetail spacing, a good steel rule is all but indispensable. This model has divisions as fine as 1/64 in. and is machined precisely square at both ends. Similar models are available in a range of lengths to suit your requirements. This 12-in. rule costs about \$10 (No. 37N08.01).

**3. Marking gauge**—The tool for scribing lines parallel to an edge is the marking gauge. Our basic unit has a single beam with one steel scribing



9

point. More sophisticated marking gauges may have multiple scribing pins or two beams for marking more than one line at a time. The rosewood tool shown is 8 in. long and features brass inserts both along the beam, under the thumbscrew and on the block face. This marking gauge costs about \$15 (No. 10N29.03).

**4. Sliding bevel**—Also called a bevel gauge, this is the tool for marking angles other than 90°. The sliding rule section can be loosened for adjustment at the brass wing-nut. Locked at the midway position, the rule displays two supplementary angles. This rosewood-handled model with brass end caps costs about \$14 (No. 24N03.03).

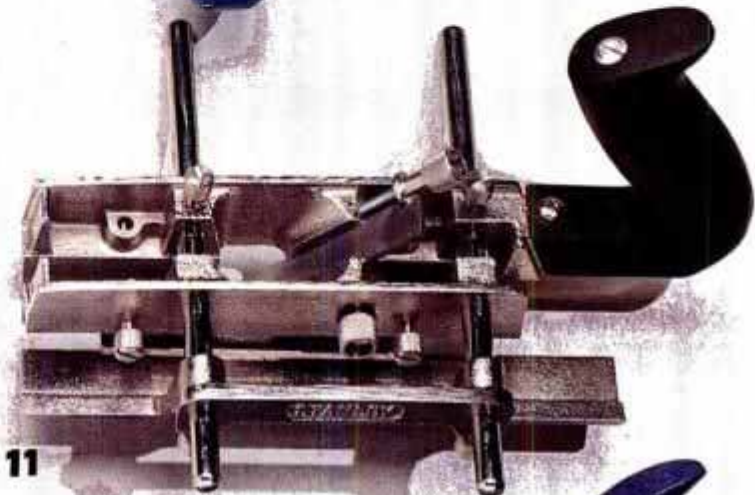
**5. Trysquare**—To make sure that your work is laid out and assembled square, you need a durable and accurate try-square. Ours features a solid rosewood stock that's bound on the inner surface with brass for durability and long wear. The blade is secured to the stock with brass-capped steel pins. This model is available in three sizes ranging from 6 to 12 in. long. Our 9-in.-long model costs about \$14 (No. 37N11.02).

**6. and 7. Water stones**—Although oil stones have been the mainstay of most North American and European shops, these Japanese water stones cut much faster. This means that keeping your cutting edges keen is less of a chore and therefore more likely to be done on a regular basis. Water stones cut fast because the surface continually wears away in normal use. This keeps the surface grits fresh and sharp. However, the stones must be flattened regularly so that your chisel and plane iron edges are honed straight. The darker stone (7) is a 1000-grit stone (about \$15, No. 49M02.01). Use it for preliminary honing. To finish the edge, move to the 6000-grit stone (6) shown underneath (about \$30, No. 49M12.01). Water stones are available in a range of grits from 800 to 8000 grit.

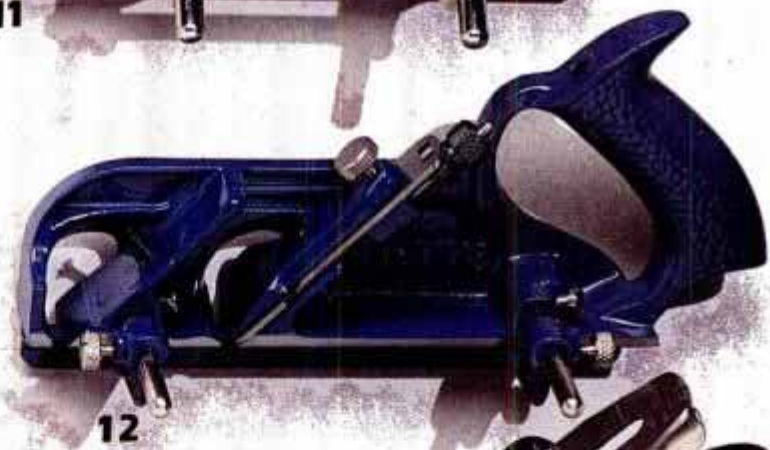
**8. Scrapers**—The best way to remove any marks left by hand planing is to use a scraper. This tool actually cuts an extremely thin layer of wood from a surface. It's sharpened by first honing the edge flat and square, and then forming a small hook along the edge. A set of three rectangular scrapers includes thicknesses ranging from .6 to 1 mm and costs about \$7 (No. 19K02.03). The thicker the scraper, the heavier the shaving you can cut. Curved



10



11



12



13



14

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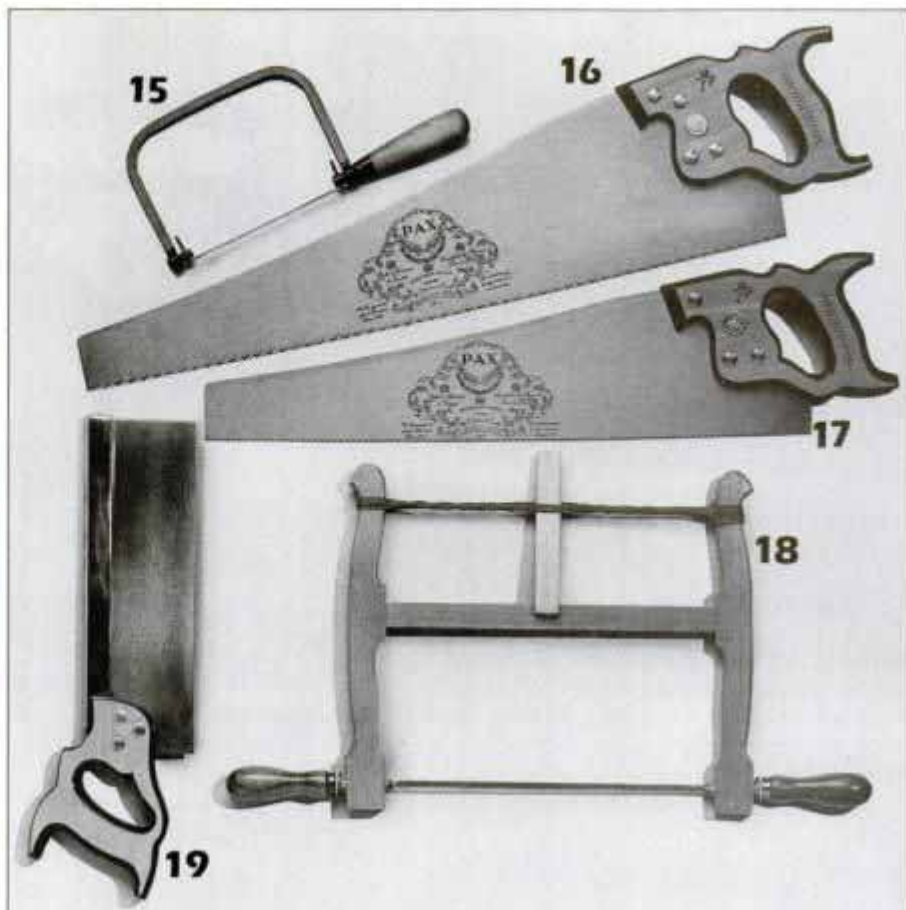
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WOODWORKING GUIDE



scrapers are available for convex or concave surfaces.

**9. Burnisher**—If you're using scrapers, you'll need one of these. Its job is to shape the hook on the edge of the scraper. This hardened steel tool (about \$9, No. 19K03.01) has a triangular shaft for use on straight-edged scrapers. For curved scrapers, a round-shaft version is available.

**10. Hand drill**—This light-duty hand drill is a good choice for boring the small holes required in most cabinet work. It features double-pinion gearing for smooth operation and has a standard,  $\frac{5}{16}$ -in. chuck. This particular model can be used as a hand drill with handle in place (as shown), or, by removing the handle and attaching the T-shaped accessory, as a breast drill. The price is about \$37 (No. 89J03.01).

**11. Combination plane**—This plane is an updated version of the renowned Stanley 45 and 55 combination planes developed during the past century. They were designed to replace the dozens of wooden specialty planes that the average cabinetmaker and joiner was expected to own. Although not quite as versatile as the 45 and 55 planes, our new model will cut grooves, rabbets and simple moldings by using interchangeable cutters. Two rails provide contact points for the cutters and a fence allows the tool

to be guided against the straight edge of the stock. Retractable spurs on each rail permit cross-grain planing and adjustable depth stops ensure a uniform cut.

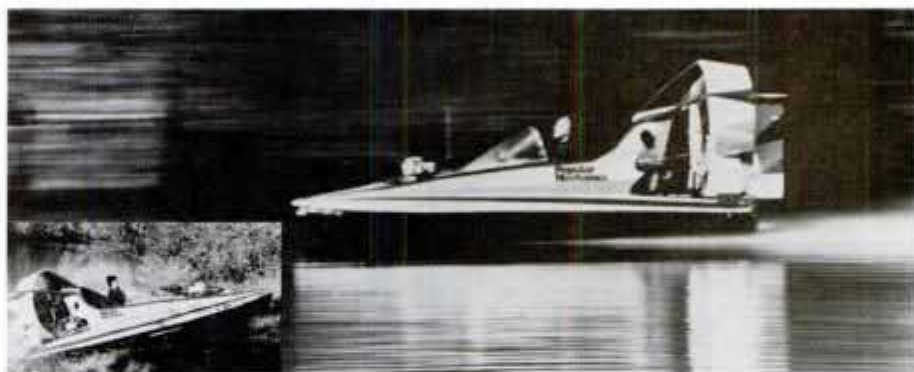
The basic combination plane (about \$166, No. 23P11.01) comes with 12 straight-edged cutters ranging from  $\frac{1}{8}$  to  $\frac{3}{8}$  in. and seven beading cutters ranging from  $\frac{1}{8}$  to  $\frac{1}{2}$  in. Also included is a single cutter for making  $\frac{1}{4}$ -in.-wide tongues (the corresponding groove can be made with the  $\frac{1}{4}$ -in. straight-edged cutter). For about \$60, you can get an additional cutter set that includes four fluting cutters, additional tongue cutters and a  $\frac{1}{2}$ -in. sash cutter.

**12. Rabbet plane**—Although the combination plane *will* cut rabbets, we added this plane to our basic tool kit because its solid, flat base enables it to shape the quarter round that appears on our secretary lid. The body of the plane provides two locations for the blade—at the plane front for planing into a corner and at the middle for general use. A knurled adjusting screw at the normal blade location permits positive blade-depth adjustment. To adjust the blade at the forward position, the blade is lightly tapped to the correct depth. The rabbet plane (about \$64, No. 10P13.01) comes with a fence, retractable spur and depth gauge.

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## WOODWORKING GUIDE

**13. and 14. Bench planes**—The modern steel plane offers several advantages over its wooden predecessor. A knurled adjustment knob behind the blade makes precise depth-of-cut control easy and a lateral adjustment lever enables you to set the blade parallel to the sole. The mouth opening on the sole can be set for either fine or coarse planing and the steel base virtually eliminates the possibilities of wear.

Steel planes are commonly available in sizes ranging from the small No. 03 smooth plane (9 in. long) to the No. 07 jointer (22 in. long). The 9 $\frac{3}{4}$ -in.-long No. 04 plane (13, No. 10P26.01) is generally used for fine surfacing and costs about \$50. For heavier work, or where a longer base is desirable, we've chosen the 14-in. No. 05 jack plane (14). It costs about \$62 (No. 10P22.01).

**15. Coping saw**—For light-duty curve cutting, nothing beats a coping saw. The 12-t.p.i. (teeth per inch) blade is kept under tension in a 6 $\frac{3}{4}$ -in.-long steel frame. Depth capacity is 4 $\frac{1}{4}$  in. The blade can be rotated to shift the frame out of line with the cut when necessary. Available in a range of sizes, this beech-handled model costs about \$12 (No. 10I7.01).

**16. and 17. Rip and crosscut saws**—With these two saws on hand you may not want to give your circular saw away, but it just might gather a little dust. Both are taper-ground for less binding—the blade is thinner at the top than at the cutting edge. The 26-in.-long, 5 $\frac{1}{2}$ -pt. rip saw (16, No. 35I02.01) costs about \$47. The cross-cut model is available in 22- or 26-in. lengths. Our 22-in., 10-pt. saw (17, No. 35I01.02) costs about \$43.

**18. Bow saw**—With a little practice, anyone who lacks a band saw can do much of the same work with one of these tools. Made of red beech, this saw comes equipped with a 12-in.-long, 9-t.p.i. blade. The blade is tensioned by twisting the rope that spans the arms and the blade can be rotated so the saw can be used at any angle. This bow saw has a throat depth of 5 $\frac{1}{2}$  in. and costs about \$60 (No. 36I03.01).

**19. Backsaw**—For the fine, straight cutting that dovetail and mortise-and-tenon joints require, most traditional woodworkers reach for a backsaw. The blade is ground flat and is mounted in a heavy brass channel to help keep the blade rigid and add weight. Although small backsaws are available as fine as 25 t.p.i., our 15-t.p.i. model combines fine cutting with speed for general work. This 12-in. backsaw costs about \$44 (No. 35I03.01).

PM



# THE CUTTING EDGE

No matter how you cut it, your tools must be sharp.

TEXT AND PHOTOS BY  
ROSARIO CAPOTOSTO,  
Contributing Editor



**O**ne of the greatest pleasures of woodworking by hand is seeing, feeling and hearing a well-honed razor-sharp chisel or plane slice effortlessly through solid wood. Not only is the work easier, but it's faster, safer and more accurate. The tool goes where you want it to go. Unfortunately, chisels, planes and scrapers don't stay sharp indefinitely. They require constant attention to keep them working at their peak. Even new tools aren't exempt. They rarely come ready to use and the best time to start learning how to sharpen them is when they come right out of the box. Both chisels and plane irons have a single, beveled cutting edge. The actual shape of the beveled surface can be either hollow or flat ground. Sharpening involves first preparing the bevel at the correct angle and then honing both the bevel and the blade back flat and mirror smooth so they meet at a straight, sharp edge.

## Getting Started

**T**OOLS STRAIGHT from the factory have a flat-ground bevel. This edge is sharpened by honing a secondary bevel at a slightly steeper angle than the primary, flat-ground bevel. While you don't need a grinder for reshaping a flat bevel, you'll need a very coarse stone and the job will take longer. Hollow grinding requires either a motorized bench grinder or a hand-operated grinding wheel. However, reshaping the bevel is faster and the resulting concave bevel provides an excellent base for honing the edge.

To get your grinder in shape for hollow grinding, you'll need a coarse (60-grit) wheel. Avoid fine wheels which cut too slowly and generate too much heat in the steel. Because chisels and plane irons are hardened and tempered through a heat process, reheating the edge can draw the temper of the steel requiring the tool to be re-ground beyond the affected area. If your wheel isn't new, shape the edge flat with a silicon-carbide stick or diamond dressing point (Photo 1). Use a star wheel dresser to renew the surface of a clogged or glazed wheel for cool, efficient grinding (Photo 2).

Bench stones are available as either water stones or oil stones depending on the lubricant they're designed to work with. Water stones are faster cutting, but wear quickly. They must be trued regularly to produce a straight edge on your tools. Oil stones are harder, require less dressing, but cut much slower. Both types are available in a range of grits.

To keep our tools sharp during the construction of our secretary, we used a 6-in. bench grinder to shape a hollow-ground bevel, a 1000-grit water stone for initial honing and a 6000-grit water stone for polishing the edge smooth.

If you're using oil stones, a fine silicon-carbide or aluminum-oxide stone followed by a hard black Arkansas

stone will produce a comparable edge.

To flatten a water stone, lay a sheet of waterproof silicon-carbide paper on a piece of thick plate glass or a flat machine surface. Then, wet the abrasive paper and lap the stone flat (Photo 3). Oil stones should be cleaned with a stiff brush and kerosene to open the surface pores for fast, efficient honing (Photo 4).



**1** Dress grinding wheel flat with a silicon-carbide dressing stick. Use a coarse (60-grit) wheel for shaping bevels.



**2** A clogged or glazed grinding wheel will generate too much heat and cut poorly. Open pores with star wheel dresser.



**3** Water stones must be frequently trued for a straight honed edge. Use waterproof abrasive paper and water on flat surface.



**4** Use a stiff brush and kerosene to clean and rejuvenate clogged or glazed oil stones for faster and easier honing.

## Shaping A Bevel

**T**O PRODUCE a hollow-ground bevel with a grinder, first check that the edge is straight, square and free of nicks. If it isn't, mark a thick band on the back of the edge with a felt-tipped pen and scribe the proper cutting edge with an awl (Photo 5). Set the tool rest on your grinder so it's square to the wheel. Place the tool flat on the tool rest and carefully bring it in contact with the wheel.

Slowly, and with gentle pressure, move the tool back and forth to grind the edge to the line. Always keep the tool moving to prevent heat buildup. To help guide the tool evenly, we clamped it to a small, T-shaped jig that fit against the edge of the tool rest (Photo 6). However, careful free-hand guiding will also do the job. Don't remove any more steel than is necessary.

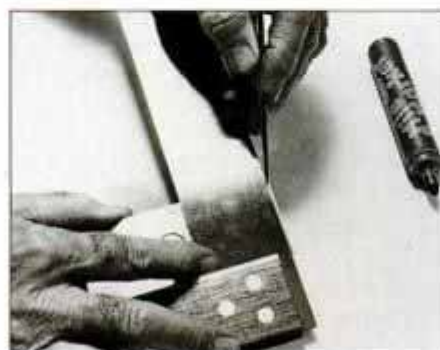
If the edge is in fairly good shape, you can also dress it straight and

square by holding it vertically and honing it on a coarse stone.

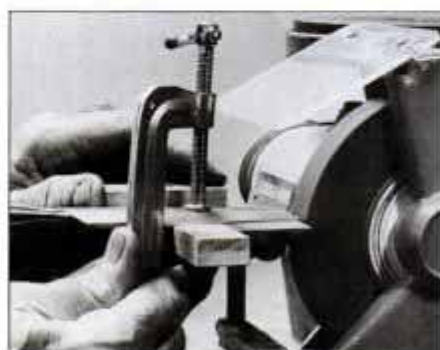
Before grinding the bevel surface, measure the existing angle to determine if it's suitable for your work. Factory ground bevels are generally about 25°. Increasing the angle (to about 30°) helps the edge stand up to harder woods without nicking, but a

relatively shallow angle (20° to 25°) cuts easier and is a better choice for paring softer wood.

With the grinder turned off, lay the tool on the grinder tool rest and adjust the rest so that the cutter makes contact with the wheel at the center of the bevel. This position will duplicate the existing bevel angle. If you wish to



**5** Prepare for reshaping the bevel by marking on back with felt-tipped pen. Scribe a straight, square line through ink.



**6** Set tool rest perpendicular to wheel and grind slowly to line. Tool clamped to sliding jig helps guiding, or do it freehand.

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change the angle, adjust the tool rest appropriately.

Then, remove the tool and turn the grinder on. Lay the cutter flat on the tool rest and slowly advance it until you see a few sparks. Examine the bevel, check that the grinding marks are positioned properly and adjust the tool rest if necessary. Shape the bevel by slowly passing the surface across the wheel with gentle pressure as shown (Photo 7).

Don't try to rush the process by pressing hard because this will overheat the steel. Periodically touch the ground bevel. If it's too hot to comfortably hold in your hand, dip it in a bowl of water to cool it down.

Be especially careful of overheating as the grinding nears the tip where the heat can't dissipate as quickly. When the hollow grinding uniformly covers the bevel, including the actual edge, the job is done.



**7** Adjust tool rest to bevel angle and slowly advance blade toward wheel. Keep blade moving and cool edge in water.

To reshape a flat-ground bevel, you'll need the coarsest oil or water stone you can find. First, hone the edge straight and square by holding the cutter vertically and moving the edge over the lubricated stone. When honing the bevel, it's easier to maintain a flat, uniform surface if you use a



**8** Flat-ground bevel (left) compared to hollow-ground. Note uniform grinding and concave surface of hollow grinding.

honing guide available from most woodworking suppliers. Check the instructions that come with the guide, then secure the tool and adjust the honing angle slightly shallower than the desired cutting angle—the final honing operation installs the actual cutting edge at the correct angle.

## Finish Honing

**B**EGIN FINISH honing by removing the grinding marks on the back of the cutter that were left by the manufacturer. Use a flat 1000-grit water stone or a coarse oil stone followed by a fine oil stone. Hold the back of the tool flat against the stone and hone in a circular motion to cover the face of the stone uniformly. Al-

though you can concentrate honing pressure near the cutting edge, resist any temptation to lift the end of the tool to make the job go faster. Once the back has a uniform finish, you're ready to hone the bevel (Photo 9).

The advantages of hollow grinding become apparent when the bevel is honed. Simply lay the tool flat on the lubricated 1000-grit water stone or fine oil stone—bevel side down. Then,

slowly raise the end of the tool so the heel of the concave bevel remains in contact with the stone. When you feel the toe of the bevel—the edge—come in contact, the tool is at the correct angle for honing (Photo 10).

While holding it in this position, apply gentle pressure and move the bevel over the entire face of the stone (Photo 11). The object is not only to hone the tool, but to wear the stone's



**9** Closeup view of chisel-back surface illustrates factory grinding marks that have been honed away at the tool's edge.



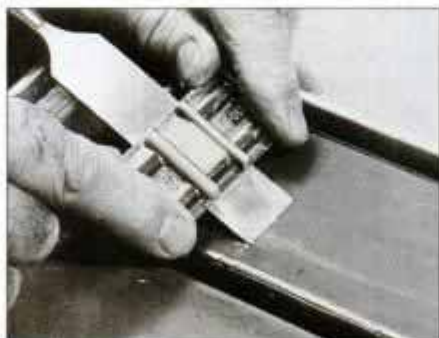
**10** Begin honing hollow-ground bevel by lifting blade until heel and toe contact stone for the correct honing angle.



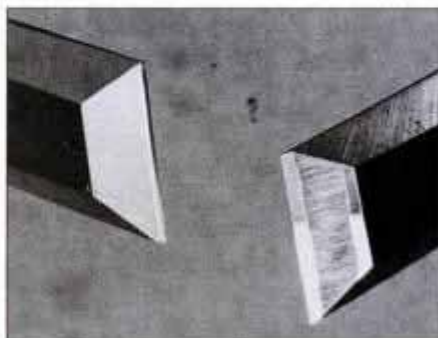
**11** Firmly hold tool with both hands while passing over entire surface to help distribute wear. Maintain consistent angle.



**12** After removing wire edge by honing back on coarser stone, hone bevel and back on polishing stone for mirror finish.



**13** Secondary bevel on flat-ground cutters is easier to shape using honing guide. Guide maintains correct angle.



**14** Finished edge on hollow-ground tool shows polished areas at heel and toe. Flat-ground tool has polished secondary bevel.

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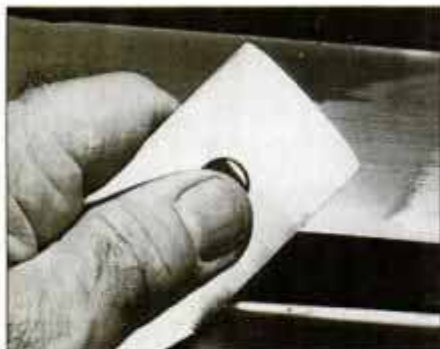
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**15** Sharpen plane irons used for rapid stock removal to a curved profile. Gently round corners of straight-honed blades.



**16** Sharpen beading cutters of combination plane by first gently honing flat sections. Then, hone back of cutter smooth.



**17** Hone concave edge of beading cutter with round slip stone. Periodically hone back of cutter to keep profile sharp.

surface uniformly. After a few passes, examine the bevel. You should see the honed areas at the heel and toe. Once they're apparent, stop honing. Flip the tool over and lightly hone the back to remove any wire edge. Then, move to the 6000-grit water stone or hard black Arkansas oil stone and repeat process to polish the edge (Photo 12).

A flat-ground bevel is finished by honing a small secondary bevel at the edge. Lay the tool flat on the stone and lift the end until the bevel face contacts the stone. Then, lift the end

slightly higher and hone a secondary bevel while holding the tool firmly at this angle. Check the edge for a uniform line of honing. Then, hone the back to remove any wire edge and repeat the process on the finer polishing stone.

Because creating the secondary bevel on a flat-ground tool doesn't offer the 2-point support of the hollow-ground method, it can be difficult to maintain a consistent angle. While you will get better with practice, a honing guide provides a quick and

easy way to achieve a flat secondary bevel at the right angle (Photo 13).

If you're sharpening a smooth plane iron, gently hone the corners round to prevent gouges in the work surface. Convex plane iron cutting edges used for heavy stock removal are shaped with a very coarse stone or grinder and then finish honed (Photo 15). The combination plane's beading cutters are kept sharp by honing the back and tips on a flat stone and sharpening the curved profile with a slip stone (Photos 16 and 17).

## Plane Tune Up

**L**IKE THE cutting irons themselves, the ordinary plane is rarely ready for work as it comes right out of the box. The first thing to check for is a flat sole. Although it may have been ground flat at the factory, stresses imparted during the casting process eventually unwind and can result in a tool that may not be capable of fine, controlled planing.

To check for flatness, install the blade and adjust it so it doesn't protrude beyond the sole. Then, hold a straightedge against the sole at various points. If you see any light between the sole and straightedge, the base should be trued.

To do the job yourself, you'll need a piece of 1/2-in.-thick plate glass; 1/4-in.-

thick glass will do if you rest it on a flat, machined surface such as your table saw top. Sprinkle coarse silicon-carbide grit on the glass and add water for lubrication (Photo 18). Because clamping the cutter in place can deform the sole, the blade must be in position but retracted for the lapping operation. Stroke the plane over the entire surface to minimize uneven wear in the glass (Photo 19). As the grits dull, clean the glass and add new grit and water. Periodically inspect the base. When a uniform matte finish covers the surface, the lapping is done. Repeating the process with finer grits will make the surface smoother, but not any flatter.

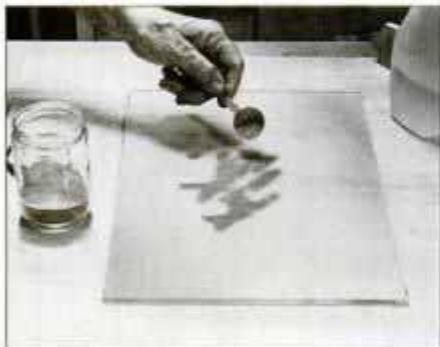
Next, thoroughly disassemble the plane. Check the mating surfaces between the frog (the angled casting

that supports the blade) and the base for globs of paint or burrs that might interfere with proper seating of the frog. Clean where necessary.

The cap iron reinforces the cutting edge and acts as a chip breaker. It must fit tightly against the back of the cutter so it doesn't become clogged with chips. Hone the cap-iron edge on a coarse stone so that it's perfectly straight and meets the cutterback surface at a knife edge (Photo 20).

Both for comfort and to reduce the risk of sharp corners that can mar your work, file a chamfer around the entire base of the plane (Photo 21). Finally, clean all components, apply a light coating of oil to all screw threads and moving parts and reassemble.

For the finest, tissue-thin shavings, set the cap iron about 1/32 in.



**18** Sprinkle coarse silicon-carbide grit on plate glass to prepare for truing plane sole. Use water to lubricate cutting action.



**19** Move plane over entire surface of glass to prevent dishing. Uniform finish appears over entire bottom surface, when done.



**20** Hone the cap-iron end to a straight, sharp, knife-like edge so it fits tightly against the back of the plane iron.

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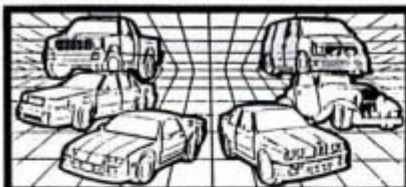
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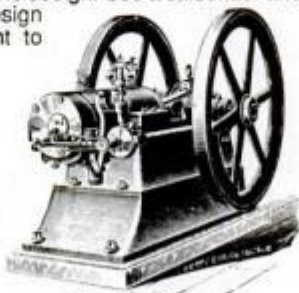
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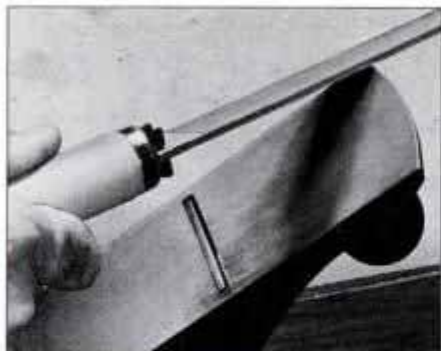
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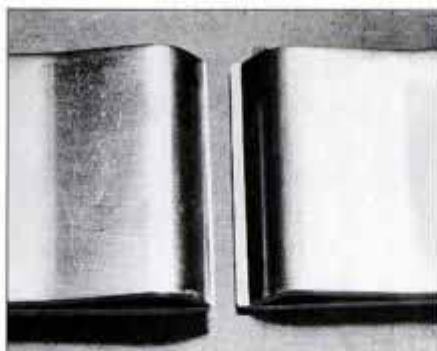
## KEEP OUT THE BAD GUYS

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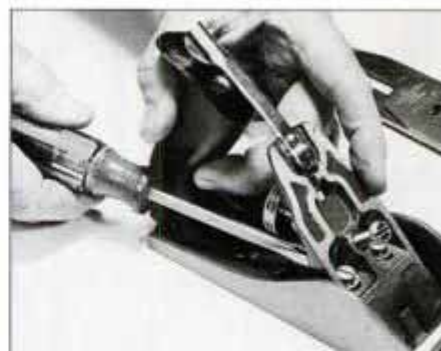




**21** Filing a chamfer around the plane base corners helps to prevent burrs or nicks from forming that would mar surface of work.



**22** Set cap iron back for coarse cuts (left). Cap iron close to edge (right) is best for fine cuts and smoothing irregular grain.



**23** Most planes have an adjusting screw at back of frog. Loosen top frog screws and then move frog to adjust mouth opening.

from the blade edge. This provides maximum support for the finely honed edge and immediately curls the shaving to help prevent tearout. Also, shift the frog forward so that there's just enough clearance for the shavings. For general work, set the cap iron about  $\frac{1}{16}$  in. from the cutting edge and position it  $\frac{3}{32}$  in. back for heavy cutting. Be sure to readjust the frog to enlarge the mouth opening for heavier work (Photos 22 and 23).

Blade depth adjustment is made at the knurled wheel behind the frog. By always adjusting the blade outward, the lever mechanism that pushes the blade is in position to resist the thrust of the cut. However, bump the nose of the plane on your bench and the cutter will shift forward and need to be reset. Equalizing the depth of cut from side to side is done with the lateral adjustment lever at the blade top. Sight down the sole and shift lever toward

the side that's protruding.

When planing, start the cut with pressure on the front knob to avoid rounding the corner of the stock. As the plane rides over the stock, gradually transfer the pressure to the rear handle. When the cut is completed, the plane should be supported by the rear half of the sole. A little paraffin or candle wax rubbed on the plane sole will reduce friction for making effortless cuts.

## Scrapers

**W**HEN PROPERLY sharpened, a scraper has a fine hook or burr shaped on the corners of both long edges of the tool. It's capable of removing that last, ultrathin shaving in preparation for finishing.

Begin sharpening by filing the two long edges straight and square with a smooth mill file (Photo 24). Then, hold the scraper square to a fine, flat stone and hone long edges smooth.

Hold the blade rigidly to achieve flat edges with sharp corners. Remove the wire edge formed from the edge-honing operation by honing the face as shown (Photo 25).

Next, hold the scraper flat on the edge of your bench so its cutting edge overhangs the bench slightly and put a drop of oil on the scraper edge. Press the burnisher against one corner at a slight angle to the blade face. Then pull it across the edge to draw the corner out slightly (Photo 26).

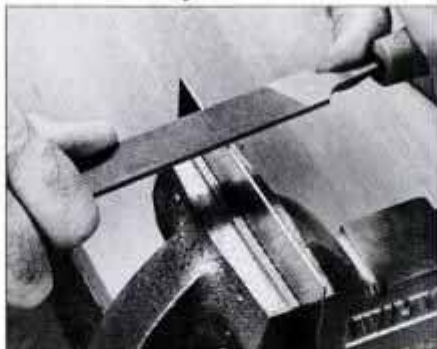
Next secure the scraper in your vise and apply a drop of oil to the edge. Then, position the burnisher on the edge and at right angles to the side surfaces of the scraper. Draw the burnisher toward you and across the edge to begin forming the hook. For each of the next three or four strokes, gradually tilt the burnisher until it reaches a roughly  $85^\circ$  angle with the scraper face (Photo 27).

After the first corner of one edge is burnished, you can shape the opposite

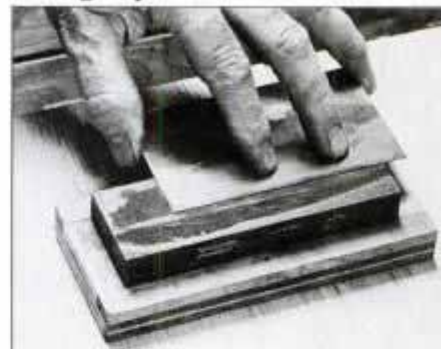
corner and the other edge in the same way. When forming the hook, avoid using too much pressure—a light stroke will produce just enough hook for fine scraping.

To use the scraper, hold it firmly on the ends and tip it about  $70^\circ$  to allow

the hook to meet the surface of the work. Bend it slightly to avoid gouging at the corners and push it across the wood. If you see fine shavings, you've done the job correctly. When the edge dulls, simply repeat the burnishing steps described above. **PM**



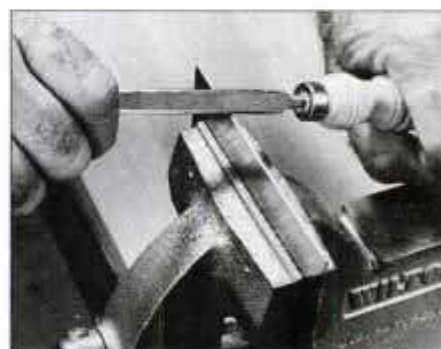
**24** Begin sharpening cabinet scraper by filing long edges straight and flat with a smooth mill file. Vise holds scraper securely.



**25** Hold scraper perpendicular to stone to hone edge smooth, then lay scraper flat on stone and gently hone away wire edge.



**26** To create cutting hook on scraper, begin by holding scraper firmly on the bench edge and drawing burnisher across face.



**27** Then hold scraper in vise and draw burnisher squarely across edge. Progressively tip burnisher to  $85^\circ$  angle.

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# STOP STEERING SHIMMY

BY PAUL STENQUIST

**A** RIPPLE in the pavement ahead is a visual warning. You white-knuckle the steering wheel, and get ready. As soon as your tires meet it, a jarring, back-and-forth shimmy is transmitted through the steering linkage right to your sweaty palms. It's enough to make your hair gray and your tires bald.

A bottle of hair dye and a new set of

tires are not the recommended fix. Instead, try a few hours on the creeper and, in most cases, a relatively modest investment in new parts.

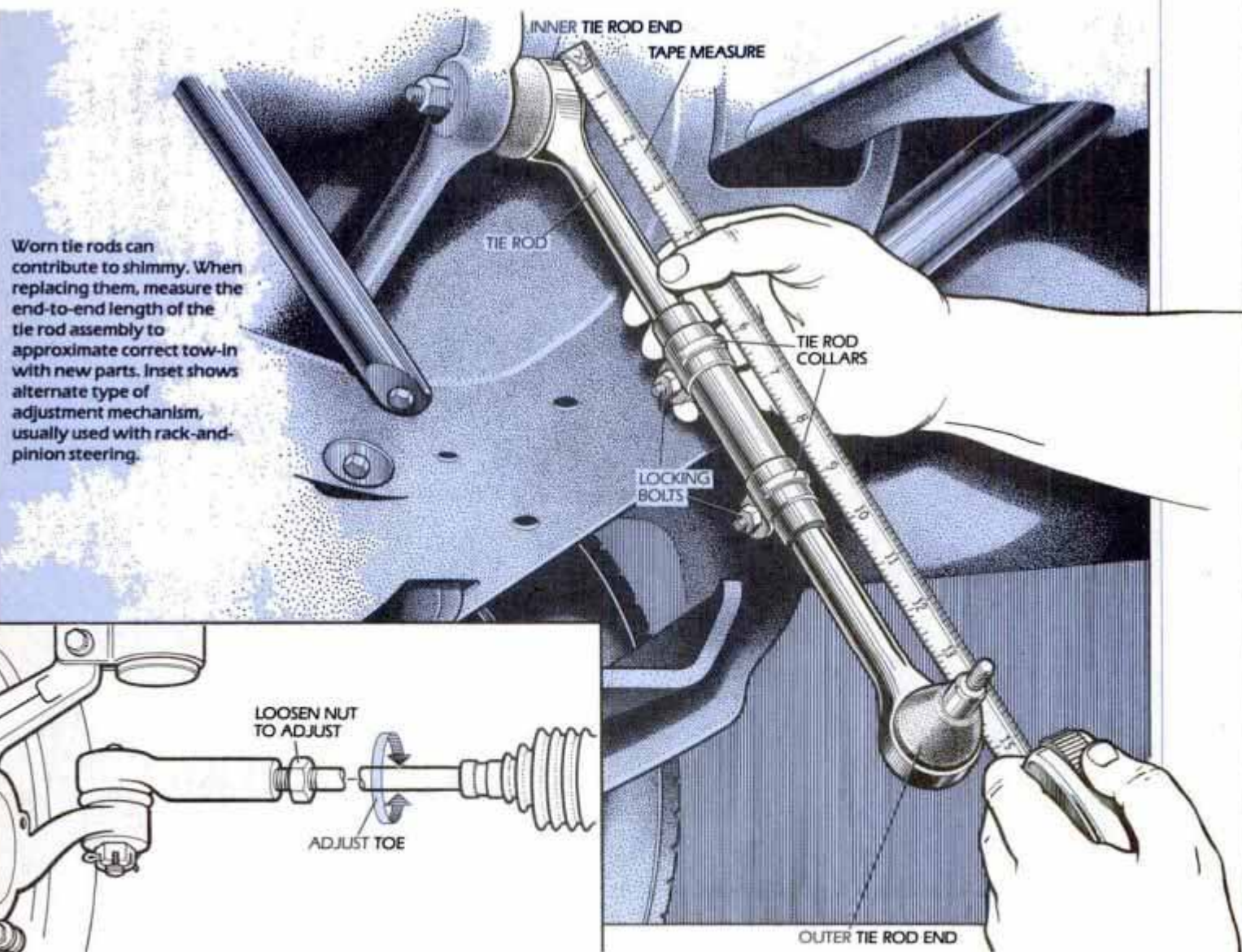
## Narrowing it down

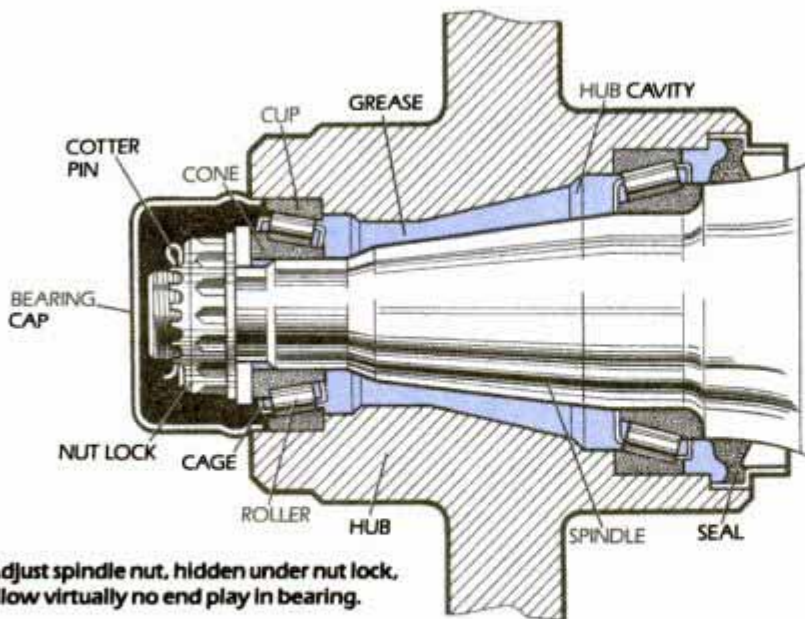
The diagnosis of steering wheel shimmy is sometimes the toughest part of the job. Potential causes of the problem on both front- and rear-drive cars include tires or wheels that are out of

balance or out of round, excessive wheel runout, a blister on a tire, loose wheel bearings, worn steering linkage parts and worn ball joints.

When shimmy is induced by a pavement bump it usually indicates that steering linkage parts are at fault. Shimmy that is noticeable only at certain speeds may be the result of tire/wheel imbalance.

Shimmy induced by braking can





**1** Adjust spindle nut, hidden under nut lock, to allow virtually no end play in bearing.

sometimes be caused by loose wheel bearings. Shimmy that occurs constantly may well be the result of a run-out or out-of-round problem.

But none of these are hard and fast rules. If, for example, the shimmy is most noticeable when one wheel hits a bump, jump ahead to the troubleshooting procedure called "Steering Linkage Slop."

If you don't know where to start, begin at the beginning.

## Tires first

A common cause of shimmy that is accompanied by vibration or a thumping noise is a tire bump or blister. So, before we start looking for more serious problems, lift the front end of the car and support it with sturdy jackstands in the jacking positions recommended in your owner's manual. With the wheels clear of the ground, carefully examine the tread and sidewalls of each front tire. A bump on the tread will usually cause uneven wear.

## Wheel bearings

Because some of our other checks are dependent on proper front wheel bearing adjustment, and because a loose bearing can contribute to a shimmy problem, it's important to make sure the bearings are okay before moving on (Fig. 1).

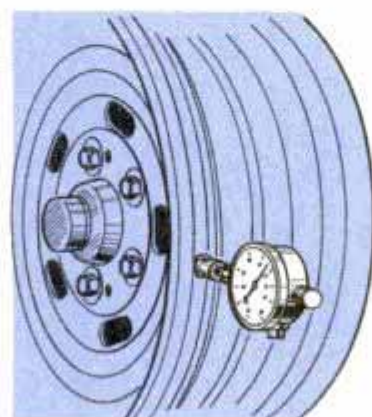
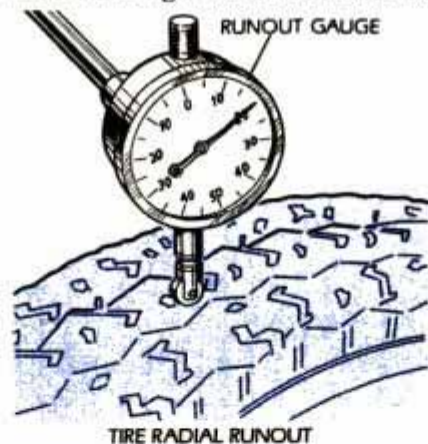
To clean, adjust and repack the front wheel bearings of a rear-drive car, remove the grease caps by gripping them with sliding-jaw pliers and rocking them back and forth slightly. Then remove the cotter pin, castellated nut lock and outer bearing.

If your car is fitted with drum brakes, attempt to remove the drums. If they won't budge, use a

brake adjusting tool to back off the adjustment. You'll have to lift the self-adjusting lever away from the star wheel with a small screwdriver.

To remove disc brake rotors, simply disengage the caliper assembly and suspend it from the steering knuckle arm with a piece of wire.

With the drum or rotor off its spindle, use a 3/4-in. drift to drive the inner wheel bearing and seal out of the hub.



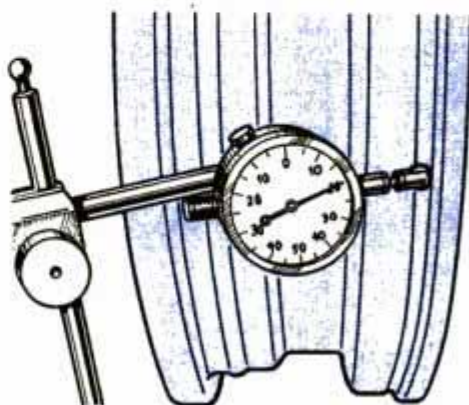
Take care not to catch the edge of the bearing race with the drift. A few taps should disengage the bearing and seal. Clean the bearings in solvent and check them carefully for signs of pitting or other surface damage. Clean the races inside the hub and examine them as well. Some minor discoloration of race and bearing is okay, but any damage is grounds for replacement.

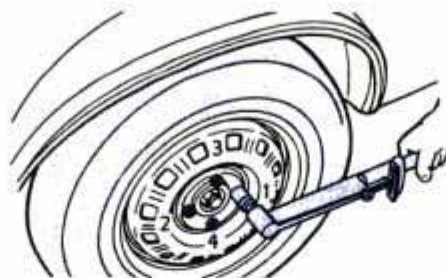
To repack a wheel bearing, scoop up a handful of wheel bearing grease, cup your hand and push the side of the bearing cage into your palm. Force the grease past the rollers and continue until grease oozes out of the top of the cage. Then rotate the bearing and do it again.

Reinstall the bearings with a new grease seal. Assemble all the parts carefully and tighten the hub nut to about 10 lb.-ft. while rotating the wheel. Then back the nut off and retighten it with your fingers. Position the nut lock slot so that it aligns with the hole in the spindle and install the cotter pin. End play should be almost imperceptible, about 0.001 to 0.003 in.

The front wheel bearings of front-drive cars are not serviceable or adjustable. If wheel looseness and/or noise indicates that a bearing has

**2** With runout gauge, measure radial runout with tire warm from short drive. Also measure lateral runout (see text). Then demount tire from rim and measure rim radial and lateral runout at tire-mounting flanges at inboard and outboard sides of the rim. Don't try to measure runout at the edge of the rim, as it has no effect on total rim/tire runout. Don't try to measure from center of rim, without demounting tire. If rim shows excess runout, sometimes tire can be rotated relative to rim 180°, otherwise rim or tire must be replaced.





**3** Torque wheels in an alternating pattern to avoid wheel or hub distortion. Check your owner's manual for the correct torque spec.

failed, the bearing assembly must be replaced. Special tools are required for this job, so you may want to delegate it to your mechanic. If you do decide to do it yourself, you'll need the factory service manual for your car.

## Tires and wheels

Now that we're certain that the wheel bearings are in good condition and properly adjusted, let's check those tires and wheels for radial and lateral runout. Radial runout is the difference between the high and low points on the circumference—the tread area—of the tire. Lateral runout is the wobble of the wheel and/or tire.

Before making any measurements, drive the car a couple of miles to eliminate any temporary flat spots on the tires. Raise the front end of the car and support it on jackstands, following all normal safety precautions and using the prescribed jacking points.

To check for radial runout, you'll need a runout gauge, which is nothing more than a dial indicator with a wheel on the bottom of its stem. Mount the indicator in such a way that its stem is perpendicular to the tire and its wheel is in contact with the center of the tread but in an area without grooves (Fig. 2).

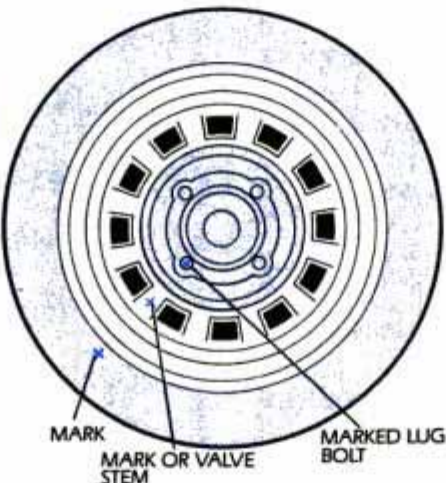
Slowly rotate the wheel and tire. Radial runout of more than 0.060 in. will usually cause shimmy or shake. Sometimes, 0.045 is enough.

Now check for lateral runout. Place the runout gauge with the stem perpendicular to the tire's sidewall near the shoulder. It must be in contact with a smooth area all the way around. Rotate the wheel. Lateral runout of more than 0.080 in. could cause a steering shimmy.

If either of these measurements are out of spec, remove the wheel in question and clean the mounting face of both the wheel and hub. Rotate the wheel a half turn so that it will mount in a different position. Remount it, torquing all the wheel nuts down to spec in two steps. Torque in a cross pattern as indicated in Fig. 3. Lube

the threads and chamfer with motor oil or antiseize compound. Look for the correct torque spec in your owner's manual. Repeat the runout checks. If the problem hasn't been solved by remounting the wheel, mark the point of maximum runout on the tire, wheel and stud (Fig. 4).

Then have the tire removed from the wheel, remount the wheel in the



**4** Before removing tire to check wheel runout, mark it relative to both wheel and hub.

same position relative to the hub as before, and measure lateral and radial runout on the wheel itself in the positions indicated in Fig. 2. If possible, check radial runout on the outboard side. If wheel design makes this impossible, check on the inboard side.

For steel wheels, radial runout should be no more than 0.040 in. while lateral runout should be no more than 0.045 in. For aluminum wheels, both lateral and radial runout should be less than 0.030 in.

■ If either runout measurement is excessive with the tire mounted, but wheel runout is okay, replace tire.

■ If lateral or radial runout was excessive on both the wheel and the tire, install a known good wheel and check runout on the wheel again. If it's still excessive, the brake disc or wheel hub is at fault and will have to be replaced.

■ If runout is okay with a good wheel,

installed, remount the tire on the good wheel and recheck. If runout is now within limits, your old wheel is defective and must be replaced.

■ If the wheel is within spec but shows some radial runout and radial runout was excessive on the tire, you might be able to effect a cure by remounting the tire in a different position on the wheel.

■ If wheel radial runout is greatest near the original chalk mark—the one you made when you checked tire runout—remount the tire 180° from its original position and recheck runout. If it's still excessive you'll have to replace the tire, or have it trued on a tire-truing machine. Unless the tire is almost brand new, this will probably remove so much rubber that you will be better off just replacing the tire.

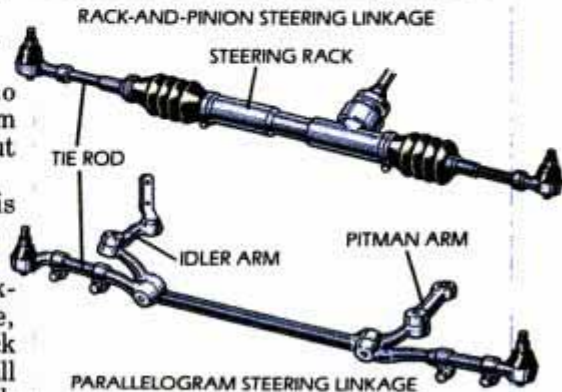
Once you're satisfied that your wheels and tires are true and free of bumps or blisters, have them dynamically balanced. A bubble balancer is not an acceptable substitute.

## Steering linkage slop

If you haven't located the cause of your problem yet—or if the symptoms lead you to believe that the condition is steering linkage related—it's time to crawl under the greasy side and check linkage parts.

Your car is equipped with either rack-and-pinion or parallelogram steering (Fig. 5). It's easy to tell which. A parallelogram linkage consists of two outer tie rods that are joined to a center link on one end and to the wheel's steering knuckles on the other end. The center link is supported by an idler arm and pitman arm.

A rack-and-pinion system consists of nothing more than the steering box itself. This long, tubular component is fitted with bellows and tie rods at each end. The tie rods are joined di-



**5** Parallelogram front-steering system has more moving parts, more places to wear out.

rectly to the steering knuckles.

After steering linkage repairs, you should have your wheels aligned at a shop equipped with a 4-wheel alignment machine. Some repairs may change the alignment angles. What's more, the shimmy problem could be partially due to misalignment, particularly because misalignment can cause the linkage parts to wear prematurely.

## Idler arm service

To check the idler arm of a car with parallelogram steering, grab the end of the idler arm that is joined to the center link and push up and down as hard as you can. It should move only about  $\frac{1}{8}$  in. or less (Fig. 6). An idler arm that clunks a  $\frac{1}{2}$  in. or so is a classic cause of violent intermittent shimmy.

To replace a defective idler arm, remove the nut that secures it to the center link. You'll need a tie rod end separator—commonly called a pickle fork—to disengage the idler from the center link. You can purchase one at any auto parts store for a modest amount. Disengage the idler by driving the pickle fork between it and the center link.

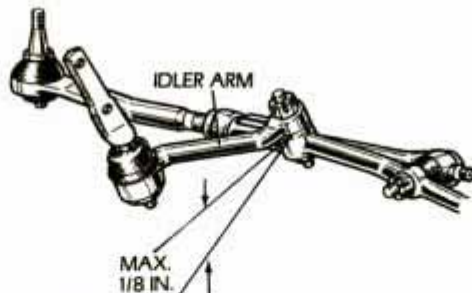
Next, unbolt the bracket that joins the idler arm to the frame. Install the new idler, tightening the bolts to the spec indicated in your factory service manual, probably around 35 lb.-ft.

Examine the hole in the center link. It should be tapered and uniformly shaped. If it's out-of-round or gouged, the center link should be replaced. Once you're certain that the center-link hole is okay, insert the rod end in the center link and reinstall the retaining nut and cotter pin. If your idler arm was attached with a locking nut, purchase a new one. *Never* reuse jam-type locking nuts.

## Tie rod end service

To check the tie rod ends of a parallelogram linkage, grab the tie rods and shake them vigorously. The rod ends should not be preloaded, sloppy or loose. Even a new rod end allows some horizontal movement but little or no vertical movement. Examine the rod end dust boots carefully. A tear is grounds for replacement.

With rack-and-pinion steering, check the bellows boots for cracks, splits or other damage. If they're not in good condition, replace them. Check the outer rod ends for looseness by shaking them back and forth as described above. To check the inner rod ends, squeeze the boot and locate the rod end. Then, with one hand



6 End of idler arm should show only slight up-and-down movement. GM specifies  $\frac{1}{8}$  in.

on the rod end, push and pull on the tire. If the rod end feels loose, it should be replaced.

To replace any of the four tie rod ends on a parallelogram linkage or the outer rod end on a rack-and-pinion system, remove the nut and cotter pin or locking nut from the rod end stud. To disengage the rod end from the center link and/or steering knuckle, drive your pickle fork between the rod end and its mounting point.

Before removing the rod end from the link, check the overall length of the link. On parallelogram systems, measure from the center of one rod end to the center of the other rod end (see lead illustration). On rack-and-pinion linkages, measure from the center of the outer end to the boot retaining groove on the inner rod end.

Once you've recorded the measurement, loosen the rod end clamps used on most parallelogram systems or the locking nut used on most rack-and-pinion linkages and unscrew the rod end. Install the new rod end, tightening it until the rod length is equal to the measurement you recorded.

## Checking ball joints

The steering knuckles of almost all cars are attached to the control arm or control arms with ball joints. Most cars with strut-type suspension have only one ball joint. Most cars with dual control arm suspension have two ball joints.

Checking ball joints used to be a dif-

ficult task, but because most cars are now equipped with wear-indicator ball joints, it's now quite easy. To check wear-indicator ball joints, the car must be on the ground or resting on ramps. (If you find that your car is not equipped with wear-indicator joints, refer to your service manual for specific instructions on checking ball-joint condition.)

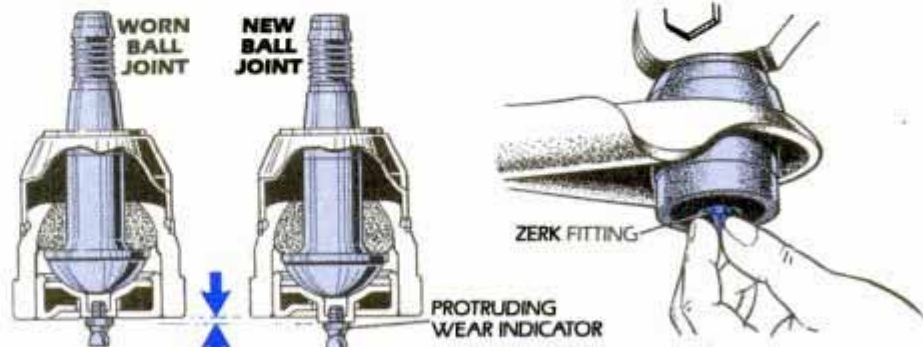
Two types of wear-indicator joints are commonly used (Fig. 7). Both types utilize the grease fitting as a measurement device. On the most common wear-indicator joints, a collar protrudes from the lower surface of the joint and encircles the grease fitting. As the joint wears out, this collar gradually sinks below the surface of the joint. If you can see a collar around the grease fitting of the ball joint, but it's no longer protruding, the ball joint should be replaced.

A second type of wear-indicator joint is used on some vehicles, including late-model Chryslers. With this type, you can check the joint by attempting to wiggle the grease nipple, or Zerk fitting. If you can move it with your fingers, the joint is worn out.

Ball-joint replacement is relatively easy on cars that have riveted, bolted or screw-in ball joints. On cars that have press-in ball joints, including most GM makes, it can be very difficult. Because the procedure varies, you'll need a service manual. You'll also need a ball-joint separator (a wide-slot pickle fork), and jack stands.

Read all the instructions in your factory service manual before you decide to attempt the job. You may find that expensive special tools are required. Some of these, like the ball-joint press required for press-in joints, may be available through tool-rental outlets or your auto parts store.

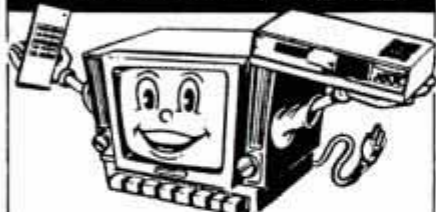
For less-experienced Saturday mechanics, ball-joint replacement is probably best left to a professional. **PM**



7 Wear-indicator ball joints provide visual evidence of wear. Check Chrysler-type by attempting to wiggle the Zerk fitting (right). If it moves, the joint is worn.

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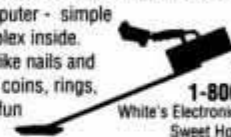
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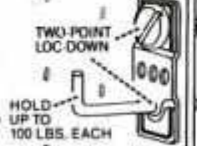


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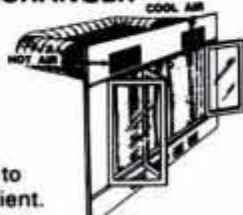
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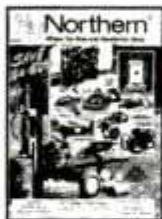
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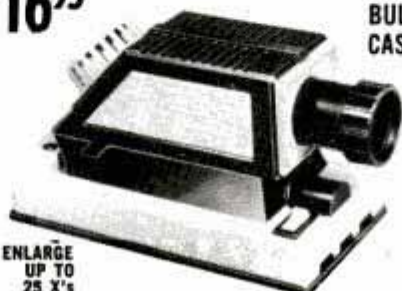


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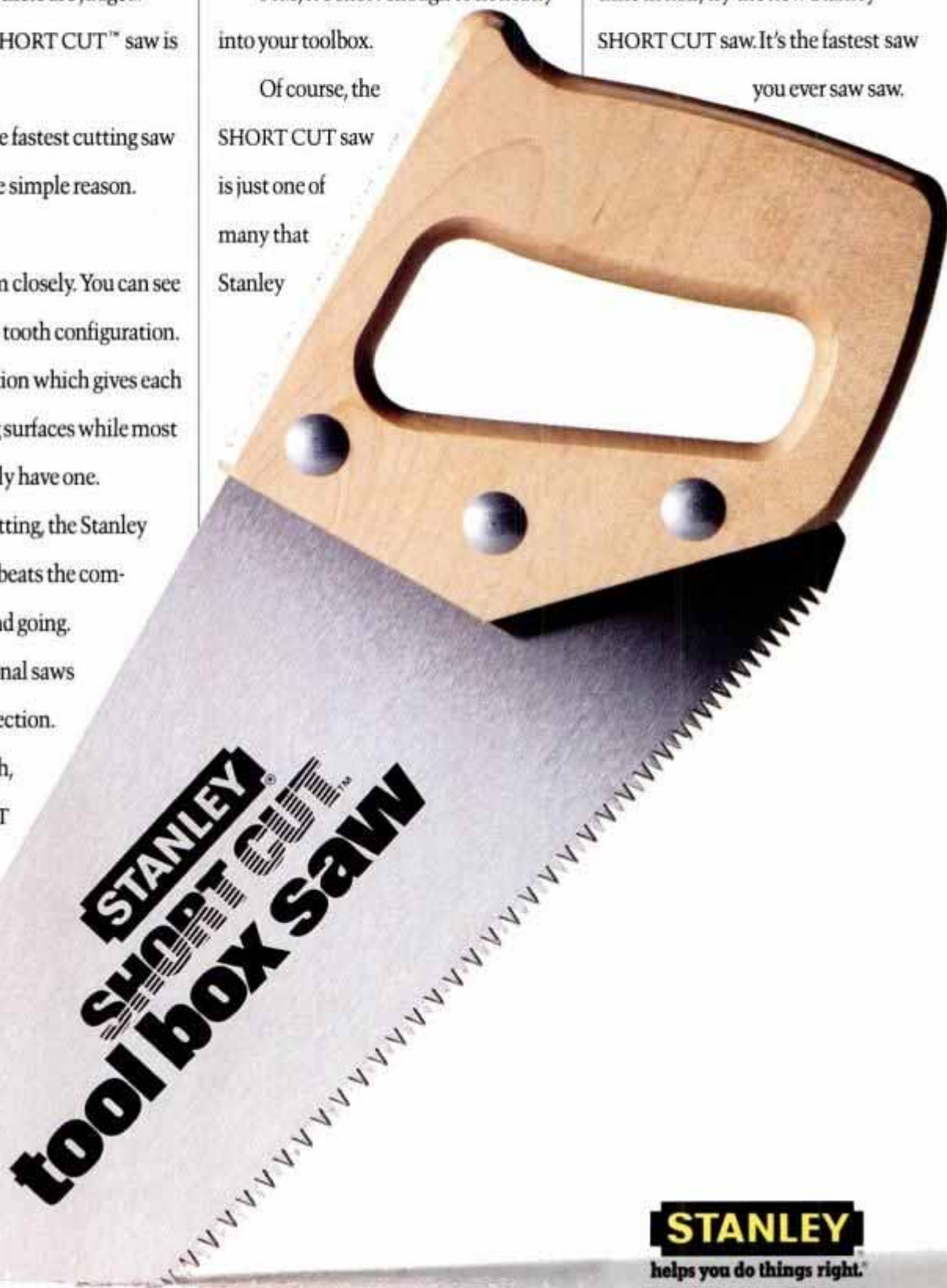
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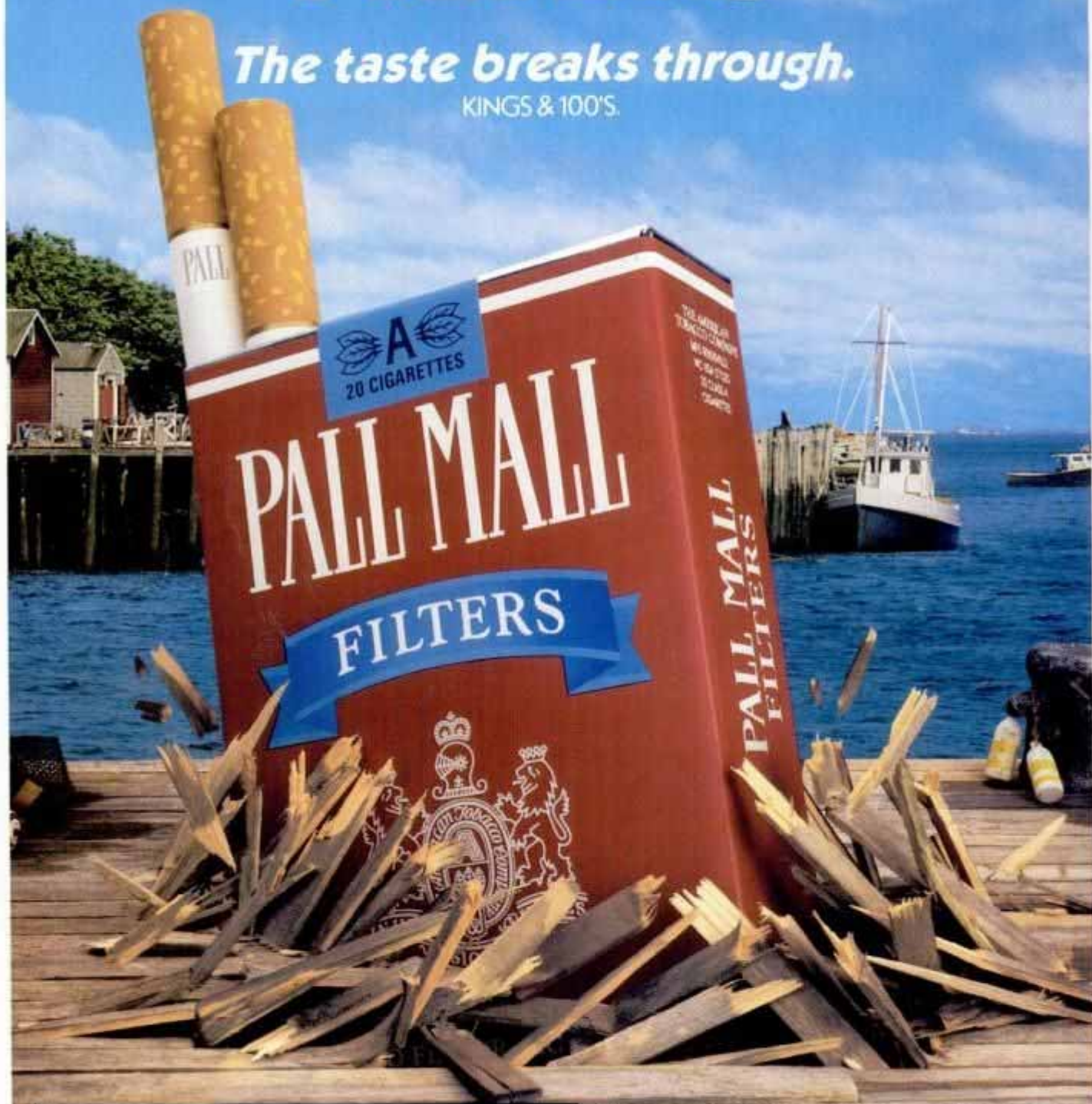
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