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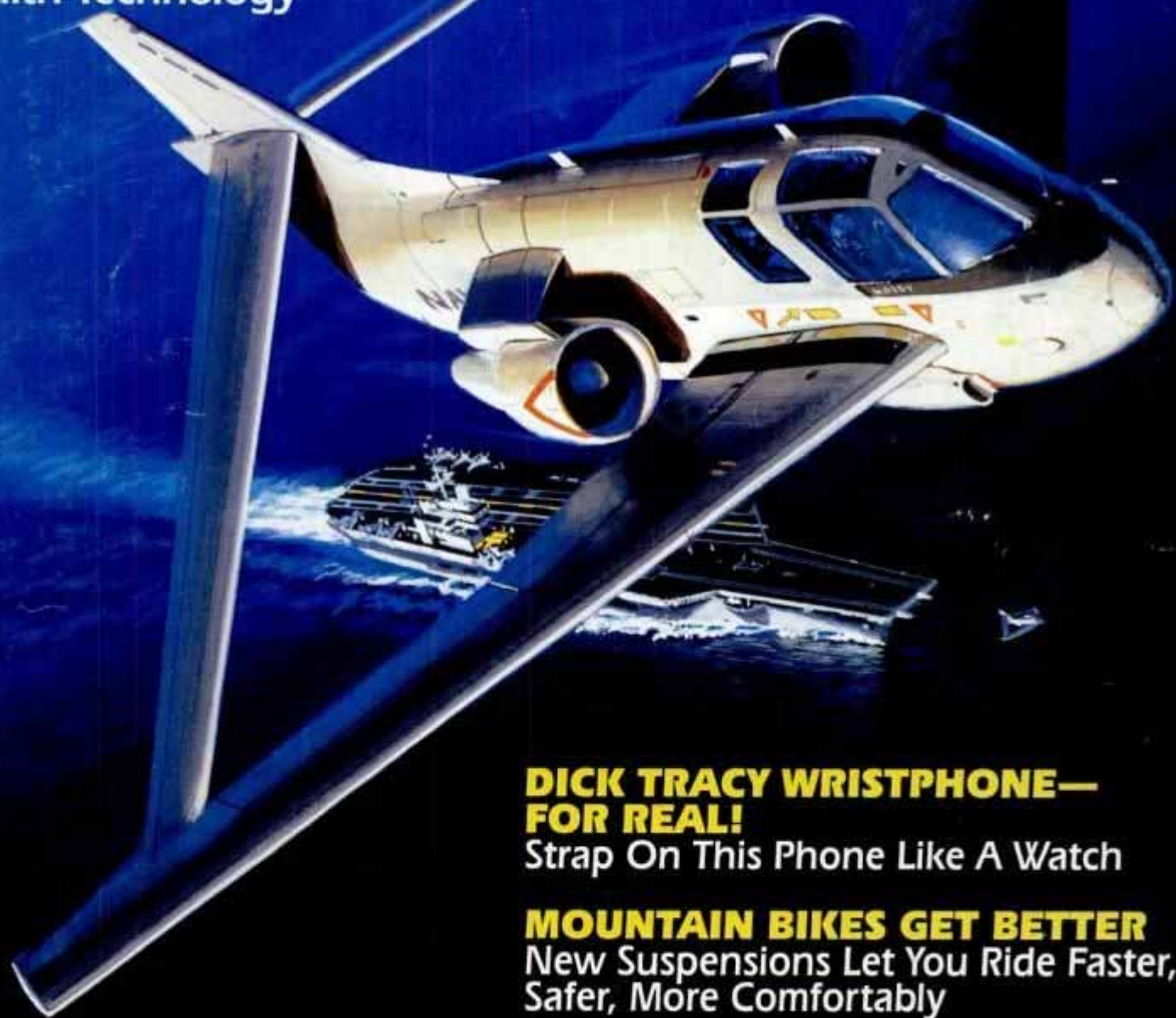
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Popular Mechanics

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How To Win The Battle
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Revolutionary Diamond-Wing
Surveillance Plane Beats
Stealth Technology



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But back in the 1890s, there was only horsepower. And tires made by Kelly-Springfield. We all had to start somewhere. And someone had to be first.

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America's
Oldest
Tire Company
Quality since 1894



Popular Mechanics®

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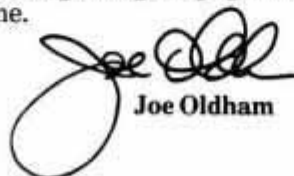
EDITOR'S NOTES

● The Indy 500 has become an annual trek for me. It's an incredible weekend, filled with sights and sounds that last a lifetime. And they're not all automotive-related either. The people you see in Indianapolis on race weekend are a show unto themselves. It's no wonder the Indy 500 is called the greatest spectacle in racing. This year was a special thrill for me. I never thought I'd see a race car in the Indy 500 carrying the name of POPULAR MECHANICS. Thanks to our association with the Dick Simon Racing team, we had not one but three cars in the race. And one of them, driven by Raul Boesel, was in the first row, having qualified third. No, we didn't win. But our cars finished fourth, sixth



... And the next day there were 400,000 people in the joint.

and 13th—no easy feat at Indy. The story of the race I'll never forget begins on page 106. . . . **The chances of you remembering** a story in our December 1988 issue are just about nil. Maybe this will sound familiar—wild cruise ships of the future with weird hull shapes and special features you thought you'd never see. Hey, the future is now. One of the ships we depicted in that article has just been completed and launched into regular service. The *Radisson Diamond* is the first of a new generation of high-tech passenger ships that will cruise into the next century with amenities that we only dreamed about—literally—just five years ago. Managing Editor Deborah Frank and Production Editor Robin LaSalle recently had the opportunity to spend some time with the ship's Captain, Rainer Hemming Tornqvist, on one of the first cruises. Their report? Superb! More on the *Radisson Diamond* on page 22. . . . **The protect-the-fleet mission** may soon have new role players as the Navy changes its warfare doctrines to address the new military role in the '90s and beyond. Production of the F-14 has already ceased as the F/A-18E/F goes into production, and the E-2C may be phased out in favor of the fascinating new aircraft depicted on our cover this month. Boeing's concept, currently designated EX for an Advanced Surveillance Aircraft, features startling diamond-shape wings that could make current stealth technology obsolete. Check the full story beginning on page 30. . . . **What does it take to drive from a standing start** to more than 300 mph in less than 5 seconds? You'll find out on page 38 as we take a look at state-of-the-art drag racing technology in photos and through a cutaway poster featuring Kenny Bernstein's championship Top Fuel car. . . . **Nothing beats lighting up an Arturo Fuente Double Corona** after dinner, especially if you're sitting in a rocking chair on the porch at the time. What? You don't have a porch rocker? So make one. Our step-by-step instructions, beginning on page 67, will make it easy. You supply the cigar. Till next time.


Joe Oldham



LaSalle (left) and Frank under Captain Tornqvist's command.

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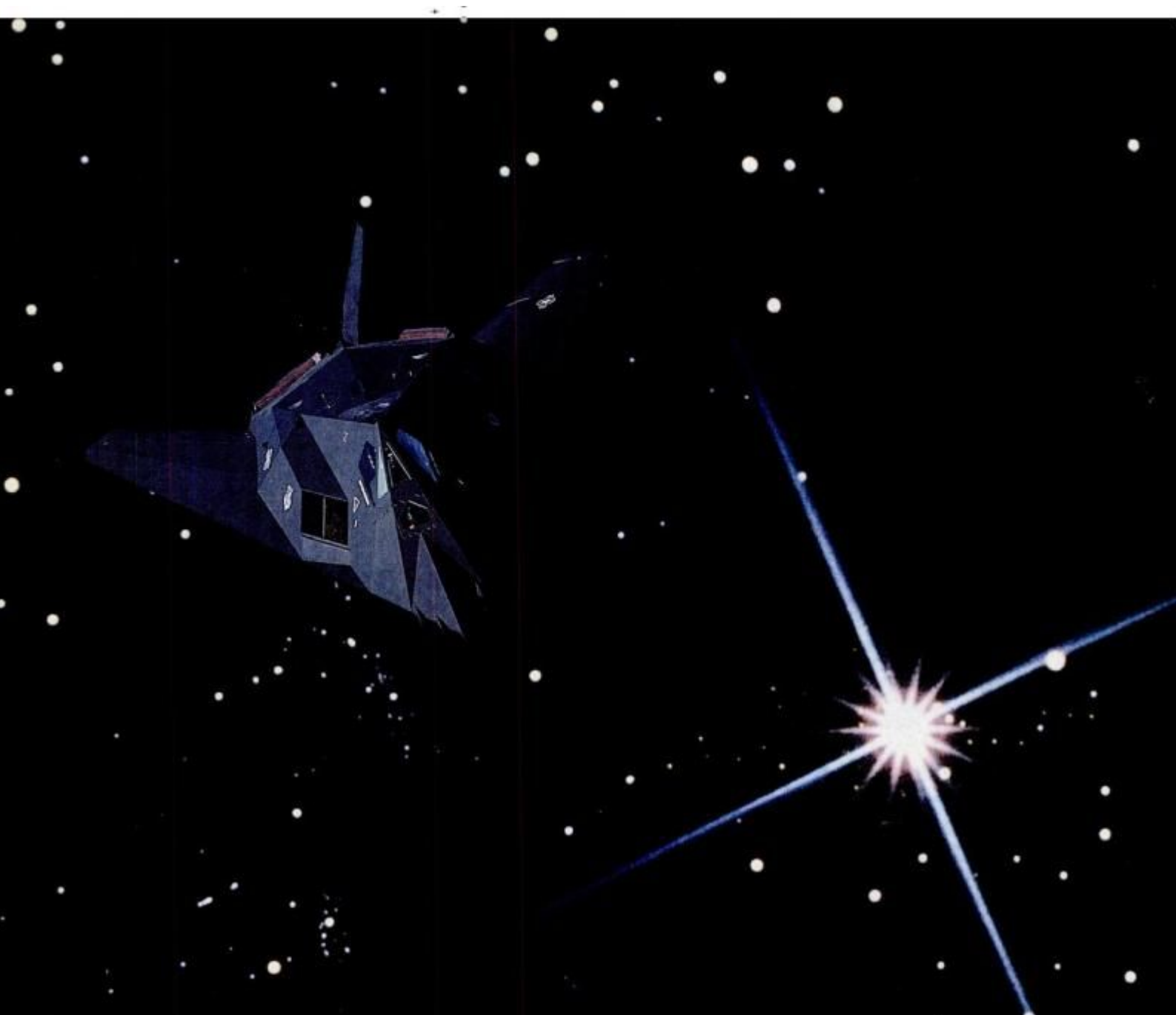
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LETTERS

Shadow Of Merrimac



Déjà vu! America's invisible warship? Where have I seen this before? Try the Civil War-era *Merrimac*. Its sides were sloped so that cannonballs could bounce off it. I was amazed by the similarity.

WALTER C. McNEESE
LEBANON, OR

Super Novi

Your pullout poster of the evolution of Indycars is a real work of art, but it repeats a long-held misconception. The fabled Novi engine of Lew Welch and Bud Winfield was not two 90-cu.-in. Offy midget engines joined on a common crankcase. You have confused the construction details of the Novi with the Meyer-Bowes supercharged straight Eight which debuted in the late 1930s. Both engines share several common links, but the Novi could not have been built from Offy parts. Its huge center main bearing called for greater spacing between the front four cylinders and the back four. The tiny Offy blocks could not line up its rods on that oversize crankcase.

TIM CLARK
AURORA, OR

Letters are subject to editing for length, style and format.

Clunker Bill

Recently, you restored a '67 Camaro, so you know the interest level in old cars. I have a profound interest in preserving our automotive heritage, which will be adversely affected by the Clunker Bill. This legislation will affect retired people with old cars as well as those who need inexpensive transportation. Broader attention should be focused on this subject. Organizations such as the Counsel Of Vehicle Associations [(800) CARS-166] are seeking members to fight against this short-sighted legislation.

ED GONFINDINI
DES MOINES, IA

There are several Clunker Bills pending. In the guise of ridding the road of old high-emissions-emitting cars, they deprive the old-car hobby of potentially restorable cars and parts. When you restore an old car, you're actually recycling it—which is, in our opinion, a better solution, and more fun.

—Ed.

Pine Cupboard

I want to thank you for running project plans in such detail and variety. I do some woodworking as a hobby, and truly enjoy working from your plans. I built this pine cupboard from the plans you ran in the November '92 Woodworking Guide. I made some modifications to meet size requirements. The cupboard is lightly stained with an Early American oil stain and finished with three coats of high-gloss polyurethane.

BARRY SCHILLING
SALISBURY, MD

We Were First

In reference to your cover story on Japan's jump-jet airliner, the Ryan Aeronautical Co. began flight trials of a fan-in-wing prototype aircraft, dubbed the XV-5A, in 1964. This single-seat aircraft contained two 62½-in.-dia., 36-blade fans in each wing and a third smaller fan in the nose of the aircraft for control purposes. Power for the fans was provided by the jet efflux from two GE J85-5 Turbojets. Takeoff and landing were controlled through a door and louver system. When conventional flight was achieved at 140 mph, the wing doors would close and the aircraft would fly normally. This was one of the United States' first attempts at VTOL aircraft designs. It was later abandoned for designs such as the AV-8B Harrier.

JOSEPH SPERONI
HIGH RIDGE, MO

You published a big, glorious story about what the Japanese are doing. Al



Reader Barry Schilling's pine cupboard, built from PM plans.



Mooney designed such an aircraft at Lockheed, and flew it, 20 years ago. Why are you discrediting our country?

DAVID D. BLANTON
AUGUSTA, KS

PM reported on both the Ryan and Mooney designs in the '60s and '70s. Now we're reporting on the latest VTOL passenger plane developments. This is discrediting America?

—Ed.

Slow Learners?

Your glowing Owners Report on the Toyota Camry overdid it. Contrast it with the matter-of-fact description of the Chevy Lumina. I don't know how your American car advertisers let you get away with this. In any case, I won't be renewing my subscription.

RALPH S. FROST
OLYMPIA FIELDS, IL

Hey Frost, before you cancel, try to understand this. It's not too difficult. An Owners Report is just that. It's the car's owners telling us what they like and dislike and how the car performs. It's not our opinion.

—Ed.

For some time I have felt that if a product is made in

the U.S., you knock it. If it's made in Japan, you praise it. Over the years, other readers have told you the same thing. I think you are slow learners.

BOB TALLMAN
HOOD RIVER, OR

You mean like the Saturn and Ford Taurus reports we recently published?
—Ed.

You wrote that the 4-cylinder automatic Toyota Camry was rated 21/27 mpg and the V6 automatic was rated 18/25 mpg. This is not good in my book. My '89 Buick LeSabre 4-door with 3800 V6 automatic is rated 19/29. After returning from a 2300-mile trip, more than half of it in the mountains of Colorado, my gas mileage was 32 mpg. For the 64,000-plus miles I have driven this car so far, I've averaged 26½ mpg. Thanks, but I'll keep and drive my LeSabre, a more comfortable car that's cheaper to operate.

ORVAN E. GILSTRAP
WINFIELD, KS

Three Points

I commend you on a stimulating magazine for young people with an interest in science. My son, William, was a place-kicker on his high-school football team when he read your article, "The Mechanics Of A Field Goal." Since he had a science project requirement, he decided to conduct a controlled experiment concerning the effect of altitude on old and new footballs as well as the use of a drag coefficient in the trajectory equation for predicting the distance traveled. The results showed that at a higher altitude, the football would go farther than at a lower altitude, and that old footballs would travel about 5 yards farther than new ones. For his efforts, he received an Honorable Mention in the schoolwide science fair.

DR. JAMES W. SAYRE
LOS ANGELES, CA

Invisible Rays, Hidden Hazards

Your article on the dangers of electromagnetic fields provided a valuable public service in alerting us to a potential hazard. You should write a followup article on natural, rather than manmade, magnetic and electric fields so that we may evaluate for ourselves the degree of hazard this controversial area presents.

DAN W. FINGER
BETHESDA, MD

Every time the communications media focuses on avoidance of one real or imagined threat to life, people shy away from that danger in panic. But

if individuals don't die of the threats they were brought to fear, they will likely succumb just as soon to some other hazard that hasn't been publicized. I have been enjoying PM for at least 65 years, and you have printed very little of the type of unproven nonsense found in "Will Your Cellular Phone Kill You?" Please don't let this be a trend in that direction.

LEO D. PATTERSON
BURLINGTON, WV

I was very interested in your article on EMF dangers. I've worked in the computer industry for 20 years, and I

feel the dangers of EMF are underestimated. Cell damage may be caused by EMF, but more importantly, what effects can EMF have on the human nervous system? I have seen people who work in high-EMF areas suffer from nerve damage, cancer, hypertension, depression and many other problems. We would not expect a radio to work in a room full of computers or under high-voltage lines because of electrical interference, so how can we expect our sensitive human electrical system to function correctly?

JOE LOGSDON
KEOKUK, IA

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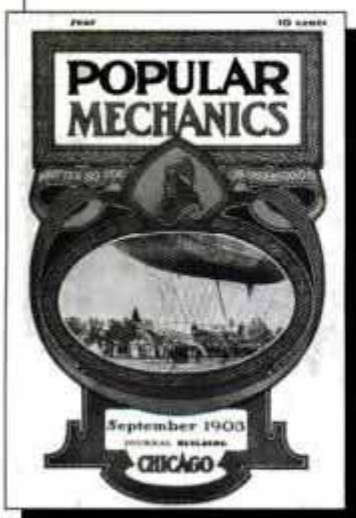
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90 YEARS AGO: SEPTEMBER 1903



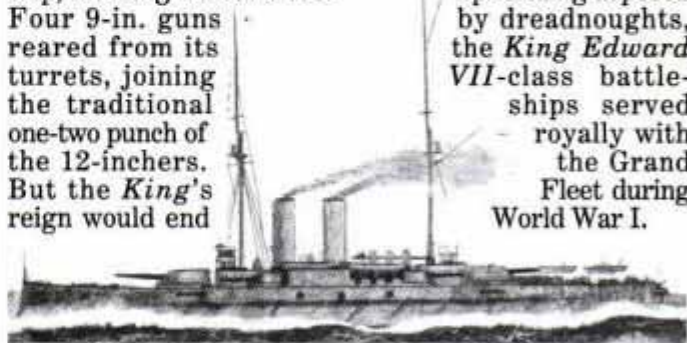
Rubber Baron

Vulcan, Roman god of fire and metalworking, made a surprise appearance on the cover to kick off our new monthly format. Perhaps he was to symbolize the vulcanized rubber on the Stanley Spencer airship pictured below him. Spencer's blimp typified efforts in the early days of lighter-than-air travel. Back then, such niceties as controlled flight and aerial navigation were unproven concepts. Hence the huge crowds that airship launches drew.

King For A Day

As the European powers tuned for the great naval buildup, Britain launched the world's biggest battleship, the *King Edward VII*. Four 9-in. guns reared from its turrets, joining the traditional one-two punch of the 12-inchers. But the *King's* reign would end

six years later when the revolutionary *Dreadnought*, packing steam-turbine drive and a dozen 12-in. guns, joined the fleet. Despite being deposed by dreadnoughts, the *King Edward VII*-class battleships served royally with the Grand Fleet during World War I.



60 YEARS AGO: SEPTEMBER 1933

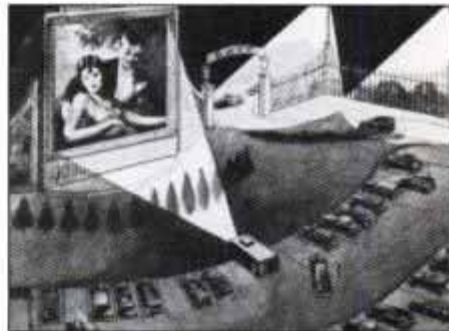


Silver Bullet

Diesel was coming to the American railroad, and the Union Pacific was ready to exploit it. An articulated 3-car trainset, capable of 100 mph on a mere 600-hp engine, was five months from its inaugural run. The M-10000's aluminum construction and streamlining were lifted from the air-transport business, which had been siphoning riders away. The train would barnstorm through 68 cities on its way to Chicago for the 1934 Century Of Progress exhibit.

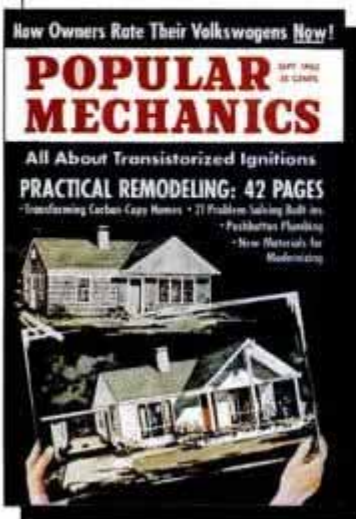
Screen Gem

During the '50s, drive-ins would reel in a quarter of all moviegoers, but Camden, New Jersey, had its own "outdoor talking-picture theater" as far back as the '30s. Four hundred automobiles could park on inclined ramps, the farthest lying a good 500 ft. from the screen, which stretched 50 ft. across. In the days before miniature car-window



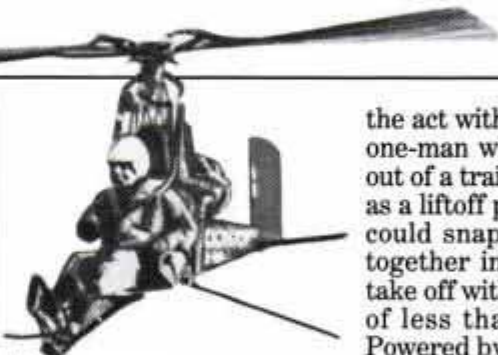
speakers, the drive-in simply blasted the area with sound, but since it was located near an airport there were few complaints from neighbors.

30 YEARS AGO: SEPTEMBER 1963



Home Work

The postwar population boom had spawned a bumper crop of housing developments, in which clone homes marched across suburbia in perfect lock-step. Now the individuality of the '60s was taking over. Our home-improvement guide featured facelift projects that added distinction to cookie-cutter split-levels. Patios, picture windows, carpools, roof cupolas and new sidings put the personal stamp on the impersonal.



Rotorman

"Flying motorcycles" continued to obsess the aircraft industry during the adolescence of the helicopter. The West German company Dornier, known for its experimental vertical-takeoff jets, got in on

the act with the Do.32. The one-man whirlybird folded out of a trailer that doubled as a liftoff platform. A pilot could snap this ultralight together in 5 minutes and take off with a gross weight of less than 600 pounds. Powered by a 100-hp BMW turbine, the Do.32 spun its rotor with compressed air fed to blade tips. Obviously impressed by the machine's performance at the Paris Air Show, the West German government briefly considered buying a 2-seat derivative. **PM**

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PRESENT

THE NATIONAL AUTO QUIZ

1. This type of aftermarket performance intake system is generally referred to as a:



A) Ram tube injection. B) Dual quad setup. C) Tunnelram. D) Hillborn injection.

2. Which is the latest industry standard to be added to motor oil labels?

A) SAE. B) SG. C) API. D) ILSAC.

3. A DOHC V-6 engine has how many camshafts?

A) 4. B) 3. C) 2. D) 1.

4. The first Jeep prototype was produced for the Army by:

A) Willys-Overland. B) Ford. C) Chrysler. D) Bantam Car Co.

5. Noisy hydraulic valve lifters can make a ticking sound when the engine is running if:

A) Valve lash is too tight. B) Valve lash is too loose. C) Lobe centers are over 110 degrees. D) Both A and C.

6. A windage tray is attached:

A) Between the crankshaft and the oil pan. B) Beneath the car's floor pan. C) Between the grille and the radiator. D) None of the above.

7. The total cash purse awarded for the 1993 Indianapolis 500 was:

A) \$800,000. B) \$2.8 million. C) \$7.6 million. D) \$11.2 million.

8. What year did Chevrolet's legendary small block V8 debut in a production car?

A) 1917. B) 1953. C) 1955. D) 1965.

9. What car company produced a V6 engine that was fitted with a single cylinder head?

A) BMW. B) Volkswagen. C) Hudson. D) Chrysler.

10. President Clinton's personal car is a:

A) 1993 Cadillac. B) 1993 Lincoln. C) 1969 Camaro. D) 1967 Mustang.

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1. C 2. D 3. A 4. D 5. B 6. A 7. C 8. C 9. B 10. D

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Unfortunately, our Hotline Phone Service is temporarily discontinued.

TECH UPDATE

News Of Tomorrow's Technology Today



SCIENCE ILLUSTRATION

SST Mothership Could Launch Orbiter

SEATTLE, WA—Stop dreaming about a ride on the X-30. The air-breathing, scramjet-packing, single-stage-to-orbit vehicle won't be built, and officials have scaled down the National Aero-Space Plane (NASP) program to putting technology demonstrations on sub-orbital rocket flights.

But the red light that froze the X-30 hasn't stopped Boeing from proposing an ambitious 2-stage-to-orbit (TSTO) launch system. Compared with NASP, however, Boeing's proposal draws on nearer-term technology.

Stage one: a beefed-up SST derived from the High-Speed Civil Transport, the Concorde follow-on that

Boeing has been blueprinting. This mothership would climb to 30,000 ft. on six afterburning turbojets. Then its seventh powerplant, a Space Shuttle Main Engine, would ignite to hike the aircraft to 100,000 ft.

Stage two: a winged reusable orbiter, carried like a baby kangaroo in a conformal slot on the mothership's belly. Its engines would also flame on at 30,000 ft. to boost the powered climb. At 100,000 ft. and Mach 3.3, the stages would separate, with the orbiter zooming on into space.

Compared with Germany's *Sanger* 2-stager, Boeing's

Editor: Abe Dane
Writer: Greg Pope
Reporters: Philip Chien, Mike Fillon

TSTO would separate at a lower speed, so its first stage needn't be built to shake off as much aerodynamic heat.

SST-derived mothership releases orbiter, depicted here with ramjets, in Boeing's 2-stage-to-orbit concept.

Highlights This Month

- **Fire Drill**—Extinguisher bores through stealth-plane skin to snuff engine blazes.
- **ICE On Wheels**—Germany's 175-mph bullet train comes to America.
- **Two Giant Steps For Man**—Shuttle and Titan could team up for a Moon shot.
- **Shopping For Security**—The Army scouts out armored peacekeepers for MPs.
- **Cruise Control**—*Radisson Diamond* tames rough seas with twin-hull design.
- **Surge Protector**—Holland's giant sea gates slam the door on floods.



Drill punctures composite skin and snuffs fire without exposing flames to more air.

Oceaneering Technologies has resculpted the cutting bit so that it drills a smaller pilot hole—key to penetrating high-tensile-strength materials. The pneumatic motor is bigger, too.

Once the drill bit gets in, ports behind the cutting head spray chemical foam or water. Because the device quenches fire internally, fire-



Stealth-Skin Driller

UPPER MARLBORO, MD—When the YF-22 belly-flopped and burned at Edwards AFB last year, fire-

fighters came up short. They lacked an extinguisher drill that could penetrate the tough composite skins of today's stealth aircraft.

Now one is available. The FireDrill-2 upgrades a tool

originally designed to puncture aluminum aircraft skins and spray extinguisher on internal fires. The new version can poke through titanium, composites, even 1/4-in. steel bulkheads on ships.

fighters needn't rip open the plane and fan the flames with a rush of oxygen.

Several airports have armed themselves with the FireDrill-2 for building and container fires.

The ICE Train Cometh

WASHINGTON, DC—If you missed the X2000 last spring (see "Bullet Train For America," page 48, Mar. '93), you have a chance to ride another European supertrain: Germany's sleek InterCity Express, or ICE.

The ICE regularly hits 175 mph between Frankfurt and Munich. Lightweight aluminum construction helps

pare down its weight to compensate for heavy-duty propulsion equipment.

Unlike the X2000, the ICE doesn't tilt, but it outperforms everything but France's TGV on the straightaway.

Starting October 3, the ICE will pinch-hit for a Metroliner between Washington, D.C., and New York.



Extruded aluminum panels give ICE its unique seamless profile.

Star Wars Moon Shot

WASHINGTON, DC—Why is the Defense Department firing a spacecraft at the Moon? Because it's an easy target.

The new Ballistic Missile Defense Organization—the

SDI follow-on—has teamed with NASA to build Clementine, (so named because

it'll be "lost and gone forever" after the mission). Clementine will test its sensors

against the Moon's well-documented ultraviolet, visible-light and infrared profile.

Clementine's lightweight technology, developed for strategic defense, could aid future NASA probes.

A Titan II will launch Clementine in January 1994.

After orbiting the Moon, the spacecraft will fly into deep space, skirting a near-Earth asteroid.

The Naval Research Laboratory and Lawrence Livermore National Laboratories built Clementine.

Clementine showcases lightweight components, such as Ball reaction wheel (far left).



FIM ILLUSTRATIONS BY ED VALOUSKIY

BALL AEROSPACE PHOTO; NAVAL RESEARCH LABORATORY ILLUSTRATION

SOSNEGA PHOTO

HOW TO FIND YOUR WAY THROUGH THE WOODS.

In woodworking, every project is an adventure. You explore the wood, studying its grain, searching for something hidden within.

Your goal is to emerge, weeks later, with a proud souvenir. A planter. A Shaker chair. Or perhaps a rustic chest of drawers.

Ironically, the ease of any woodland journey depends largely on a decision you make *before* embarking: your choice of tools.

To this end, a move in the right direction is Skil Woodshop Tools.™

Skil Woodshop Tools are a full line of woodworking tools designed to make any project a pleasure.



Every step of the way. Enter the woods with a confident first cut on the 3400 10" benchtop table saw. Its powerful 13.0 amp motor and exclusive Accu-Lign™ self-aligning, quick-set rip fence makes short work of sizing raw stock.

Whatever your plans call for next, the HD 1875 plunge router is sure to be part of them. Its 2¼ hp motor can carve signs, cut joints and trim decorative edges with power to spare.

For accurate, repetitive drilling, the 3380 benchtop drill press is precisely what you need. The depth measurement and sturdy, adjustable table guarantee consistency from first hole to last.

When it's time for



assembly, try the innovative HD 1605 plate joiner. Simply cut matching slots, pop in a wooden biscuit, glue and you have yourself a quick, durable joint.



Once it's all together, give your project a once over with the HD 7576

palm grip sander. The 7576 performs an exacting 1/16" orbit 13,000 times a minute for a fast finish.

Next time you explore the woods, bring along the perfect traveling companions—Skil Woodshop Tools. You'll find those shown here and other Woodshop tools in stores everywhere. Just look for this label. It's a sure sign you're on the road to woodworking success.



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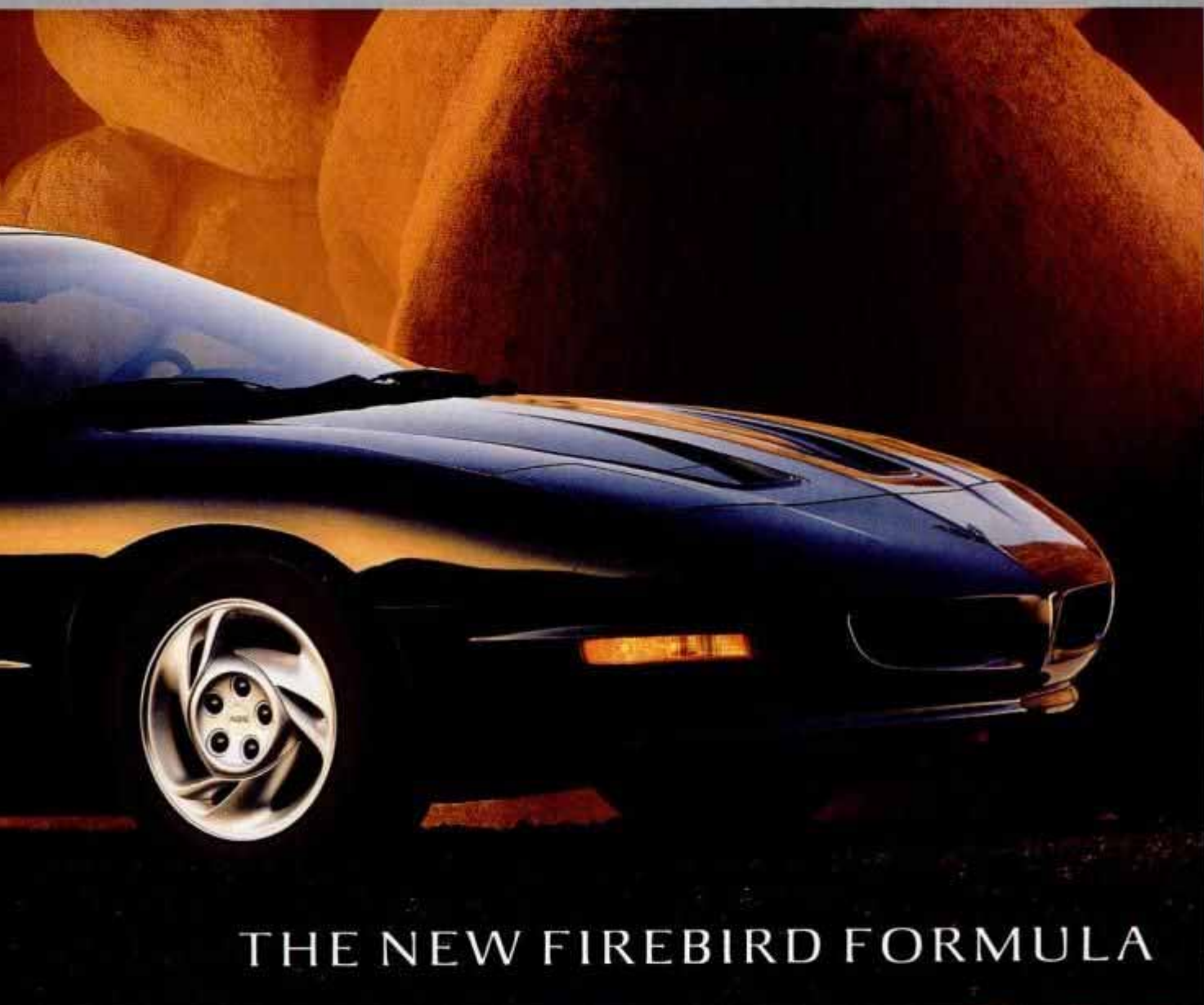


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Dodge Stealth R/T	YES	NO	YES	222	\$27,366
Mitsubishi 3000 GTR4	YES	NO	YES	300	\$37,250
Nissan 300 ZX 2+2	YES	NO	YES	222	\$34,040
Toyota Celica All-Trac	YES	NO	YES	200	\$28,588
Acura NSX	YES	YES	YES	270	\$69,500
BMW B50Ci	YES	YES	YES	298	\$83,400
Porsche 96B	YES	YES	YES	236	\$39,950

[†]\$17,995 MSRP, including dealer prep, tax, license, destination charge and optional equipment additional. Prices higher in CA and NY. Always wear safety belts, even with airbags.
*Excludes other GM vehicles.

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Moon On A Budget

SAN DIEGO, CA—No need to reinvent the Saturn V, say engineers at General Dynamics: The Shuttle and today's rockets could supply the lifting power to put men back on the Moon.

The scenario—presented to NASA last spring—calls for the Shuttle to loft a new 4-legged lunar excursion vehicle (LEV) topped with an Apollo-style return capsule. Meanwhile, a Titan IV or European Ariane V would bring a juiced-up single-engine Centaur upper stage into the Shuttle's orbit.

This Centaur would dock with the lander and then fire its engines to rocket the whole assembly Moonward.

Two missions would deposit supplies and a habitat on the lunar surface. A third



trip would bring two astronauts for a 2- to 3-week sojourn. Subsequent missions could build up a permanently manned base.

Except for the LEV, the

plan draws from existing hardware. And hoisting the crew capsule with the Shuttle would obviate the expense of man-rating a heavy-lift rocket. Total cost: as

Lunar excursion vehicle and wide-body Centaur dock prior to translunar injection.

little as \$6 billion, that is if Europe kicks in with some hardware.

Peacekeeping On Four Wheels

WARREN, MI—Somewhere between the Humvee and the Marines' LAV-25 8x8 lies a medium-weight armored vehicle that would suit the Army's peacekeeping missions. Trouble is, the Army's inventory doesn't include such a vehicle—yet.

To fill the gap, the Tank-Automotive Command will start looking this fall for an off-the-shelf Armored Security Vehicle, or ASV.

Requirements? All-wheel drive with run-flat tires. Enough armor to rebuff 7.62mm ammo, plus extra metal to withstand mortar fire and small antipersonnel mines. Protection against nuclear, biological and chemical contamination. A weight that permits transport via



Germany's Thyssen Henschel offers Condor (above) and TM 170 Hardliner (below).



Versatile V-150 runs on diesel V8 and features unitized body of steel plate.



C-130. And a turret for either a grenade launcher or a .50-caliber machine gun.

Likely to receive consideration are two 4x4 Cadillac Gage vehicles, the Commando Scout and the V-150. The former is a low-slung tactical-reconnaissance vehicle, while the latter evolved from Vietnam-era military-police vehicles. The similar Dragoon, from AV Technologies, will also compete.

Manufacturers in Germany, France, Italy, Spain, Sweden and Israel are also proposing candidates.

The Army intends to buy 95 vehicles for its military police, although the number could climb if the Air Force joins the project.



Dragoon shares components with existing Army vehicles such as M113 APC.



Zippy, 3-man Commando Scout boasts maximum range of 800 miles.

AV TECHNOLOGIES PHOTO; CADILLAC GAGE PHOTO

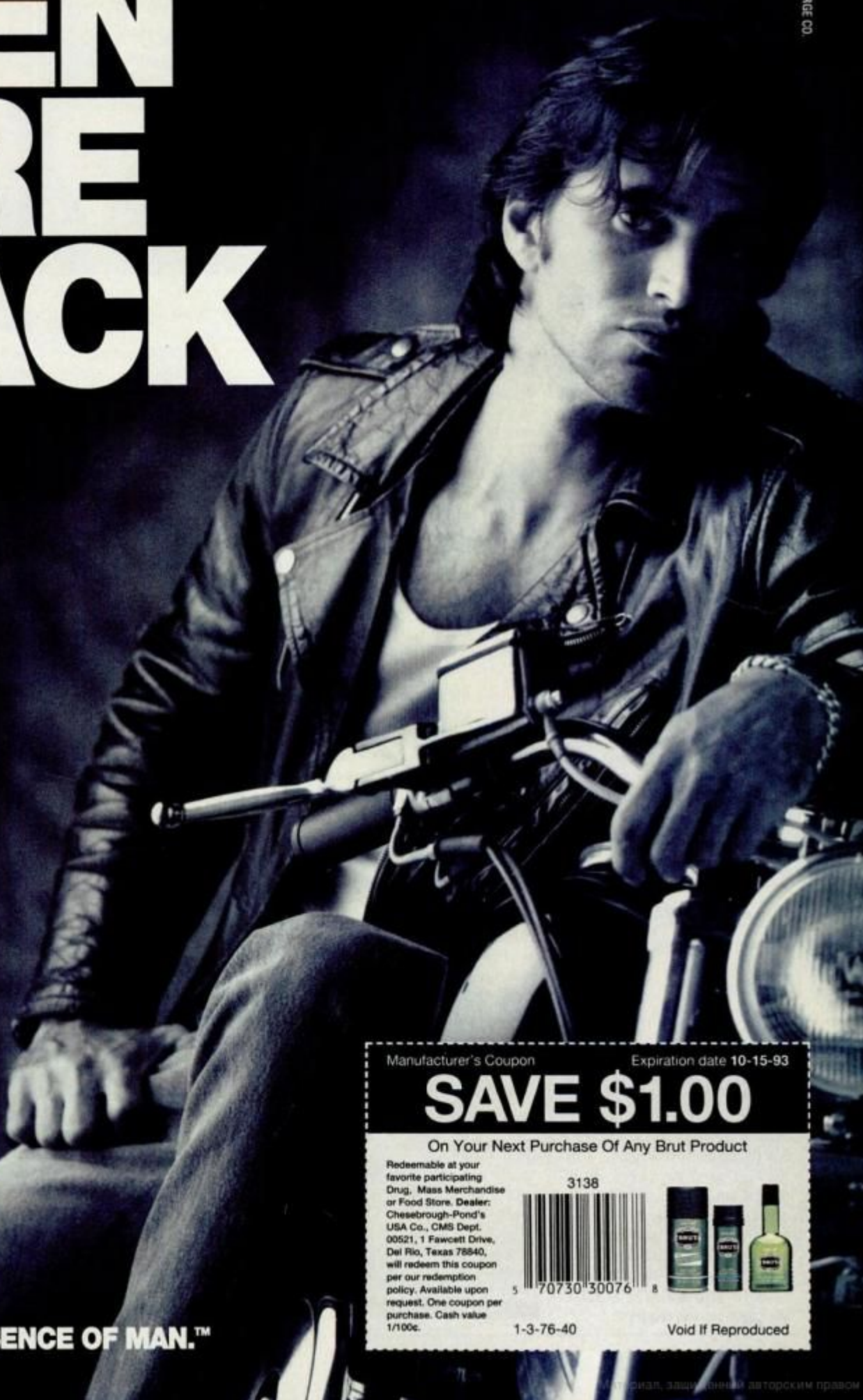
GENERAL DYNAMICS ILLUSTRATION

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A Diamond In Rough Waters

SAN JUAN, PR—The small-waterplane-area twin-hull (SWATH) revolution continues to cruise right along, with the debut last year of the *Radisson Diamond* (see Tech Update, page 14, Sept. '90). PM edi-

tors recently toured the Finnish-built vessel.

SWATH ships ride high on twin submerged hulls to keep passenger compartments out of choppy waves. Not only do the *Diamond's* two torpedo-like hulls con-

tain engines, but one even has a window for underwater sightseeing.

The deck that straddles the hulls stretches 103 ft. across, making the *Diamond* as beamy as the *Queen Elizabeth 2* with less than half the *QE2's* length.

Technological sophistica-

Diamond leaves twin wakes. Inmarsat-G radome (above) provides satellite links.

tion matches the decor. Security measures include bug sweeps to prevent corporate espionage during business conferences. Comsat provides extensive satellite communications services.



Ranger tests helmet-mounted thermal-sight display and built-in sound enhancement.

Seeing-Eye Army Hats

FORT BENNING, GA—Army Rangers have been trying out the superhelmet developed under the Soldier Integrated Protection Ensemble program (see Tech Update, page 18, Apr. '91).

The visor displays thermal images from a soldier's M16-mounted sight. The helmet also captures long-range sound, provides intersquad communications and even sends video images back to a squad leader.

Engineers must now shrink the helmet's still-heavy power source.

Time For A New Clock

BOULDER, CO—One second's loss every 300,000 years just isn't good enough for the National Institute of Standards and Technology. So NIST engineers have built a new atomic clock that is 10 times more accurate.

Like previous superclocks, NIST-7 uses cesium atoms to tick off the seconds. The atoms first must be excited. They then jump again



NIST-7 uses laser, rather than magnets, to stimulate cesium atoms.

microwaves, to lock them into a frequency that maximizes the number of atoms that are boosted. That frequency then drives the clock.

NIST-7 improves on the previous clock by using lasers to do the initial excitement, stimulating more atoms for a stronger, steadier signal.

into an even higher energy state. Microwaves trigger this second energy boost. A feedback loop fine-tunes the

Early Cataract Catcher

CLEVELAND, OH—Lasers can detect signs of cataract formation before the lens starts clouding over. At NASA's Lewis Research Center, a device built for Shuttle experiments has been refocused toward eye exams.

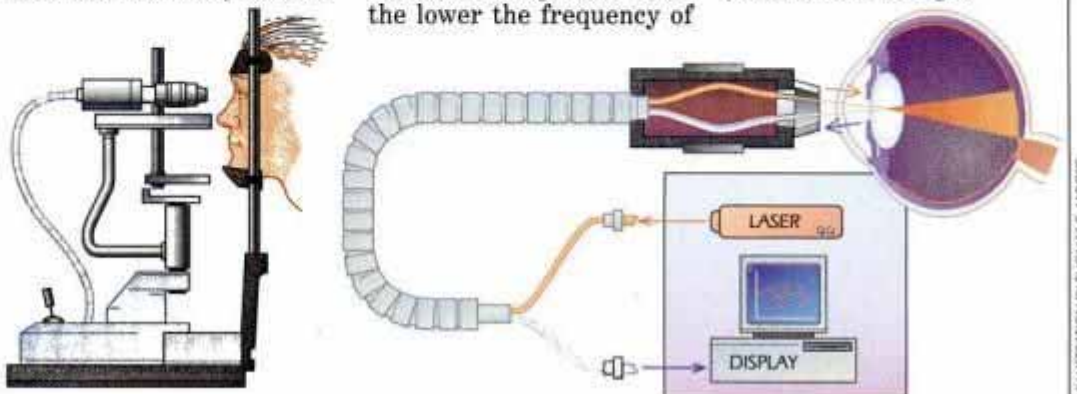
The laser shines a low-power beam through the eye's lens. The motions of microscopic protein particles dancing in the lens's fluid modulate the beam.

The bigger the particles, the slower they move—and the lower the frequency of

the modulation. A computer can analyze the beam after it reflects off the retina and chart the size of the particles.

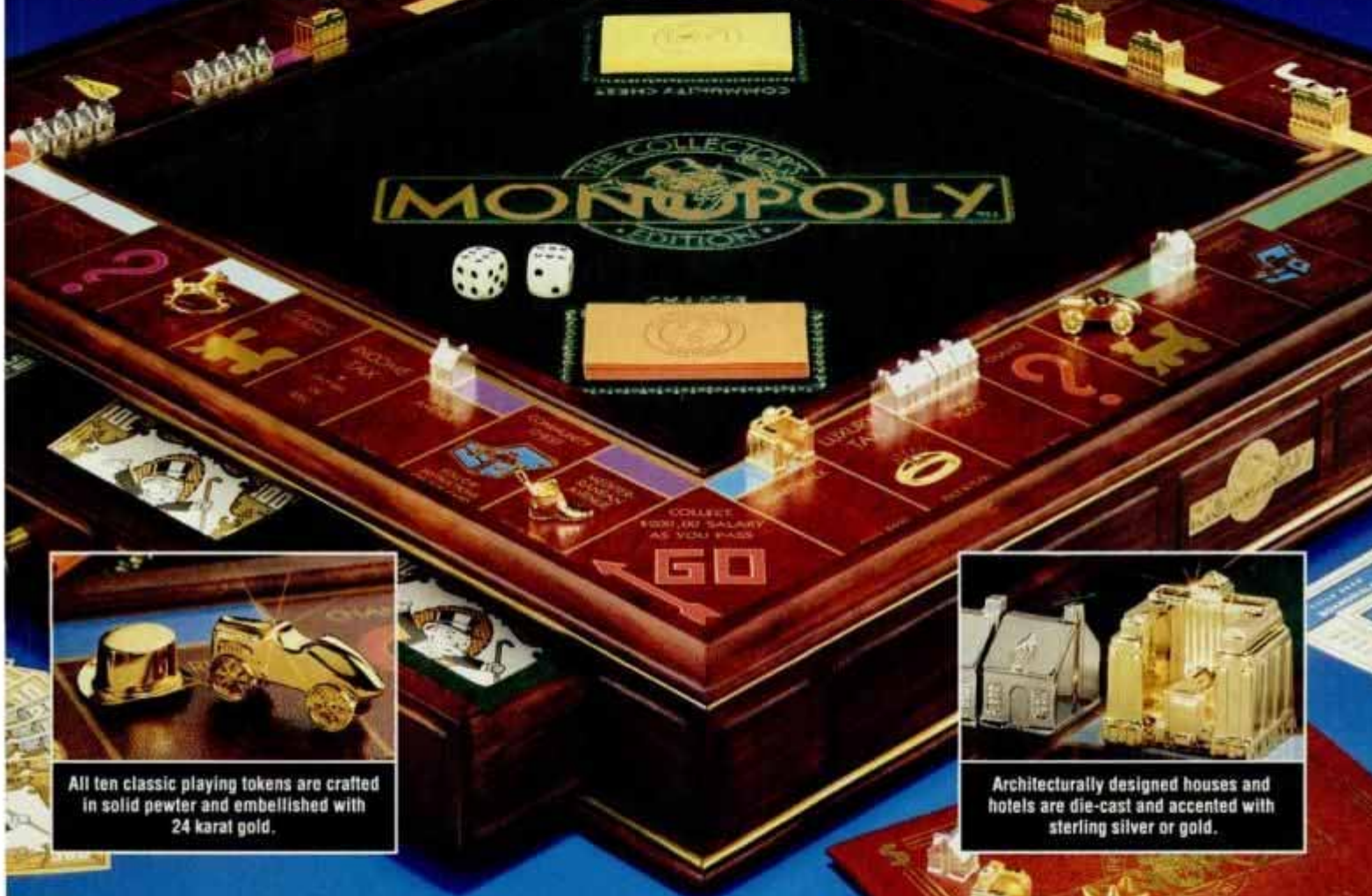
The device may speed development of drugs to short-circuit cataract formation.

Laser beam passes through eye's lens, where precataract particles modulate light.



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Swinging Dutch Doors

ROTTERDAM, NETHERLANDS—Holland has spent the past 40 years raising its dikes and flood barriers. But storm tidal surges can still penetrate through the huge shipping canal that runs from the North Sea to Rotterdam, the world's biggest port.

The solution? Two gigantic motorized floodgates that will swing into place if threatening waters rise. Unlike fixed solid barriers, they neither block shipping nor damage the environment.

Resembling twin Eiffel towers laid out flat, a pair of triangular steel trusses will pivot from ball-and-socket joints at the canal's banks. The trusses end in curved 689-ft.-wide hollow gates.

Once the gate tips touch,



valves will open to flood them. They'll sink, closing off the canal. Later, pumps will force air into the gates, which will float to the surface and retract into the banks.

The ball joints, made of steel plate coated with molybdenum, are the world's biggest, measuring more than 33 ft. across.

A consortium of Dutch en-

gineering firms is building the gates, which should be complete by 1997.

gineering firms is building the gates, which should be complete by 1997.



Sky Camera Maps Targets

HOUSTON, TX—Shuttle shutterbugs snap hundreds of photos through the Orbiter's Earth-looking windows. When they get home, however, they often have trouble locating what they photographed.

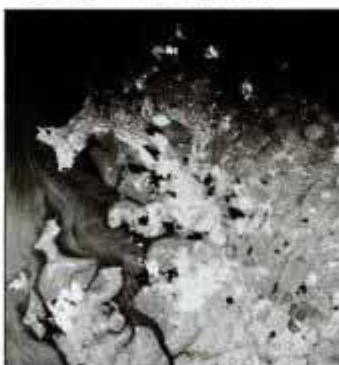
A camera tested on two recent missions should solve the problem. It goes by the name of Handheld Earth-Oriented Real-Time Cooperative User-Friendly Location-Targeting and Environmental System (HERCULES for short).

HERCULES consists of a Nikon F4, modified for electronic still photography, linked to an inertial-measure-

ment unit (IMU) and a computer.

Before a shot, the astronaut has to punch the Shuttle's location and orbit into the computer, then aim the camera at two stars to align the IMU. When the astronaut snaps the shutter, the IMU calculates the direction the camera is pointed and the computer whips through some trigonometry to determine the subject's latitude and longitude on Earth.

The Army and Navy jointly sponsored HERCULES' development.



HERCULES camera logs in latitude and longitude of subjects shot from space.

GE Airs Out New Megajet

PEEBLES, OH—The huge GE90 turbofan engine is scheduled to fly this fall under the reinforced left wing of a Boeing 747. Meanwhile, General Electric has been running the powerplant through a grueling series of ground-based tests.

The GE90, which will loft the coming super-twinjet Boeing 777, will be rated at 87,400 pounds of thrust, but GE plans to push future versions beyond 100,000 pounds. Last April, the engine set a gas-turbine thrust record of 105,400 pounds.

Because of the GE90's size—its 10-ft. fan stretches 2 ft. wider than the 767's CF6-80C2—GE had to sink more than \$70 million into new test facilities. These include a rail-mounted mobile wind tunnel designed for crosswind tests.

The 777 will also fly on 80,000-pound-thrust engines from Pratt & Whitney and Rolls-Royce. The first GE90-driven 777 will enter service with British Airways in 1995.



Giant golfball structure smooths out airflow during intake tests of GE90 turbofan.



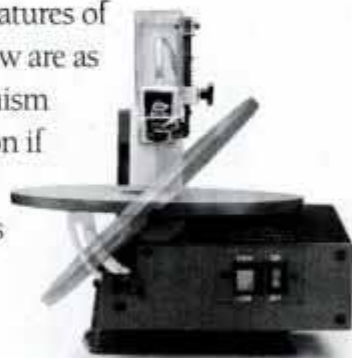
What it takes to cut it as a Consumers Digest Best Buy.

You don't get named a *Consumers Digest* Best Buy without working at it. You have to be an *outstanding* value. That's the Dremel 1671 Scroll Saw.

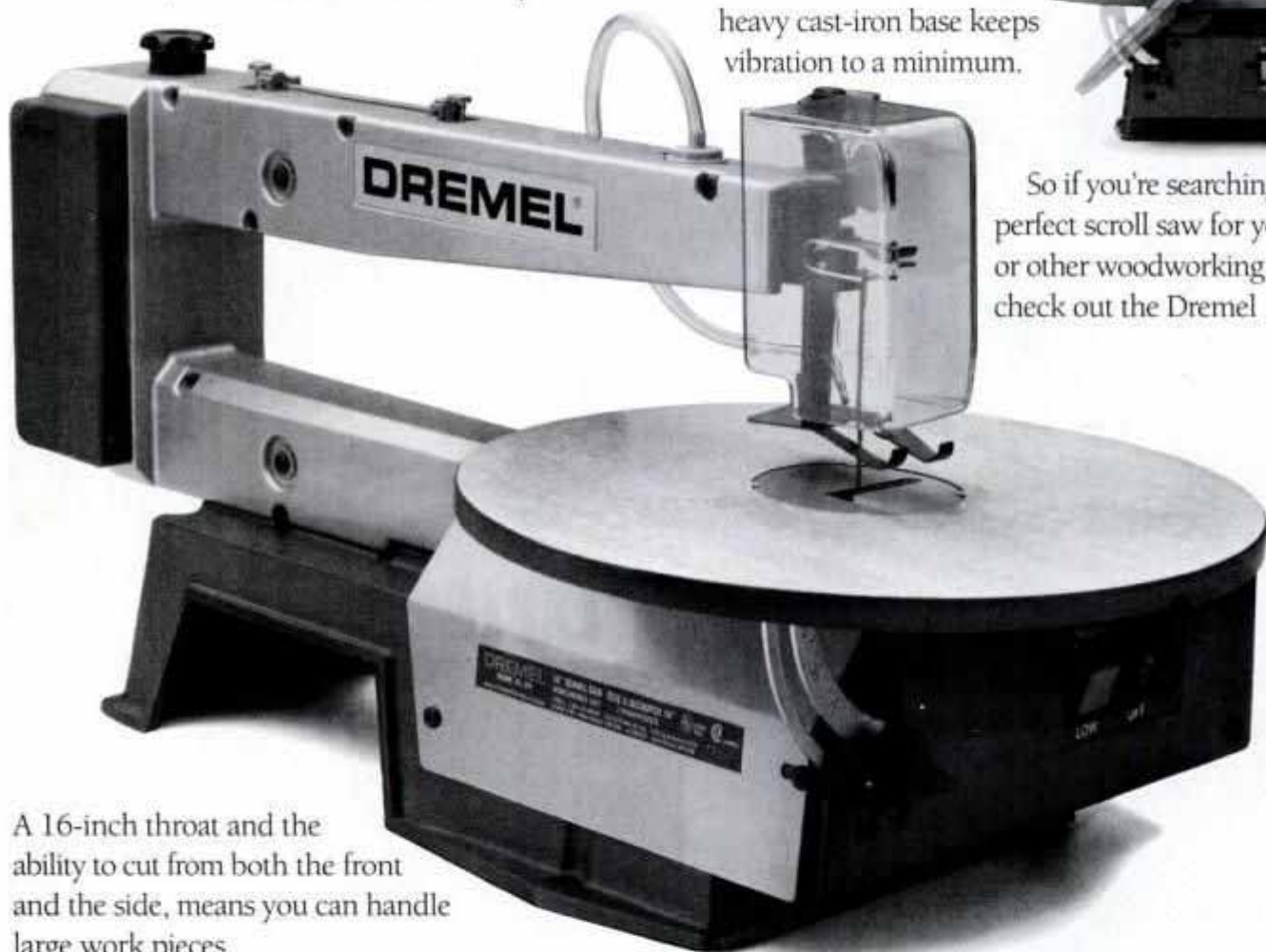
The Dremel 1671 has a lot of features that make it a pleasure to use. It has two cutting speeds and a powerful motor that lets you buzz through wood up to two inches thick, as well as sheet metals and plastics.

The sturdy, 12-inch cast aluminum table is adjustable from 0° to 45° for accurate bevel cuts up to 1-inch thick.

Of course, not all the features of the Dremel 1671 Scroll Saw are as obvious. A special mechanism quickly stops cutting action if the blade breaks. And the heavy cast-iron base keeps vibration to a minimum.

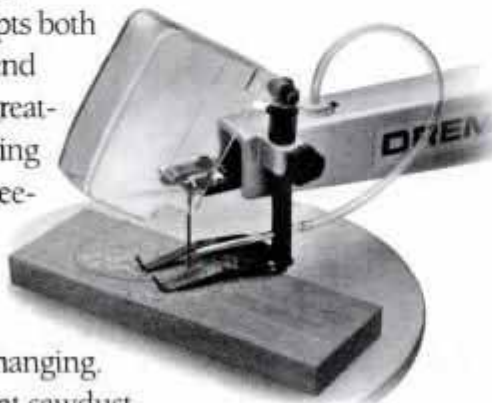


So if you're searching for the perfect scroll saw for your craft or other woodworking projects, check out the Dremel 1671.



A 16-inch throat and the ability to cut from both the front and the side, means you can handle large work pieces.

The saw accepts both plain- and pin-end blades, for the greatest possible cutting versatility. The see-through blade guard pivots out of the way for easy blade changing. And a convenient sawdust blower keeps your cutting line clear for accurate cuts.



And see why *Consumers Digest* placed it a cut above the rest.

For a free copy of the *Dremel Scroll Saw Blade Application Guide* write to: Dremel, Dept. S-PM, P.O. Box 1468, Racine, WI 53406-1468.

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SERIES



EXPERIENCE

Come Sunday afternoon, you'd think our engineers would be practicing their drives out on the golf course. The fact is, a lot of them have chosen a different type of driving. They're deep in the pits of a Ford race team, learning what it takes to make a car excel under pressure. So come Monday morning, we can turn that firsthand knowledge into the best Ford cars and trucks for the street. That's why we race.



HAVE YOU DRIVEN
A FORD LATELY?

Why We Race

ROCK SHOCKS

Dual-suspension systems tame the beast in cutting-edge mountain bikes.

BY CHARLES PLUEDDEMAN

- Your high-torque, low-rpm motor is at full throttle as you bank into the blind hairpin turn. Suddenly, the smooth dirt track turns into a rock-infested washboard, and you're going too fast. You jig to the left and the right. You pulse the brakes. But there are too many obstacles. Bam! Your front wheel hammers a rock, but the oil-damped shock telescopes and absorbs the punishment. Bam! The rear wheel hits, but the cantilevered rear swing arm and monoshock suck up the impact. Amazingly, you're through the turn and still in control. Then you shift your high-torque, low-rpm motor—your legs—into high gear and tackle the next hill.

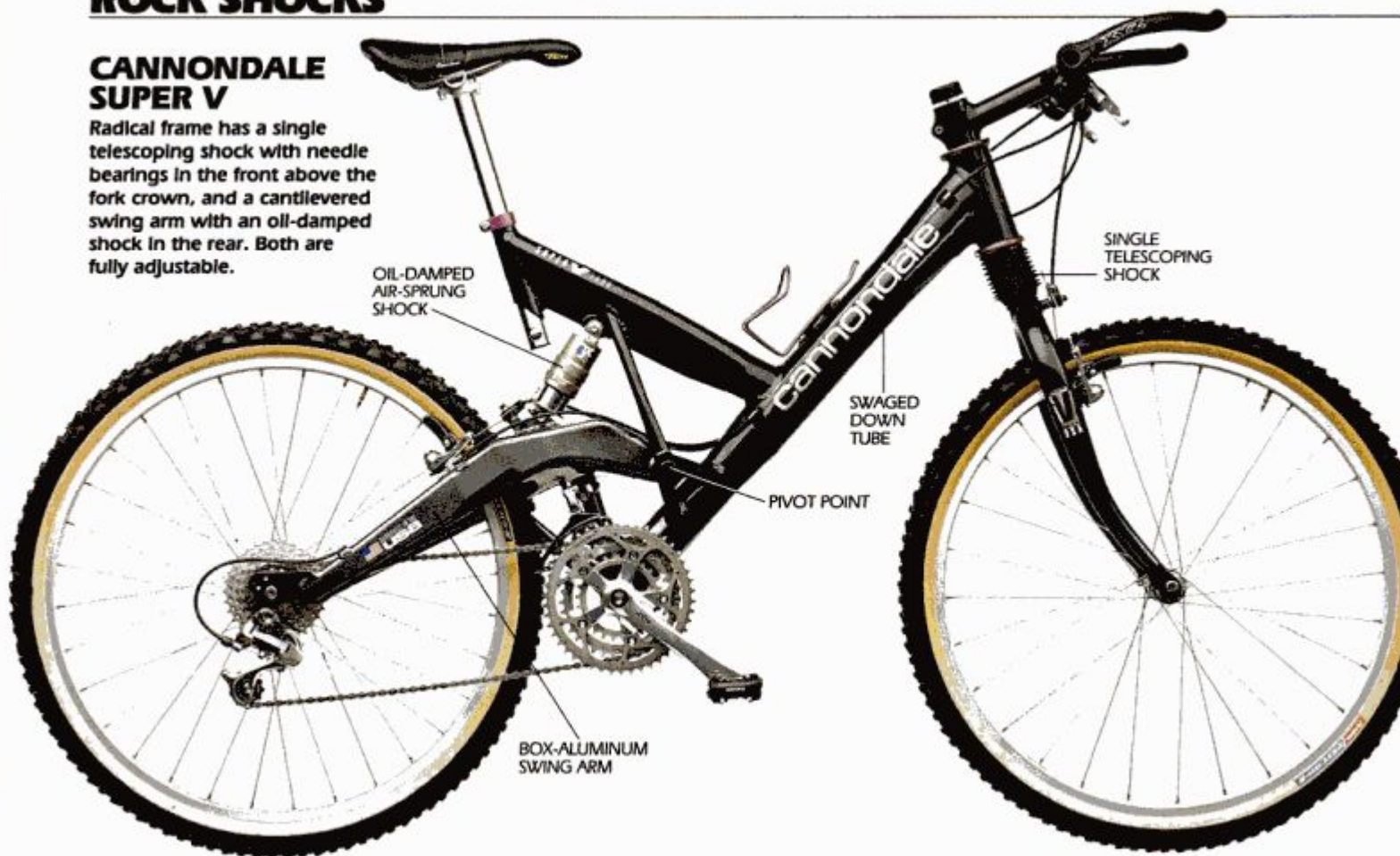
Welcome to the new world of dual-suspension mountain bikes, which combine the light weight of a modern bicycle with the sus-

A Team Specialized (S-Works) mountain bike rides hard and in control even over washboard, thanks to a motorcycle-inspired suspension system.

ROCK SHOCKS

CANNONDALE SUPER V

Radical frame has a single telescoping shock with needle bearings in the front above the fork crown, and a cantilevered swing arm with an oil-damped shock in the rear. Both are fully adjustable.



pension of an off-road motorcycle.

Attempts at bicycle suspension have been around for years—a grade-school buddy of mine had a Schwinn with a crude springer fork—but the modern era started in 1989 with a suspension fork for mountain bikes called Rock Shox.

Soon after, manufacturers began designing framesets with suspension systems for the rear wheels. The goal was to keep the wheels on the ground to provide comfort and constant traction when braking, steering and

climbing. Today, state-of-the-art full-suspension bikes offer a variety of innovative designs.

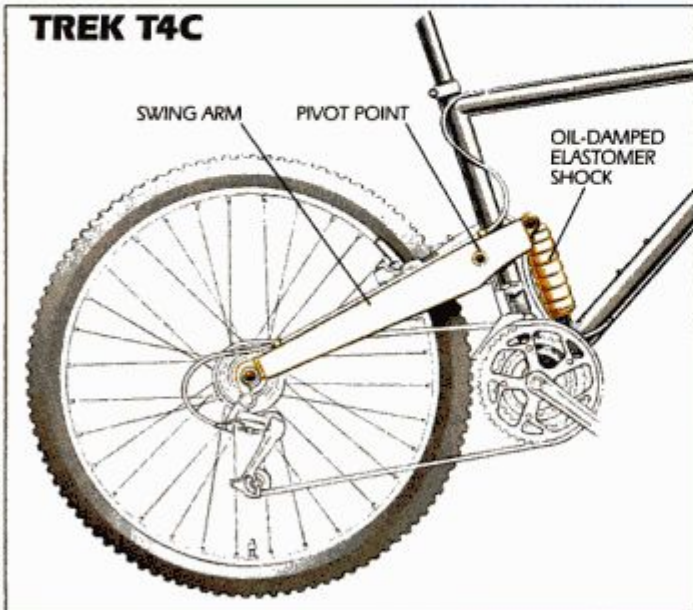
The most common front-suspension design system remains the motorcycle-style telescoping fork pioneered by Rock Shox, where a pair of steel stanchions slide within each fork blade. Suspension and damping are provided by either air pressure and oil damping (like a motorcycle), or by a block of urethane elastomer.

The air/oil forks provide a wide array of adjustments for expert

riders. External knobs or screws change the shock valving to adjust the compression and rebound rates. Adding or releasing air pressure adjusts spring preload. Some common air/oil forks are: Rock Shox Mag 21 (\$389), Specialized Future Shock FSX (\$500) and Trek Mogul Black Diamond (\$450).

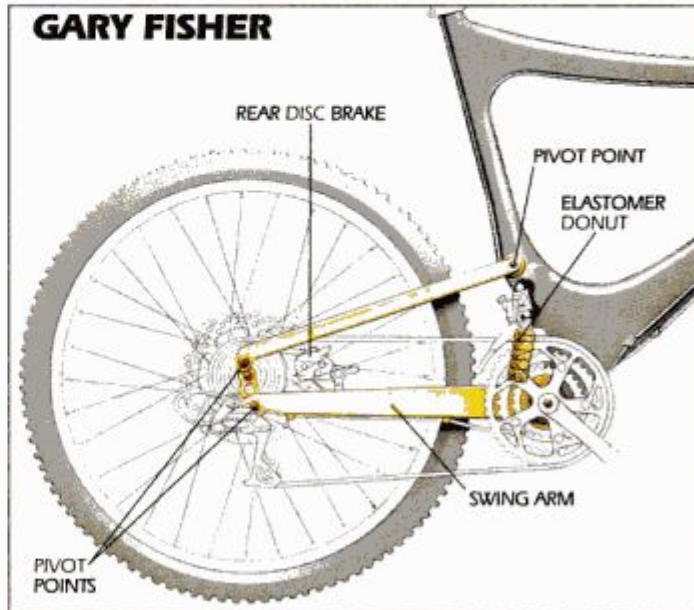
Elastomer-sprung forks cost less and are less adjustable. Shock in these models is absorbed as the stanchions descend and compress a block of elastomer. Common models

TREK T4C



Trek's box-section swing arm, with a single pivot point above the crank spindle, comes in either aluminum or carbon fiber.

GARY FISHER



Dirt-track motorcycle legend Mert Lawwell designed this suspension with multiple pivot points and an aluminum disc brake.

by Rock Shox Quadra, RST, Tange and Trek cost between \$200 and \$260.

The down side of fork-type suspension is added weight and the tendency of the stanchion bushings to bind in the fork tube and fail to react to small bumps. Cannondale sought a solution to this problem in its Delta V system, which places an air spring and oil damper within a sliding steering tube above the fork crown. The tube moves smoothly over sets of needle bearings.

Suspending the rear wheel presents a more complex challenge than the front because it must be designed as an integral part of the frameset. Bike designers had to devise a flexible subframe to cushion trail shock without absorbing rider energy or adding much weight.

The Trek T4C system is perhaps the simplest design. It features a box-section swing arm that pivots at the seat tube above the crank spindle. The inboard end of the swing arm acts against an elastomer spring that's wrapped around an oil-damped shock located low in the frame. Both spring preload and shock damping are adjustable. Mated with the Trek Mogul Black Diamond front suspension, the T4C is offered in aluminum on the Trek 9200 (\$1800) and in carbon fiber on the Trek 9500 (\$3000).

Gary Fisher Bicycles turned to dirt-track motorcycle-legend Mert Lawwell to create a trapezoidal design with four pivot points. The lower aluminum swing arm pivots at the bottom bracket, while the upper arm pivots on the seat tube. A pair of elastomer blocks, mounted above and behind the bottom bracket, act as springs. The power of the chain passing over the trapezoid link creates lift in the bottom bracket and forces the

FRONT SUSPENSIONS



The modern era of suspended bikes was born with telescoping forks (right). New is Cannondale's single shock above the crown.

rear wheel down into the ground for excellent traction when climbing. A special Campagnolo rear hub incorporates a stout 14mm axle to stiffen the rear end and a threaded collar to accept a Pro-Stop aluminum disc rear brake. Combined with a Rock Shox fork, the Lawwell rear suspension is offered on the aluminum-frame Fisher RS-1 Pro (\$3500) and the carbon-fiber-frame Fisher Alembic (\$4500).

Specialized sought to eliminate the influence of chain tension with its FSR rear-suspension design, which has parallel upper and lower links. The lower link pivots at the bottom bracket, while the upper link pivots at the seat post. These links are connected by a stay that creates a parallelogram. An adjustable coil spring

and oil shock is located between the upper link and the seat post. As the suspension moves up and down, the twin links maintain a constant distance between the rear wheel and crank, so wheel movement isn't affected by chain tension. The Specialized S-Works FSR model (\$2599) features FSR rear and Future Shock FSX front suspensions.

The Cannondale Delta V 1000 (\$1847) and Delta V 2000 (\$2199) employ a triangulated swing arm with a pivot midway up the seat tube and an adjustable coil spring/oil-damped shock near the top of the seat tube. Like the Trek T4C, the Delta V's high pivot point forces the swing arm down under heavy chain tension until the shock tops out and pedal energy is directed to the ground.

On the leading edge of suspension design is the Cannondale Super V (\$3519). This radical aluminum bike concentrates material where strength is essential and shaves it away from noncritical areas. The front wheel is suspended by an adjustable Delta V system located in the steering tube. In the rear, a box-section welded-aluminum swing arm is mated to the frame at a massive 4-in.-wide pivot point forward of the crank. An oil-damped air spring located between the swing arm and seat post provides fully adjustable suspension.

It's clear by the high prices that fully suspended mountain bikes are intended for serious riders, but expect to see costs tumble as designs and materials are perfected. Factory-installed front suspension is now available in bikes starting as low as \$700. As more riders venture off the road, full suspension will help keep them in control no matter how rough the trail.

PM



Specialized's fully adjustable suspension also has multiple pivot points with upper and lower links to a trapezoidal design.



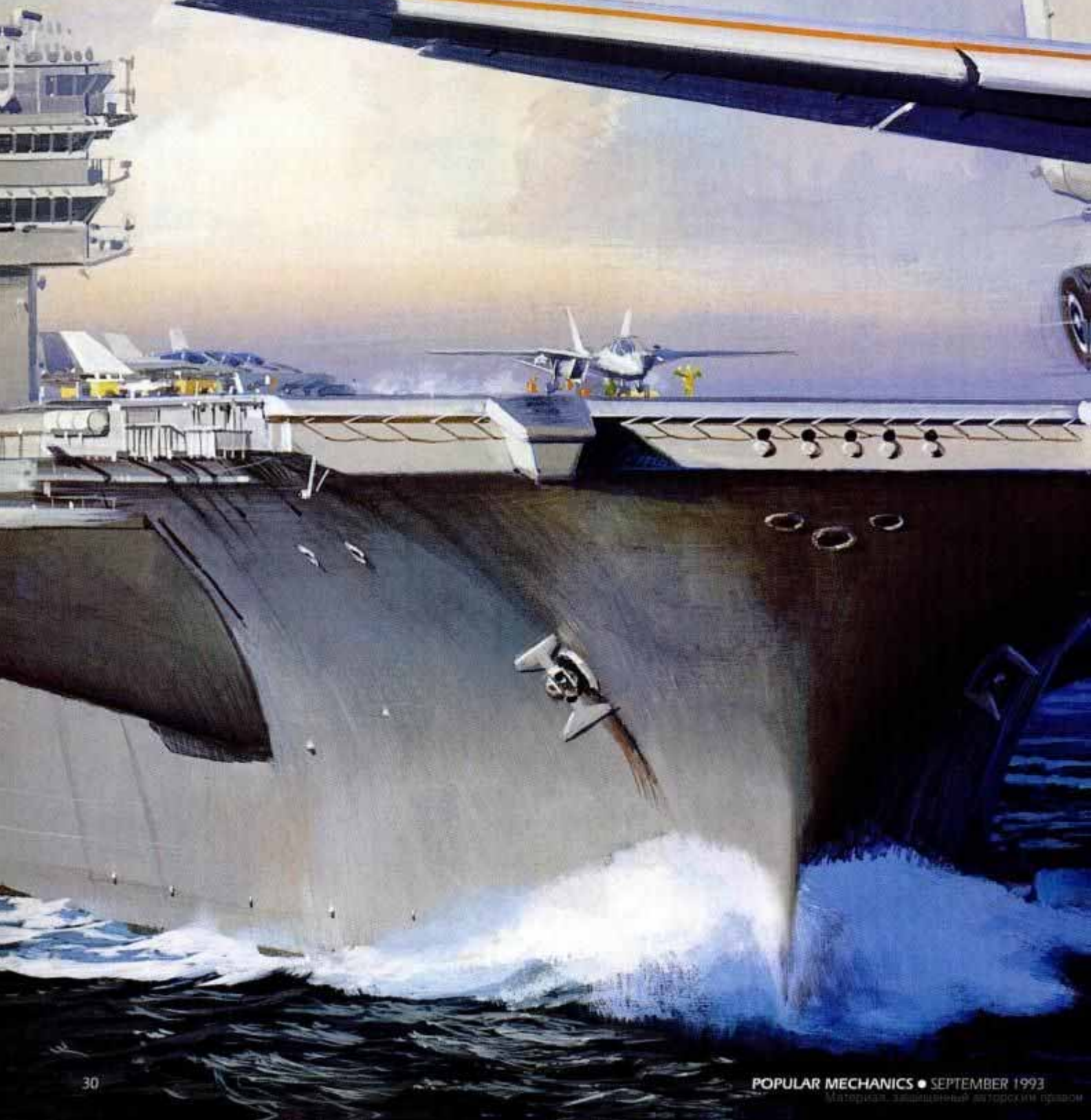
The Delta V's triangulated swing arm has a single pivot point on the seat tube above the crank spindle.

COVER STORY

DIAMOND EYES

Boeing proposes a radical new shape for the Navy's next-generation radar plane.

BY ABE DANE, Science/Technology Editor
PM Illustration by Attila Hejja





• The total destructive power wielded by the aircraft, frigates, destroyers, cruisers and submarines of a single U.S. carrier battle group outstrips the arsenals of all but a handful of nations on Earth. Yet the safety of these great armadas hangs by a thread. Without the ability to see the enemy coming well beyond the horizon, the battle group goes from an irresistible force to an irresistibly fat and juicy target.

Responsibility for early warning of incoming aircraft and missiles now rests squarely on the shoulders of one plane—the Grumman E-2C Hawkeye. Recognizable by the 24-ft. Frisbee-shaped rotodome that encloses its radar antenna, this 50,000-pound twin turbo-prop workhorse has been watching over the fleet for 20 years.

In that time, the world has grown ever more deadly. Threats are faster, smaller and pack a bigger punch. Struggling to keep up, the old E-2C airframe has had to accommodate increasingly sophisticated electronics, backfitted and grafted on wherever there was space. An estimated 36 miles of wire is now packed into its 57-ft. fuselage.

The latest variant, the E-2C Group 2 can spot large enemy aircraft more than 300 miles away and track more than 2000 targets at once. But tactical ballistic missiles like Scuds are still too fast for its slow-turning rotodome to track, and the radar signatures of low-flying cruise missiles are growing smaller and more difficult to distinguish from background clutter. At this year's Paris Air Show, the French declared their intention to break America's monopoly on stealth aircraft. Others can't be far behind. Inevitably, the day will come when all of this is just too much for the old Hawkeye.

What then? Will the carrier battle group go the way of the dreadnought? It's just possible that it may not.

Stealth/counterstealth

Just as one confluence of technologies has advanced the art of evading radar, another now appears to be on the verge of transforming radar into a sensor that will be far more difficult to evade. The question then becomes: Can these advances be put into a plane with the performance to get where it's needed when it's needed and the toughness to stand up to life on a carrier deck?

DIAMOND EYES



Of the handful of defense contractors seeking to answer this question, Boeing Defense and Space Group's Military Airplanes Division has moved most aggressively. Although the Navy has so far provided little direct funding and only lukewarm encouragement, Boeing has gone ahead and put millions of its own dollars into a concept called the EX, for Electronics Experimental. The company believes its design constitutes such a leap beyond today's airborne early-warning planes—and that the need for its capabilities will eventually be so urgent—that even in an austere fiscal climate the Navy won't be able to turn it down.

Airplane as antenna

Boeing's confidence springs from its discovery of the near-perfect match-up between a curious, NASA-tested experimental wing and the ideal shape for an advanced-technology radar antenna. The joined wing, as it's called, has a pair of primary lifting surfaces that sweep aft from the nose to meet another, slightly smaller, pair sweeping forward from the tail. Mounting radar arrays on the resulting diamond-shape planform turns the whole airplane into a giant radar antenna. And that, according to Boeing EX program manager Larry Gilbert, is exactly what's needed to spot the small, stealthy threats of tomorrow.

From the outset, the design has charmed engineers with its ability to satisfy apparently conflicting demands. "There was continuous discussion between the electronics guys and the aerodynamics guys," says Gilbert. "We found more and more ways that the antenna was complementary with four wings."

In the rough

Joined wings had intrigued NASA and university researchers for nearly 20 years on the strength of aerodynamics alone. After considerable wind-tunnel testing, however, the flying properties turned out to be only marginally better than those of conventional swept wings. No aircraft builder wanted to gamble on the untried diamond shape with so small a payoff, so it never got out of the lab.

Meanwhile, the makings of a revolution in radar technology were gradually coming together. Electronically steered phased arrays had already made the whirling antennas of mechanically steered radars obsolete in many applications. But phased arrays still had limited flexibility, and they were far too bulky for use in airborne surveillance.

The phased array's problem is that, although its antenna contains thousands of individual elements, the radio frequency pulses with which they scan the skies all originate from a single transmitter (often a huge vacuum tube) and return to a single receiver. A convoluted and power-wasting plumbing system is required to route the signals back and forth. Also, a failure in either the transmitter or the receiver, both of which are complex and ponderous pieces of equipment, can bring the whole system down at once.

But in recent years, DOD-sponsored semiconductor research has brought into being a new class of microelectronic devices called monolithic microwave integrated circuits (MMICs). Onto the surface of one of these small chips of gallium arsenide can be etched a complete radar transmitter, along with the high-power part of the receiver. This makes pos-

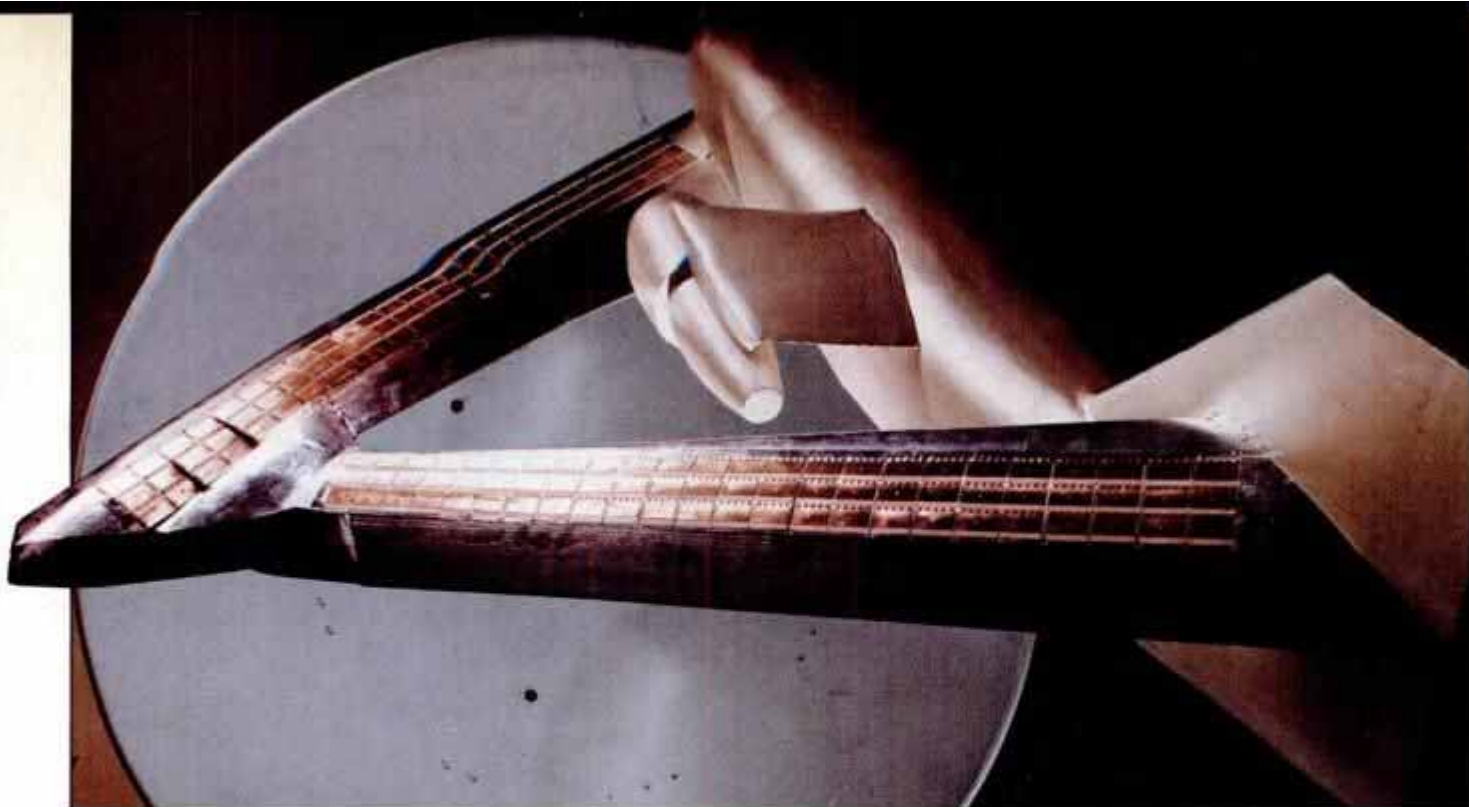
sible an entirely new approach to radar design called an active aperture array (see *Tech Update*, page 15, Jan. '90). By giving each antenna element its own tiny but powerful transmit/receive module, these radars not only do away with the danger from single-point transmitter or receiver failures, but are also far more versatile than their phased-array predecessors.

In a conventional phased array, control over the individual antenna elements is limited to phase shifting. This shapes the output of all the elements into a single beam of radio waves and steers that beam around the sky. But with separate transmit/receive modules, each antenna element's frequency, amplitude and waveform can be controlled independently as well.

Schizophrenic radar

The active aperture antenna thus becomes a radio-frequency tool of almost endless flexibility. Its radar modes can be tightly interleaved, so that it has the characteristics of different types of equipment almost simultaneously. During one fraction of a second, the antenna might work like a pulsed-doppler radar to hunt down low-flying missiles. It could then switch into other modes, such as "synthetic aperture" for terrain mapping, or interrogating aircraft IFF transponders to determine whether they're hostile or friendly. The array can also do signals intelligence, listening in on enemy transmissions, and then switch over to jamming their communications and radar equipment with blasts of precisely modulated noise. Communications, missile guidance, battle management and datalink functions are possible as well.

But for the EX, the crucial advan-



tage of an active aperture radar is that it lends itself to installation in what's known as a conformal array. Lacking the phased array's tangle of plumbing and the massive, centralized transmitter, it can be integrated neatly into the aircraft's structure. No drag-inducing rotodomes or other protuberances are required.

Still, the antenna must be installed in a part of the plane that provides an unobstructed, 360° view of the sky. That's where the joined wing, which wraps almost completely around the aircraft, comes in, and why this laboratory curiosity may find practical use at last.



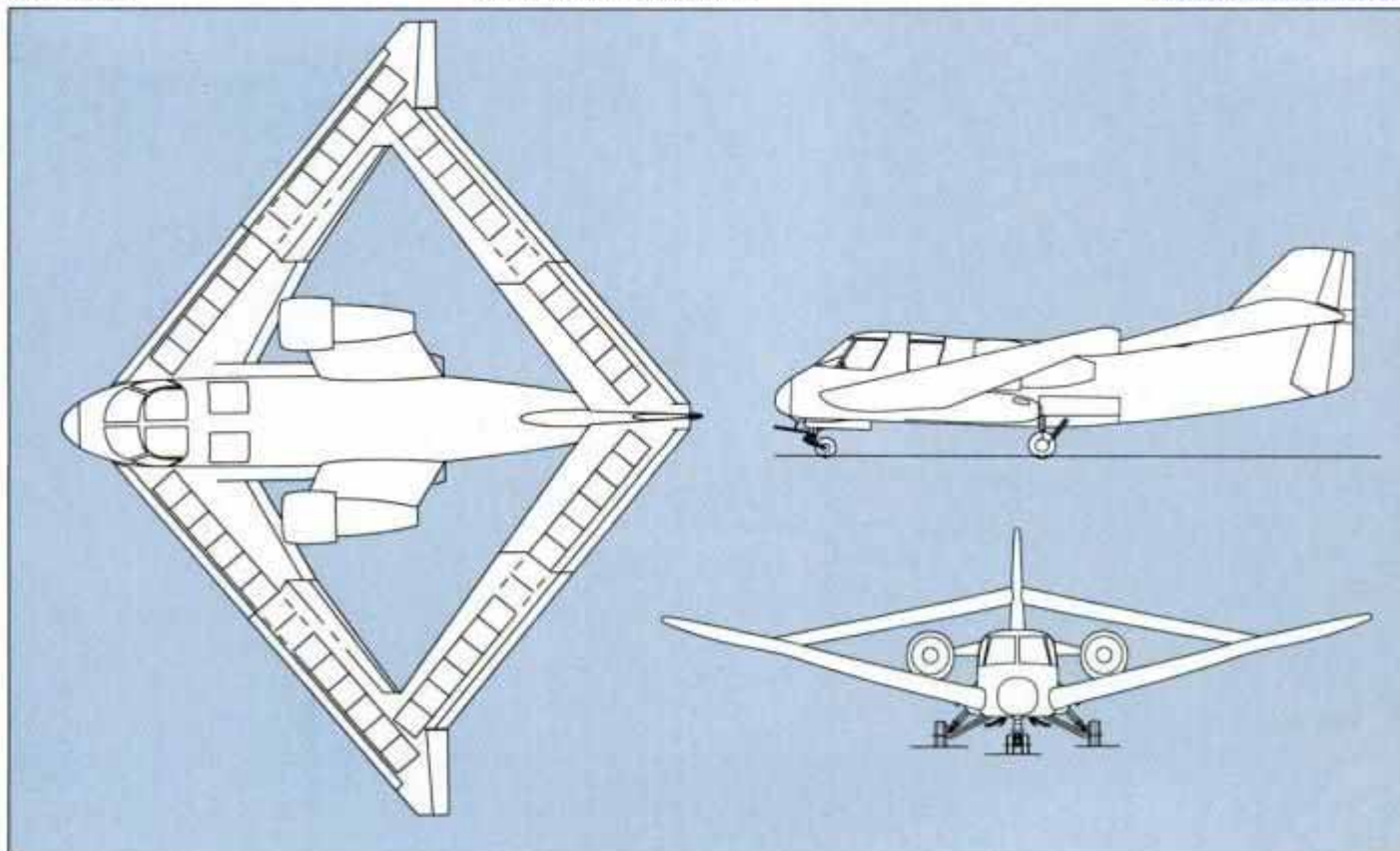
Boeing tested a 1/5-scale model of the EX's conformal radar (above). Three-view (below) shows how the joined wing provides unobstructed radar vision.

Ace of diamonds

Boeing began preliminary design on the EX in 1988, and initial wind-tunnel tests were performed in 1991. At press time, another round was scheduled for NASA Langley's high-speed tunnel in July of this year. The basic external shape of the plane is now established, and detailed structural engineering is underway.

Previous attempts to build conformal-array wings have been unsuccessful, but Boeing has tested a unique approach in 1/5-scale models, and is confident that it can be scaled up. Each wing will derive its strength

(Please turn to page 105)





Nonfiring guns are the safe alternative for collectors. (clockwise from upper left): U.S. M1873 Cavalry pistol from 1873 in a quick-draw holster, breech-loading rifle used by buffalo hunters in the 1870s, Russian AK-47 assault rifle, U.S. M1911 .45 automatic and Sharps breech-loading pistol from 1852.

CEASE FIRING

Nonfiring replica guns are a safe and easy way to appreciate the fine art of collecting firearms.

• Memorabilia buffs are sticklers for authenticity. This is especially true of gun collectors. To enthusiasts of the Wild West, the pioneer era, the military, the Civil War and even the Roaring '20s,

BY ALEX ZIDOCK

the act of field stripping an M-16 assault rifle or quick drawing a 6-shot single-action revolver is the next best thing to putting a piece of history in one's hands.

But the truth is

that of all the tens of thousands of gun collectors in the country, there are only a relative handful who collect authentic firearms. The vast majority actually are not collectors in the strict sense, but are best described as gun fanciers. These individuals typically own a couple of hunting rifles, a handgun, a family hand-me-down or two and probably



Great guns that look and feel like classic and current weapons (from top to bottom): Israeli Uzi submachine gun, U.S. M-16 assault rifle and a Thompson M1921 submachine gun, also known to gangsters of the Roaring '20s as the "Chicago Typewriter."

CEASE FIRING

an old military piece that harkens back to time spent in the service.

When these individuals purchase a firearm of historic value for the office or den, they are most likely joining the fastest-growing segment of the collecting fraternity and entering the world of the nonfiring replica gun collector.

Not to be confused with toy guns, nonfiring replicas are fabricated mainly of a zinc-oxide alloy with polished hardwood grips or stocks. Except to highly trained eyes, these fakes can fool most people. They have working actions, a familiar weight and balance and a full complement of moving parts. They are, in fact, authentic in every way except one—they cannot be fired. All the parts have been altered by roughly a millimeter so they cannot chamber or fire live ammunition.

It was during a trip to Japan 25 years ago that Thomas B. Nelson discovered replica guns. Craftsmen there were producing high-quality replica firearms to satisfy collectors

hampered by the terms of occupation following the second World War. Even today, stringent laws in Japan forbid personal ownership of authentic handguns.

At the time of Nelson's trip in 1967, lawmakers in the United States were pushing for stricter gun-control laws, and Nelson, a noted authority on small arms, determined that new laws would restrict the availability and transfer of real firearms. Returning home, Nelson decided that the time was right to start an import business for replica guns. In relatively short order, he became one of the leading distributors of nonfiring guns in the world. Today, Nelson not only sells guns from his own catalog, the *Collector's Armoury*, in Alexandria, Virginia, but also supplies most of the other catalog and mail-order companies. Many of these replicas not only come from Japan, but from Italy and Spain as well.

Although replica guns are perfect in every detail, they aren't deactivated originals nor are they made with

original parts. As noted, the dimensions have been altered by a millimeter or two, and this means that actual gun parts cannot be interchanged with a replica to make it capable of firing live ammunition. As a further precaution, a high-carbon steel rod is integrally formed along the axis of the bore, blocking the entire length of the barrel. According to Nelson, each replica his company handles passes inspection by the Bureau of Alcohol, Tobacco and Firearms, and each receives a certificate stating that it isn't a firearm.

Among the many advantages of replica gun collecting is the ability to own lookalike weapons that otherwise are illegal to possess or require cutting through extensive red tape. One such popular piece is the Thompson M1921 machine gun. The replica version of the "Chicago Typewriter," as it was called by gangsters in the Roaring '20s, contains 59 parts, including a vertical fore-grip and detachable butt-stock and a 20-round box magazine. It measures 35 in. long and weighs 9½ pounds, just like its real counterpart. Also, it can be completely disassembled.

Another advantage of replica firearms is price. The lookalike Thompson M1921 submachine gun sells for less than \$300. A real Thompson machine gun would cost as much as \$3000, plus a \$200 payment of a Federal Transfer Tax.

Military buffs might be more interested in the M1911 .45 automatic pistol, a standard government Army-issue sidearm that dates back to 1911. This familiar piece has seen action in WWI, WWII, Korea and Vietnam. Replicas are available for roughly \$100.

Police buffs might be more interested in the .44 Magnum revolver made famous by Clint Eastwood in the "Dirty Harry" movies. This model features a 6-shot swing-out cylinder in both single and double action. Cost is about \$90.

Like all products in the marketplace, replica guns are subject to the whims of the public. During the 1960s and early 1970s, Western quick-draw revolvers were tremendously popular. During the mid-'70s, the pistol used by agent 007, James Bond, a German Walther PPK, was a big-selling replica model. Modern military and assault weapons, like the Russian AK-47 assault rifle and Israeli Uzi submachine gun, were popular in the 1980s, and now Civil War firearms are hot.

While most of the firearms mentioned above are perennial favorites, replicas are also made for fanciers who wish to extend their collections

Replicas And The Law

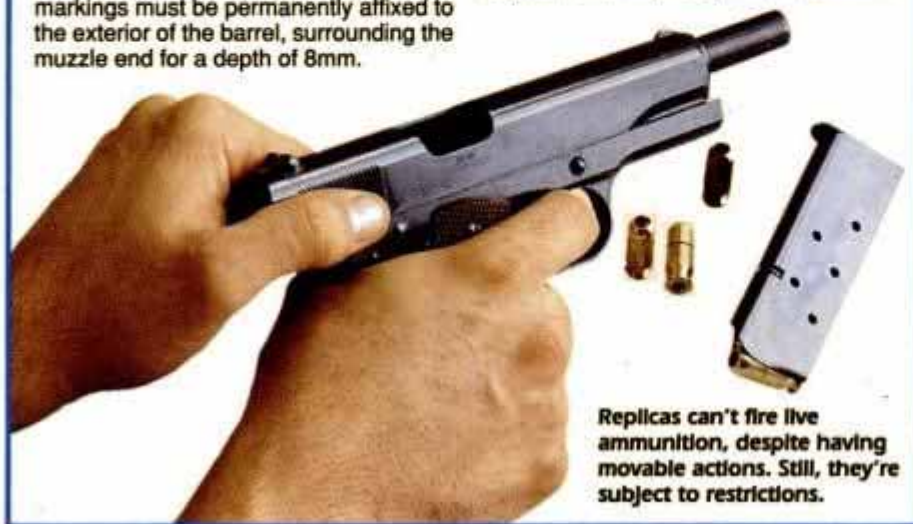
● Interestingly, recent gun-control legislation has had little effect on the sale, purchase or distribution of nonfiring replica firearms. However, under the terms of the Federal Energy Management Improvement Act of 1988, replica gun fanciers were not so lucky.

Under Part 1150 of Section 4, which has become known as the Look-Alike Law of 1988, it states that anything that looks like a gun manufactured after May 5, 1989 must conform to certain regulations. For some models this means, "A blaze orange solid plug will be permanently affixed to the muzzle end of the barrel as an integral part of the entire device and recessed no more than 6mm from the muzzle end of the barrel."

For toy cap pistols, noisemakers, water guns, light-emitting guns, air-gun ejectile toys and lookalike firearms that discharge such things as water, light and nonmetallic projectiles, blaze orange markings must be permanently affixed to the exterior of the barrel, surrounding the muzzle end for a depth of 8mm.

Antique firearms, fortunately, are unaffected by this law. However, they are covered by the Federal Gun Control Act of 1968, which states that "any toy, look-alike or firearm that is a nonfiring replica of an antique firearm modeled on a real firearm designed, manufactured and produced prior to 1898 is considered an antique." By the terms of this law an original pre-1898 revolver that fires cartridge ammunition is considered to be an antique. A reproduction of that same revolver, if it fires a modern cartridge, falls under the jurisdiction of the Look-Alike Law. One exception is a blank-firing gun used as a stage prop.

A much bigger exception, however, pertains to firearms that use black powder. These are considered antiques and are exempt from the Look-Alike Law, even if they are replicas. As a result, black-powder firearms are the hottest segment of the replica gun market. —A.Z.



Replicas can't fire live ammunition, despite having movable actions. Still, they're subject to restrictions.



Nonfiring guns are appreciated for beauty and historical significance (clockwise from upper left): Remington 141A Gamemaster slide-action repeater, Savage 1899A lever-action repeater, Win-

chester 1886 lever-action repeater, Civil War-era percussion-cap Kentucky rifle, Rogers & Spencer .44 percussion revolver and Colt Civil War Army .44 percussion revolver.

farther afield. These include antiques ranging from the Colonial blunderbuss to ornately decorated flintlock pistols and derringers. George Washington's favorite 18th-century flintlock pistol has also been replicated and so has an interesting curio, the ivory-grip Ladies' Muff Pistol, circa 1775. The list includes Russian, Spanish, English, Scottish and French flintlock pistols and derringers, plus Western derringers and Civil War rifles and pistols.

Some of these firearms are intended to be hung over the mantelpiece or on the wall and are considered decorator pieces. In fact, replica guns, according to Nelson, are divided into four classes: 1. Decorator models that have a minimum of working parts and cannot be disassembled, 2. High-quality weapons that have many working parts and can be disassembled, 3. Blank-firing reproductions that can be used as starter's or stage pistols, and 4. Pre-

mier-quality replicas such as those offered by The Franklin Mint, of Philadelphia, Pennsylvania.

Of the four classes, The Franklin Mint series is the top of the line in replica guns. It includes sidearms used by President Theodore Roosevelt, Buffalo Bill Cody, Wild Bill Hickok and Wyatt Earp (a Smith & Wesson .44), and Jesse James' Remington revolver.

In addition to The Franklin Mint, another source of replica firearms is *The Regimental Quartermaster*, of Hatboro, Pennsylvania, one of the largest suppliers of Civil War rifles and handguns. The difference with these firearms is that they use black powder and can be fired.

As mentioned, one of the primary benefits of collecting replica guns is affordability. An original Winchester M1873, for example, is valued at \$2795 in excellent condition by Stoeger's *Gun Trader's Guide*. A nonfiring replica can be purchased

from *Collector's Armoury* for \$149.

But just because replicas are affordable doesn't mean they aren't valuable. An interesting trend to emerge recently is that nonfiring replicas themselves have become pricey collectibles. Some of the early replicas from the 1960s and '70s were discontinued after the molds wore out, and these firearms have skyrocketed in value. Originally sold for about \$79, these replicas now fetch as much as \$450. So, even replicas are now collectibles. **PM**

SOURCE LIST

For more information about nonfiring firearms, black-powder rifles and pistols, and replica guns, contact the following:

- *Collector's Armoury*, 800 Slaters Ln., P.O. Box 59, Dept. 93A, Alexandria, VA 22313; (703) 684-6111.
- The Franklin Mint, Franklin Center, Philadelphia, PA 19091; (215) 459-6000.
- *The Regimental Quartermaster*, P.O. Box 553, Hatboro, PA 19040; (215) 672-6891.



THE NEED

Highly sophisticated technology is helping drag racers achieve speeds and elapsed times once thought impossible.

• The concept of drag racing is brutally simple—cover a straight quarter-mile, 1320 ft., from a standing start quicker than the guy in the other lane. That's it.

On the racetrack, infrared computerized timing gear provides each car with an elapsed time to ten-thousandths of a second, gives each car its terminal speed and selects the winner in races too close to call by human eye. In the pinnacle of the sport—Top Fuel—the fastest accelerating piston-engine cars in the world make a pass in less than 5 seconds at more than 300 mph. A Corvette ZR-1, the quickest production car *POPULAR MECHANICS* has ever tested, covered the distance in 12.72 at 116 mph. In drag racing, a 10th of a second is a lifetime.

The sport, particularly under the auspices of the National Hot Rod Association (NHRA), has made light-year strides from its formative post-World War II days, when budding competitors raced illegally on the streets of Southern California. Now

TEXT AND PHOTOS BY JON ASHER



Crew of seven shows racing's professionalism.

there's an 18-event national tour that draws almost 2-million spectators annually to purpose-built, stadium-like venues like the Texas Motorplex and Indianapolis Raceway Park. Racers in three professional categories—Top Fuel, Funny Car and Pro Stock—battle for millions in prize money and contingency awards.

The cars entertaining these crowds have taken similar leaps from the Flathead Ford Roadsters raced on L.A. streets. From on-board comput-

er systems recording virtually every aspect of the race car's operation to multidisc clutches that have replaced transmissions as we once knew them to fuel systems seemingly strong enough to empty Lake Powell in a few hours, drag racing technology is arguably on the level of current Indycar science and clearly ahead of stock car racing (see PM, Mar. '93 and June '93).

Pro teams operate out of quarter-million-dollar tow rigs that are actually rolling race shops. Race cars can easily cost \$150,000 without the first spare spark plug, and a serious campaign for the NHRA Winston Championship easily consumes a 7-figure sponsorship package.

Picking up the tab are big-name corporate sponsors from McDonald's, Budweiser and the Hawaiian Tourism Board to automotive-related companies such as motor-oil makers, car companies and parts distributors, each trying to grab the attention of the 100-million people drag racing reaches each year through televised events.



FOR SPEED



The greasy mechanic in the was-white T-shirt has been replaced with a highly trained technician who specializes in one aspect of the car's operation and gets paid a fat 5-figure salary with retirement benefits. Add a zero for crew chiefs with the tuning skills of Austin Coil, who calls the shots on the Castrol GTX Oldsmobile Funny Car driven by 2-time Winston Funny Car-champ John Force.

At national events, the quickest 18 qualifiers in each class race tourna-

ment style. The losers go home. The winners get back to the pits and prepare their car for the next round.

Top Fuel

The rear-engine Top Fuel dragster was invented in 1970, by "Big Daddy" Don Garlits, the most famous drag racer of all time, after a transmission explosion in his front-engine machine stole half his right foot. Today's "diggers" still follow this design, weigh a minimum of 1950 pounds and

Level of sophistication includes (clockwise from bottom left) clutch timing system, offset front ends, purpose-built aluminum supercharged nitromethane-fueled 500 cid engines and complicated on-board computers to monitor all of the car's functions.

have a maximum wheelbase of 300 in. Power comes from supercharged fuel-injected 5000-horsepower aluminum aftermarket engines, based on Chrysler's hemispherical (Hemi) combustion-chamber design used in passenger cars in the '50s and '60s.

THE NEED FOR SPEED



They burn nitromethane, a highly combustible fuel, and create enough sound that earplugs are as common in the stands as cold beer. Idle is a violent 2500 rpm, and a good run has the motor spinning in the 7200- to 7500-rpm range from start to finish.

With special tools and components designed to speed the process, teams strip down their 500-cu.-in. engines to the bare blocks *after every run*, many times replacing internal components from steel cylinder sleeves to rods, pistons and bearings, rebuilding them completely in the 90 minutes between rounds. And if the damage is too severe, a new engine is installed.

They also adjust the multidisc clutch and/or replace it as necessary. Clutch adjustment usually wins or loses the race. Too tight and wheelspin is guaranteed. Too loose and not all the available power is used.

It works with multiple clutch discs separated by many floaters. As the car races down the track, multiple counterweight arms swing forward to apply more pressure to the clutch, quickly resulting in a locked nonslipping system. This gradual application of the clutch has completely replaced the transmission. Before this clutch design, getting 5000 hp to the ground was impossible.

In all the pro categories, computers are used universally to monitor engine functions, but no engine function may be computer controlled in drag racing. Computers are only permitted for data gathering.

John Force's Funny Car team was the first to utilize components like the Raytech noncontact thermometer, which measures track and tire

temperatures after the tire-heating burnout, allowing the crew to better judge the tire's adhesion. Now all the top teams have such devices.

As speeds increase, so does the importance of efficient aerodynamics. Wind-tunnel testing is now the norm, and more downforce is the goal. Doug Herbert's Top Fuel crew gives much credit for its recent success to an aerodynamic device, bolted be-

cause a driver cannot deal with complex controls when a whole race takes less than 5 seconds. A lever on the right controls braking. Two pedals actuate the clutch and throttle, although the clutch pedal is only used to shift into Reverse after a burnout. The multidisc centrifugal clutch is engaged automatically with the application of the throttle. There's a fuel-pressure gauge, a toggle switch to

activate the clutch timing system which begins working at full throttle and a switch that begins data recording.

Kenny Bernstein's Budweiser King fueller bristles with the latest technology. Bernstein's car has a 285-in.-long wheelbase, which resists distortion under starting-line loads and increases traction. Temperature transducers on the exhaust headers provide Crew Chief Dale Armstrong with some information on the performance of each cylinder. Fuel lines deliver juice at 42 gallons per minute, and 32 injector nozzles are machined directly into the cylinder heads.

Immediately after the finish line blurs past, double parachutes are deployed to help the marginally effective rear-only brakes.

Funny Car

Strap into a 5000-hp Funny Car and you immediately realize the name is an oxymoron. The lowering of a Funny Car's fiberglass body has been compared to the closing of a coffin. Under the caricature of a production-car's body is basically a short-wheelbase front-engine Top Fueller, with the same 500-cu.-in. aluminum supercharged fuel-injected nitromethane-burning bomb sitting in the driver's face.



Teams strip engines to bare componentry between rounds of racing. Critical adjustments will be made to the multidisc clutch that has replaced the transmission (left) while handheld noncontact thermometers are used to check track and tire prior to racing.

neath the engine, which directs airflow up over the huge rear slicks.

Herbert's car, somewhat typical of a modern Top Fuel racer, utilizes a small Racepak on-board computer for post-run analysis. Additional data-gathering devices and batteries are housed beneath the car's lightweight magnesium skin.

The controls of Herbert's car are also typical—and amazingly simple



This combination slingshots Funny Cars through the quarter-mile in about 5.10 seconds at speeds of more than 290 mph.

Since the motor's in front of the driver, where he's much more vulnerable to the results of an engine failure, Funny Cars are equipped with on-board fire systems that are designed to keep flames off the driver. New innovations—many first

gloves, boots and face protection.

Unlike Top Fuel cars, Funnies have both front and rear brakes, but the cars still slow down with the help of double parachutes. Funny Cars also use the multidisc clutches and the data-gathering computer systems found on Top Fuelers, and their motors are also rebuilt or replaced between each round of drag racing.

ed motors. Reigning Pro Stock world champion, Warren Johnson's Olds Cutlass Supreme, for instance, is similar to a dealer-sold unit in body styling and fuel only. But even then, the removable body panels are carbon fiber and the fuel is a very-high-octane gasoline, entering the motor through huge twin carburetors flowing more than 2300 cfm sitting atop a handmade, sheetmetal,



seen on Force's car after his '92 season was literally one fireball after another—are designed to further ensure the safety of the car's occupant. Now many Funny Cars have body ejectors that dislodge the very burnable body off the car in a fire, keeping the flames controllable and the driver's vision and exit clear. And Force has just added a metal barrier between himself and the motor for further protection. All Funny Cars have escape hatches in the roof, and all professional drivers wear fire-resistant driver's suits,

Pro Stocks are far from stock (clockwise from top left): Driver is protected by steel-tube cage and fire extinguisher. Engine is 500 cid and runs on racing gas. Fuel tank, filter and pump are in front of radiator. Five-speed gearbox uses no clutch and gearing is easily changed. Front suspension is coil-over shocks and special mounts. Computer chips limit engine's max rpm.

Pro Stock

The only thing stock in Pro Stock is the name. These are pure-bred, scratchbuilt, round-tube, chrome-moly-chassis race cars powered by 500-cu.-in. 1000-hp normally aspirat-

tunnel ram intake manifold.

Oldsmobile Cutlass Supreme dominates this class in entry numbers, but Scott Geoffrion's Dodge Daytona is tough too. Pontiac Firebirds, Chevy Camaros and Lumina's abound, along with the occasional Grand Prix and Beretta. And the winningest drag racer of all time, Bob Glidden, does battle in a lone Ford Probe.

The drivers of these "doorslammers" are surrounded by rollcage tubing and watch a large tachometer with a big red warning light preset to

(Please turn to page 118)



121 MPH
USTA

THE MECHANICS OF A POWER SERVE

When the strings of Pete Sampras's racket smash into the ball at this month's U.S. Open and send it hurtling across the net at over 120 mph, biophysics and aerodynamic forces will combine to score yet another ace for one of tennis's top seeds.

BY STEVE FLINK; PM Illustrations by Paul Kratter

● Many matches played in men's professional tennis are essentially exercises in brutality, featuring explosive power almost across the board. This generation of combatants is strong and durable, capable of blasting the opposition off the court with the extraordinary pace of its shotmaking, and is able to produce blinding winners from almost anywhere on the court.

While power prevails throughout the competitive game of tennis, it is most evident, and probably of greatest significance, on the serve. With one swing of the racket, the server can begin and end a point abruptly, keeping a rival completely off guard with the speed, spin and placement of his delivery. The most potent servers enjoy an immense advantage over those who cannot produce the same degree of pace. The ability to generate an enormous amount of speed on the serve translates into free points, intimidates those on the receiving end who have trouble coming to terms with the high velocity and provides a cushion in the heat of a long battle.

In any event, today's game is dominated to a large extent by the big servers. The best players in the sport are propelled forward by the strength of their serve, using it as the primary weapon on their path to success. Quite simply, it is nearly impossible these days to reach the top of the ladder in men's tennis without a powerful serve. The most striking example of a champion coming into prominence in large measure because of a big serve is Pete Sampras, who moved to No. 1 in

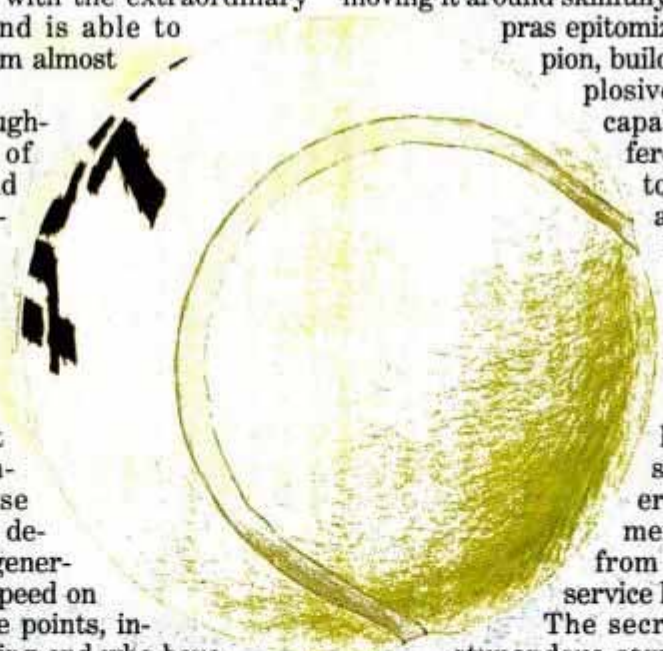
the world back in April of this year.

Sampras has demoralized more than his share of opponents with his devastating first serve, keeping them constantly guessing about where he is going with it, moving it around skillfully from corner to corner. Sampras epitomizes the modern men's champion, building his game around the explosive serve, pulling away from

capable foes with the effortless ferocity of his delivery. That astonishing serve—clocked at as high as 129 miles per hour—is precisely what separates Sampras from the pack. This velocity occurs in a relatively small space when you consider that the court measures 78 ft. in length and 27 ft. in width for singles' tennis. The serve operates within even tighter dimensions in that the distance from the server to the opposite service line is about 60 ft.

The secret for Sampras and other stupendous servers like Boris Becker and Goran Ivanisevic is that they win about 80% of all points when they get their first serve in play. That ratio of success is a direct result of power. But where does the power come from on the serve? How do the best of the breed create such remarkable velocity with regularity?

To be sure, there are common components shared by all of the great servers, even if techniques vary from competitor to competitor. As Allen Fox, former American Davis Cup player and current tennis coach at Pepperdine University, explains, there are "three or



THE MECHANICS OF A POWER SERVE

four" sources of power, which are utilized to the hilt by players who know what they are doing.

"The object is to get the racket head moving as fast as you possibly can," says Fox. "It is done like a linear accelerator. You keep adding boosts of power from various sources until you get the ultimate racket velocity. That comes from bending your knees, throwing the racket head up over your shoulder and rotating your shoulders. That adds to the speed already coming from your legs and torso. Then you snap your wrist. Add all of those elements together, and that is where you get your power."

Australian Colin Dibley is now a teaching professional in New Jersey, but when he played the circuit in the 1970s he had the biggest serve of his era. He describes the basis for power similarly to Fox, but adds a few of his own comments to the equation.

"You've got to use your whole body," remarks Dibley. "I know from my own experience that if I try to hit the serve too hard, I can lose it all. It is a matter of timing and balance. You have to transfer your weight into the ball. Players often get their weight forward too soon, and they end up hitting only with their arm."

Making the toss

Dibley emphasizes the importance of a good ball toss in developing a forceful serve. "To get power," he says, "you always have to go up after the ball. Wherever you toss the ball, you have to make sure you are extending up after the ball. A lot of club players toss too high and let the ball drop too low, or they don't throw the ball high enough and therefore don't extend for power."

To get maximum power on the serve, the player must toss the ball

out in front of his body, but not too far forward. "The ball should ideally bounce 6 to 9 in. in front of your body if you were to let your toss drop to the ground rather than making contact with the ball," notes Dibley. "If you toss too far out in front of your body, you will be at the end of your reach and will get too much arm and very little else into the serve. But if you can meet the ball at the peak of the toss—or somewhere near the top of the toss—and place the ball slightly in front of your body, then you will get the most power."

Undoubtedly, the toss is the single most crucial element. The consistency and placement of the toss will determine the direction and pace of the serve. According to studies done by the Vic Braden Tennis College in Cota de Caza, California, the ideal toss should be 17 to 20 in. above the racket hand, at what is called the

In Or Out? A Computer Makes The Call

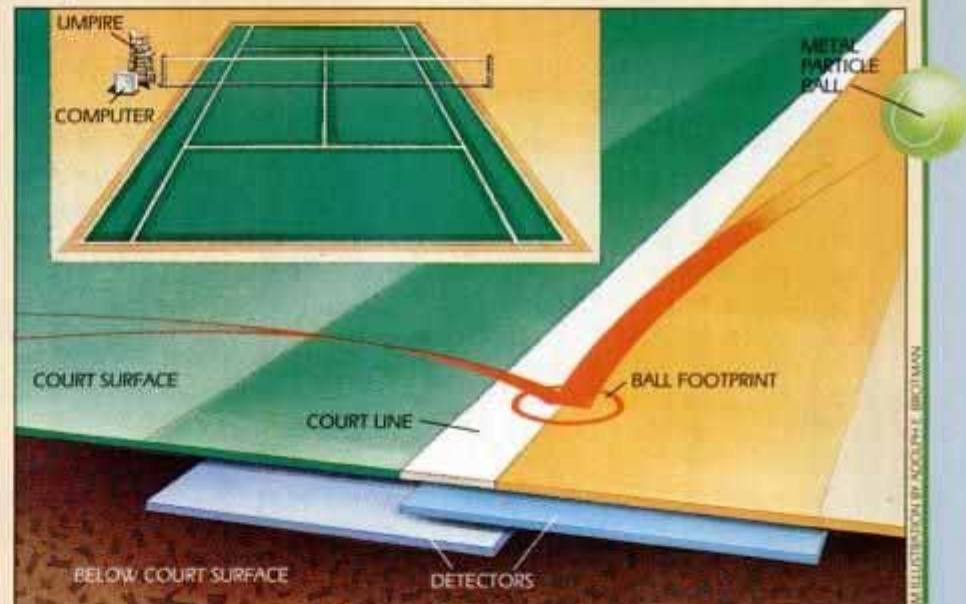
● The fastest recorded serve of 1992 was a 132-miles-per-hour rocket delivered by the Dutchman Richard Krajicek. No fewer than 10 men produced serves moving faster than 125 mph during that year. Under these circumstances, how can a linesman possibly use his eyes to keep up with the astonishing speed being displayed by so many players? Can an umpire know one way or another whether a ball is in or out when a player appeals to him to overrule a linesman on a controversial call? What is the long-term solution to this persistent problem?

The solution may be on the way. TEL Proprietary Ltd. has come up with an automatic system that can call every line on the court electronically. To be precise, TEL is an electromagnetic system involving the placement of coils underneath the court's surface. These coils carry electrical currents operating at different frequencies.

TEL was tested on an experimental basis at the 1992 and 1993 Australian Opens with the results tabulated privately and compared with the actual calls made by the linesmen at those tournaments. The initial findings appear to cast TEL in a favorable light.

How does it work? When a ball moves into the magnetic field, iron particles in its filler are detected. Each line is linked to a 16-bit microprocessor, with a master processor supervising the line processors. The master processor makes certain the system is operating properly, checking it 20 times a second. As a ball nears one of the lines on the court, the computer tracks and registers the impact, making the call within a quarter of a second. The information appears on a handheld receiver kept by the umpire.

TEL is one of about a half-dozen systems being evaluated now for use in the future on the IBM/ATP tour. As technical advisor to the ATP, Ram Ramnath is



Electromagnetic sensors under the court lines monitor the ball as it approaches. The ball contains metal particles for easy detection.

studying the merits and demerits of all the proposed systems. He is encouraged about the potential for this technology.

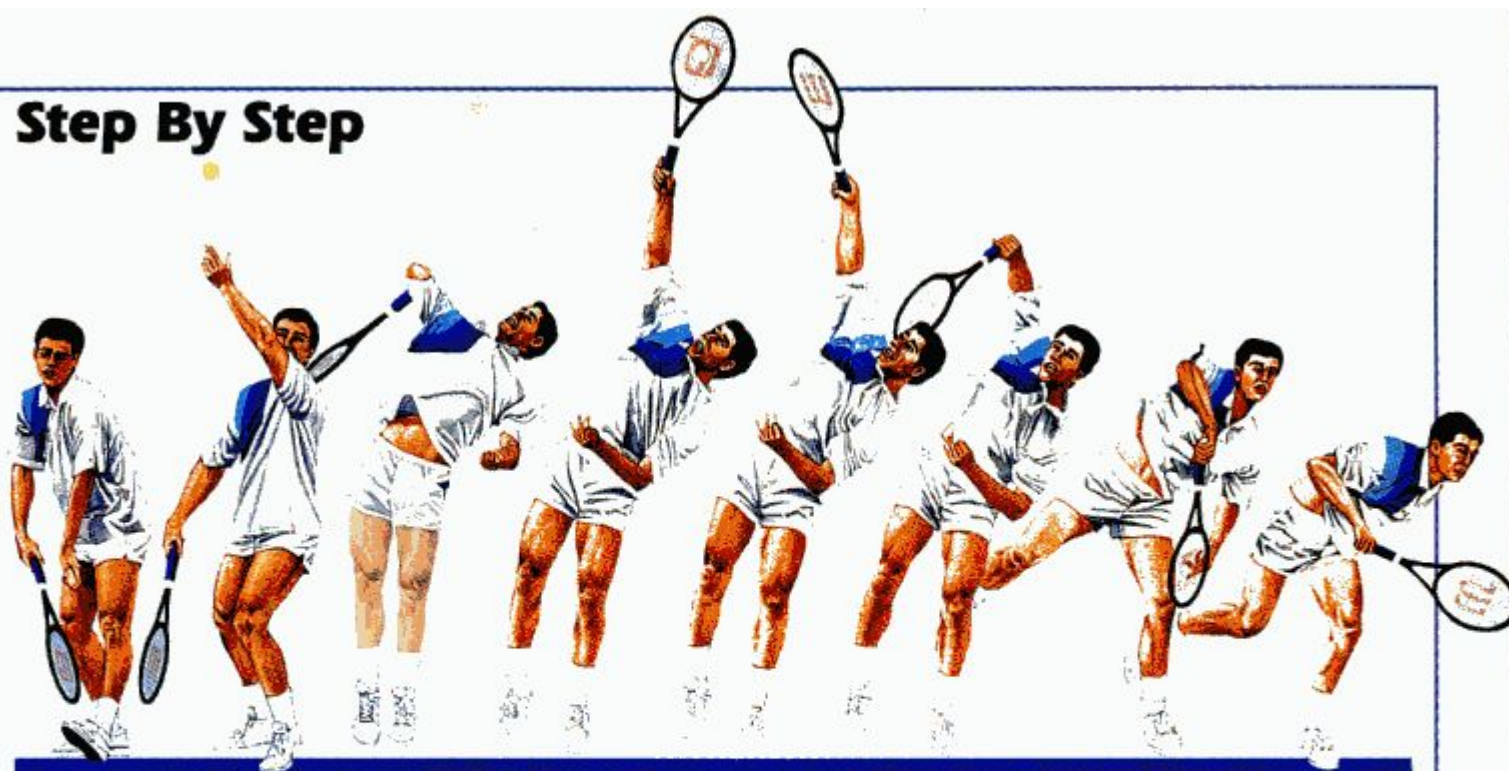
"Everyone wonders," says Ramnath, "whether a machine system taking the place of human beings will add or detract from the drama of a match. But I have talked to players on the pro tour about this and most of them feel that an impartial electronic system would be very desirable."

Ramnath explains, "I have established guidelines for accuracy, consistency and reliability. The different systems are all over the place in terms of different characteristics, but this is definitely a great technological development. As for TEL, since the court is flooded with an electromagnetic field, that raises a question in itself. Some studies have been made about its safety. If there were high levels

of radiation, it could be dangerous. But in the case of TEL, it is low-level radiation. Based on what we already know, it is not dangerous. But what is not known is the long-term effect of low-level radiation on the soles of tennis shoes."

While professional players try to sort out this situation, recreational players can gauge their service power potential by testing new products like Serv-O-Meter. The device weighs less than 1 ounce and is attached to the side of a racket frame with Velcro straps. The Serv-O-Meter uses a calibrated, spring-loaded internal mechanism. After every swing of the racket, the meter must be reset by turning a knob. Serv-O-Meter is designed to measure racket speeds of 40 to 80 miles per hour and ball speeds of 60 to 100 mph. It is available in eight colors and costs \$19.95; (800) 232-3687. —S.F.

Step By Step



Pete Sampras begins his serve (1) by rocking onto his back foot with both hands pointing to the ground at the same time. This allows his tossing arm and his racket arm to go up into the tossing and hitting position simultaneously. (2) Sampras keeps his eye on the ball during the toss. (3) Sampras's motion allows him to get a full shoulder turn and deep knee bend in the preparation position. The knee bend is a crucial part of his preparation. (4) Sampras then moves into

the classic back-scratch position with his left arm returning to a more balanced position. He is jumping into the air, propelling himself into the court. (5) This is a classic full extension up into the hitting position. Pete uses a 5¹/₄-in. grip, which is uncommonly large but helps him hold the racket very softly in his hand, thereby letting him snap at the ball with his wrist and accelerate the racket head. (6) The wrist snap has just taken effect. He is seeing the ball leave his racket while

holding his head still through the contact point. If he were to move his head down it would jerk the serve. (7) Now the wrist snap has been completed and his left knee is slightly bent as he has nearly finished his swing. (8) Notice how low his body is. This allows Sampras to accelerate into the net behind his serve, with a powerful first step helping him to move in quickly. He looks like a sprinter ready to power off that left leg.

—Paul Cohen
former coach of John McEnroe

“peak of the reach.”

Of course, the top players toss the way it works for them, and it is as simple as that. Steffi Graff, widely acknowledged as the best and biggest server in women's tennis, has an unusually high toss, which can cause her considerable trouble when the ball is blown around in the wind. Ivan Lendl has another uncommonly high

toss, although he has altered it over the years to make it lower.

Despite the disparity in their tosses, all servers share something more significant. No matter how high or how low they make their tosses, they place the ball in the same place time after time, point after point, and therefore, they get not only power but consistency as a reward for their

discipline and effort. Furthermore, those who excel in the serving department share another trait that is not related to the toss—a relaxed serving arm.

“The arm has to be loose,” confirms Fox, “because it is essentially a passive element. The arm is accelerated by the shoulders, the legs and

(Please turn to page 120)

Evolution Of The Tennis Racket



WOOD

At 75 sq. in., the wood racket survived through the 1960s and most of the '70s. The sweetspot is low on the racket.

METAL

In the 1970s, stiffer metal rackets appear, but they are the same size as their wooden predecessors, and the sweetspot is the same.

GRAPHITE

After 1976, bigger and wider rackets come into play—some as big as 120 sq. in. The sweetspot moves toward the center of the racket.

COMPOSITE

Rackets like the new 10-ounce Wilson Hammer have 60% of their weight above the center point so the sweetspot rises to where most balls are hit.



DODGE INTREPID

LONG-TERM TEST CARS

Three new cars join our fleet.

● With this report, our long-term test fleet expands by three cars. All of the vehicles we added last report are still with us. But we've also taken on one of the most written about new cars in history—an LH sedan, the Dodge Intrepid, from Chrysler Corp. We've also added Mazda's very contemporary 626, an all-new iteration of its family sedan. And finally, the car that Subaru hopes will put it into the small-car mainstream, the Impreza, joins our fleet in wagon form.

Dodge Intrepid

We wanted an example of an LH car from Job One. Unfortunately for us, and fortunately for Chrysler, LH cars were and are in short supply. Our Intrepid finally arrived and, frankly, it was worth the wait.

Our Intrepid wears a silver/bronze metallic clearcoat paint worthy of a European luxury car—it's devoid of flaws or orange peel. The 3.5-liter 24-valve engine delivers at least the advertised 214 hp. The trunk is nearly as cavernous as the back seat—as reported by those who've ridden in that seat.

Things we appreciate so far are the engine and transmission, the optional traction control and the killer stereo. Another feature we enjoy is the trip computer/compass/outside thermometer on the overhead console. So far we've enjoyed excellent fuel mileage—nearly 20 mpg in traffic and touching 27 mpg on the parkway with the cruise control set.

—Mike Allen

Mazda 626

With its stealth paint job and subdued styling, Mazda's 626 doesn't look like a street tiger. But there's a fair bit of tiger beneath that rounded sheetmetal, enough to make this one of the more entertaining midsize sedans you can buy. Its suspension tuning gives it gratifying agility, its 5-speed manual transmission is exceptionally precise—particularly for



MAZDA 626

PM PHOTO BY DAVID DEWA-JUST

a front-drive car—and the engine is sheer joy. At 165 hp, Mazda's 2.5-liter 24-valve dohc V6 isn't the most potent V6 around, but it produces excellent midrange response and makes a satisfying growl while doing so.

Our initial impression (1845 miles) of this newcomer to our test fleet is that it is not the quintessential family sedan. That distinction goes to some of the bigger entries in this class—the Toyota Camry, for example, or the Ford Taurus.

But for the sedan buyer who wants to blend sports-car handling and lively acceleration with that extra set of doors, the V6-powered 626 has few—if any—rivals in its class. We're looking forward to the miles that lie ahead.

—Tony Swan

Subaru Impreza

The Impreza is Subaru's new player in the compact sweepstakes, and we've decided to live with the jaunty wagon version. So far we've found this pleasant little hauler to be the kind of competent, versatile, small family car that we quickly take for granted. Although it's not likely to set any hearts on fire with its 0-to-60-mph performance, it seems to be the kind of car that wins hearts over time by thriving on neglect and being generally unbreakable.

So far—just 2518 miles—that's our impression. The 16-valve sohc 1.8-liter flat Four makes nice low-end torque. The 5-speed gearbox is precise. Clutch engagement is light and smooth. It's easy to drive with good driver's sightlines in all directions.

The Impreza is built on the Legacy platform, which makes it bigger inside than its predecessor, the old faithful Loyale. There's plenty of front-seat legroom, and with the rear seats folded flat the little wagon will swallow a fair amount of cargo.

It's also much more conventional than previous Subarus. It's conventional in every way. How a more conventional Subaru will stack up against the Honda Civics and Toyota Corollas of this world remains to be seen. In our book, to date, it has its share of strong points. Time will tell.

—T.S.

Toyota Corolla LE

We keep waiting for something to go wrong, for our positive opinion to change. But our long-term Corolla won't let up. It keeps going and going. And after racking up more than

SUBARU IMPREZA



PM PHOTO BY DAVID DEHURST

16,000 miles in five months with an average 29.3 mpg for mixed highway and stop-and-go New York City driving, we've stopped waiting.

Toyota's solid construction and excellent fit and finish have not allowed a single squeak or rattle, no matter

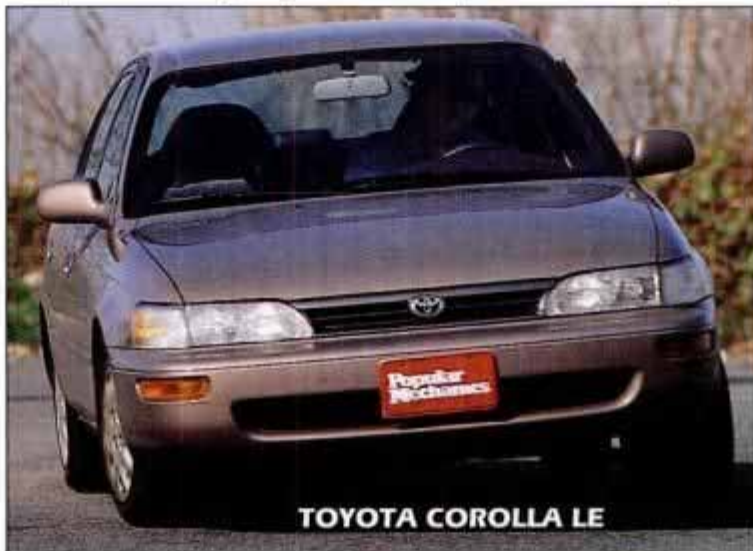
analog gauges is a welcome departure from cluttered electronic digital displays. And driver's sightlines are unsurpassed. Nothing obstructs your outward view, even if you've loaded the car with all your worldly belongings and moved to another town.

Which is what we did.

For more than a couple of weekends, we turned our Corolla into a mini house mover. Roominess is actually an understatement when you consider what we've been able to shove into this compact with the available trunk space and the rear seats folded down, including a 36-in. round wrought-iron table and two chairs.

We still have a few more months left with our Corolla, but we're already starting to miss it.

—Deborah Frank



TOYOTA COROLLA LE

how many NYC potholes we hit. The incredible silence in the cabin literally equals that of a luxury sedan. The manual radio antenna, however, reminds one of Corolla's economy-car roots.

The simplicity of Corolla's dashboard with its big, well-positioned

GMC Suburban SLE

Like the rabbit in the battery commercial, our Suburban just keeps towing and towing and towing. We've run up almost 13,000 miles—midway through the racing season—almost all of it with a trailer and our trusty



GMC SUBURBAN SLE

PM PHOTO BY ROY THURSBY

LONG-TERM TEST CARS



CADILLAC ELDORADO
TOURING COUPE

PHOTO BY ROY ATTALWAY

Honda Prelude VTEC hooked on behind it.

This adds up to almost nonstop heavy duty, and the Suburban thrives on it. The 454 V8 flattens out the hills and eats up the miles without breathing hard. It's no lightweight in the fuel-economy department—about 10 mpg loaded, 13 mpg unloaded—but that's the price of major-league torque and major-league towing capabilities. Those capabilities, incidentally, extend to towing in adverse conditions. More than once our Suburban's 4wd system has gotten us out of a muddy racing paddock that left others mired down for hours.

Through all these miles, we've recorded only two negative comments in the logbook. One concerns the ventilation controls, which are difficult to adjust for blend. The other mentions the shoulder belt, which chafes the driver's neck.

But these are small irritations in an otherwise totally positive experience. The Suburban tackles hard work with authority, it's comfortable over long hauls and, in our experience to date, it's mechanically bulletproof. —T.S.

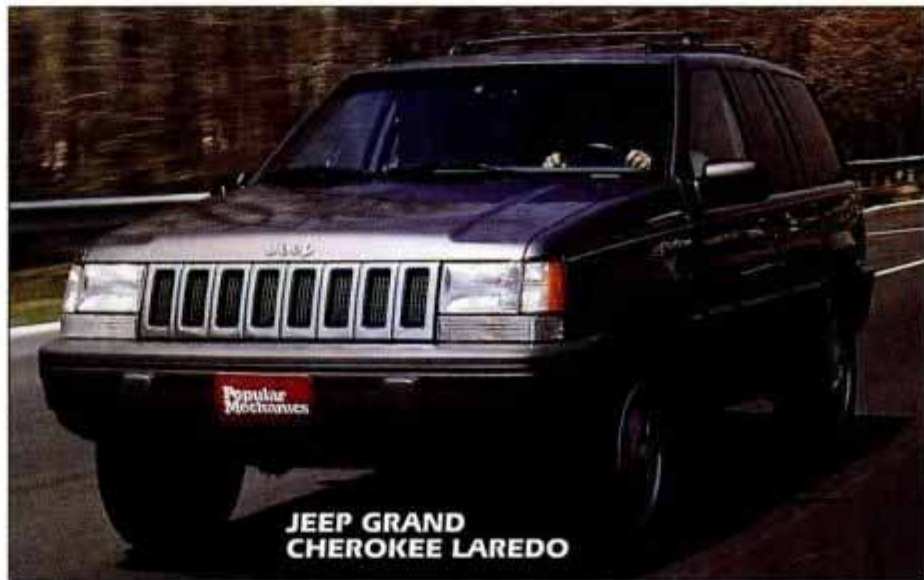


MERCURY VILLAGER LS

PHOTO BY JIM DUNNE

Cadillac Eldorado Touring Coupe

At 4530 miles, the Driver Information Center on the Eldo's dash lit up, informing us that we should have the car serviced. This was a little annoy-



JEEP GRAND
CHEROKEE LAREDO

PHOTO BY ROY ATTALWAY

ing, as the owner's manual states that 7500 miles is the normal service interval, unless the car is subjected to "severe usage." Apparently, being a POPULAR MECHANICS test car qualifies as severe usage. We remember the same thing happening with our Cadillac Seville last year.

Unfor-

tunately for the car, we didn't get in to Brogin Cadillac in Ridgewood, New Jersey, until the odometer read well past 8000 miles. Cost: \$337.07.

We asked the dealer to perform the regular service and also to check the front-end alignment as the car had begun to feel a little twitchy under power. And when a Cadillac Northstar V8 engine is under the hood, the car is under power quite often. Sure enough, the front end was way out of line. If you have a front-wheel-drive car with a powerful engine, and it just doesn't feel stable or right, especially when your right foot is making waves, check the front-end alignment.

Speaking of the Northstar, which is really the subject of this test, it is a delight. On a recent trip to Montreal for a weekend, this car just rolled. And not a whimper from the Northstar. We're beginning to feel like this may be one of the best engines GM ever made. With about 14,000 miles

on the odo, we'll continue to rack 'em up and keep you informed.

—Joe Oldham

Jeep Grand Cherokee Laredo

Our Jeep Grand Cherokee has had its share of trials and tribulations since our last report.

First, some jerk decided that he didn't like the shape of the Grand Cherokee's windshield, so he threw a golf ball through it while it was parked one night. Cost: \$295.

Then, we got stuck. We were on a road that quickly changed from pavement to gravel to dirt to mud in less than a mile. Before we could bail out, the Jeep was hub-deep in loose mud which was too much for the 4wd's Low

(Please turn to page 118)

A man in a military uniform is working on a piece of electronic equipment. He is looking at the camera with a slight smile. The equipment has a digital display showing '0066'.

Business Major

RUBEN F. CASTILLO II
Student, Palo Alto College
Specialist, U.S. Army Reserve
238th Maintenance Company

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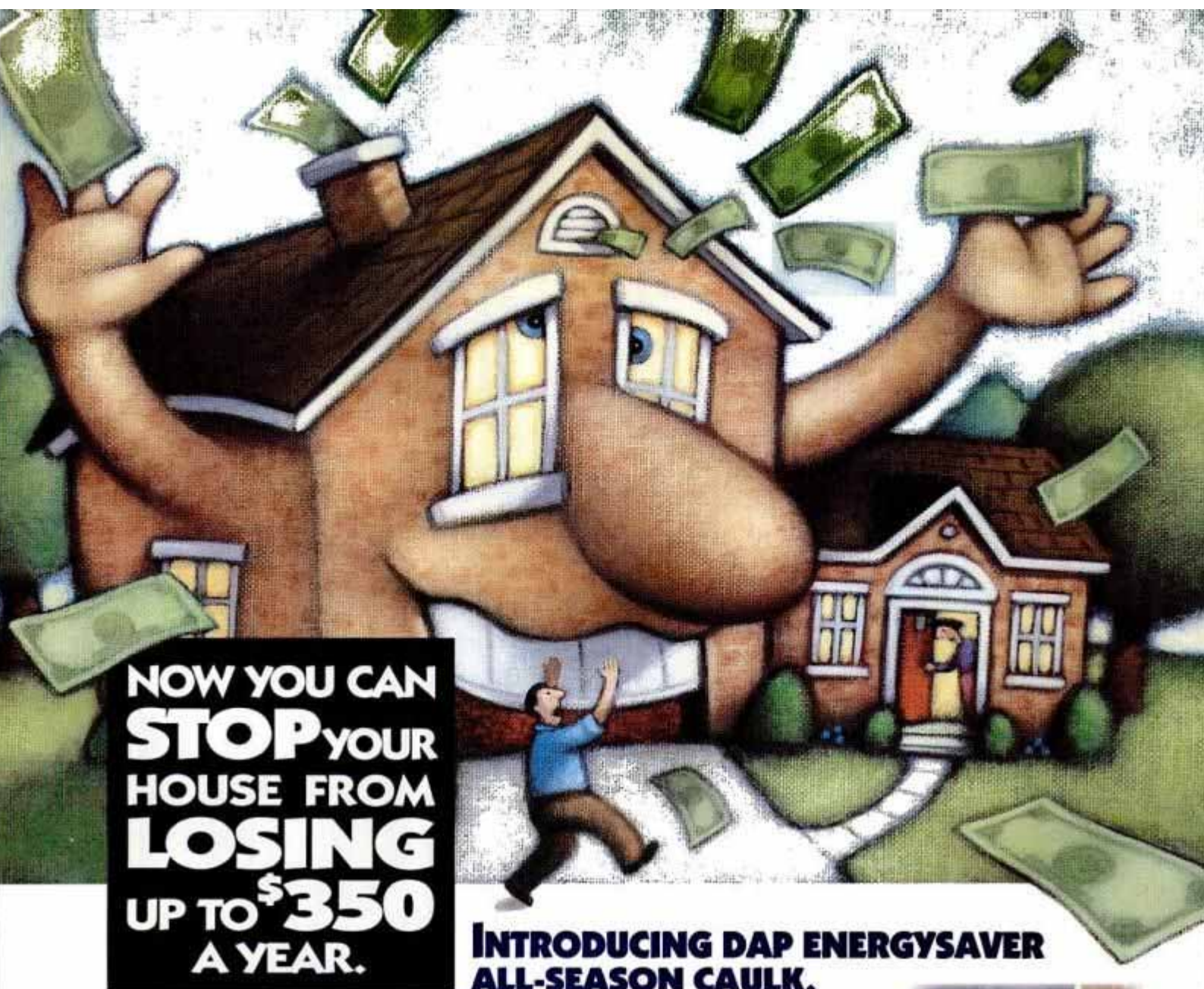
1 weekend/month, plus
2 weeks/year

*\$23,500 combines Montgomery GI Bill benefits
with pay earned during a standard enlistment.

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 ALL-SEASON CAULK.**

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All-season solution. New DAP *ENERGYSAVER*™ Caulk is specially designed to stop energy loss and save you money. Our unique formula gives you a seal that's so flexible, it's guaranteed for 50 years. And it comes in white or clear.

Easy-to-use applicator cap. Our patent-pending DAP CAP™ makes every job goof-proof. So you'll always get professional-looking results. Sealing—and saving—just got easier. Thanks to new DAP *ENERGYSAVER* All-Season Caulk.



USE IT AROUND DOOR JAMBS, AROUND WINDOW FRAMES, ANYWHERE YOUR HOME LOSES ENERGY.

OUR PATENT-PENDING DAP CAP MAKES IT EASY TO GET PROFESSIONAL-LOOKING RESULTS EVERY TIME.



*Source: US Dept. of Energy.



HOME IMPROVEMENT

RUST PREVENTION

A homeowner's guide to fighting rust.

BY ROY BERENDSOHN, Assistant Home Improvement Editor

● **Steel rusts.** Even if it's painted, it can still rust and look lousy. Aluminum rusts, too. But just because these metals rust, doesn't mean you have to accept it. Fortunately, you can fight back and win the battle against corrosion.

To win, you need to be well prepared—armed, if you will—with the right tools, materials and information. As far as tools and materials are concerned, everything you need is at your local hardware store, paint

store or home center. Just remember to bypass those products that promise a quick and permanent end to rust and to stick with the basics that we show here. The process is straightforward and, in some respects, remains the same as in the past. Remove as much of the rust as you can, then paint. Fortunately, today's corrosion-fighting products make this job easier than before.

To get the right information for

this story, we went to the experts—the National Association Of Corrosion Engineers (NACE). NACE steered us to Edgar Dreyman, a professional engineer with 30 years of experience fighting corrosion.

Know the enemy

First, Dreyman advises, know the enemy.

Photo: Rosano Caporasto
Illustrations: George Retseck

Corrosion is not necessarily synonymous with rust. Rust is just one form of corrosion, namely the brown stuff that forms as a result of corrosion on steel. This article will deal with all the simple forms of corrosion found around the house: rusting steel, galvanic corrosion and corrosion on uncoated aluminum.

Here's a simplified version of the complex electrochemical process that causes rust to form on painted steel: First, moisture penetrates through pores in the paint film or through a scratch (see illustration below). Then the oxygen in the water combines with the iron in the steel, and a minute amount of iron is dissolved, forming a solution. Because there is an imbalance of electrons between the solution and the surrounding steel, a flow of electrons, or current, begins. As long as the current flows, the steel will deteriorate (corrode) and rust will form.

Because the rust has more volume than the steel, it expands and helps form a blister under the paint. The blister will cause the paint to fail, exposing the steel to more moisture and accelerating the corrosion process.

The same situation can occur in reverse. If you paint over damp steel, you've trapped the moisture against the metal. Sun beating down on the metal will convert the moisture to vapor. The vapor will expand upward, lifting the paint in the process and forming a blister. Steel, like wood, should be dry when you paint it.

Dreyman's Four Rules Of Success

First the bad news. Like everything else around us, steel obeys the laws of thermodynamics and always will return to a state of low energy. In other words, corrosion is the inevitable means by which steel returns to iron oxide, its most relaxed, low-energy form.

Now, the good news. By expending a little energy of your own, you can greatly slow the decay of steel.

Here, then, are four easy corrosion-fighting steps. Note that the steps are interrelated and that paint can play a role in each step.

Step 1—Keep it clean. Dirt holds moisture, and we've seen the effect moisture has on steel.

Step 2—Keep it dry. No moisture, no rust. This puts a premium on repairing blistered paint and using the right paint for the job.

Step 3—Insulate it. Not only does paint keep the metal dry, almost all paints act as insulators. By stopping current flow, paint prevents corrosion. Also, a variety of substances—from salts to alkaline materials—accelerate the corrosion process. Paint protects the metal against these damaging substances.

Step 4—Galvanize it. Galvanized steel is coated with zinc. The steel is dipped in molten zinc (known as hot dipped), or it is plated by being immersed in an electrochemical bath (see illustration on page 61). Homeowners can't be galvanizers, of course, but they can use galvanized hardware. They can also use a high zinc content primer.

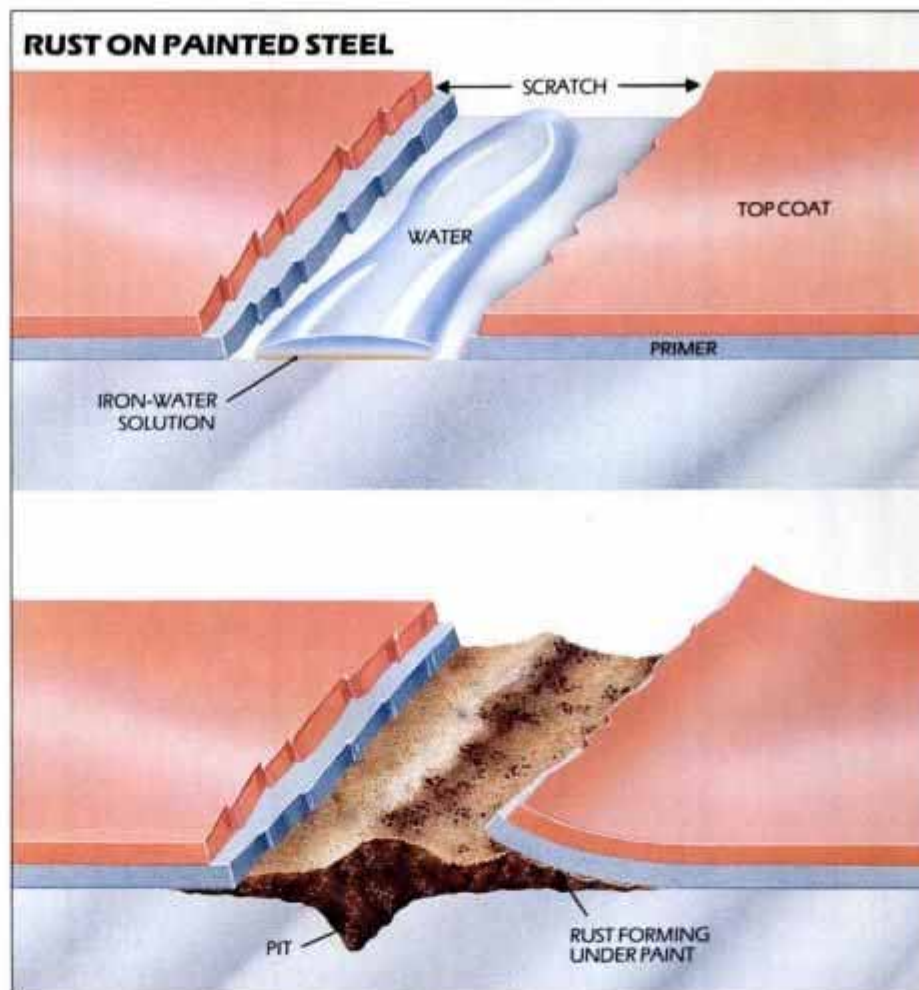
Zinc is a special material, as far as steel is concerned. In corrosive conditions, it loses electrons at a faster rate than steel does. If you cover the steel with zinc, the zinc will corrode away, but the steel remains un-

scathed until the zinc is gone.

A related means of protection is to position a zinc bar—called an anode—near the steel. This is the method used to protect steel swimming pools. Likewise, magnesium anodes are used to protect hot-water tanks.

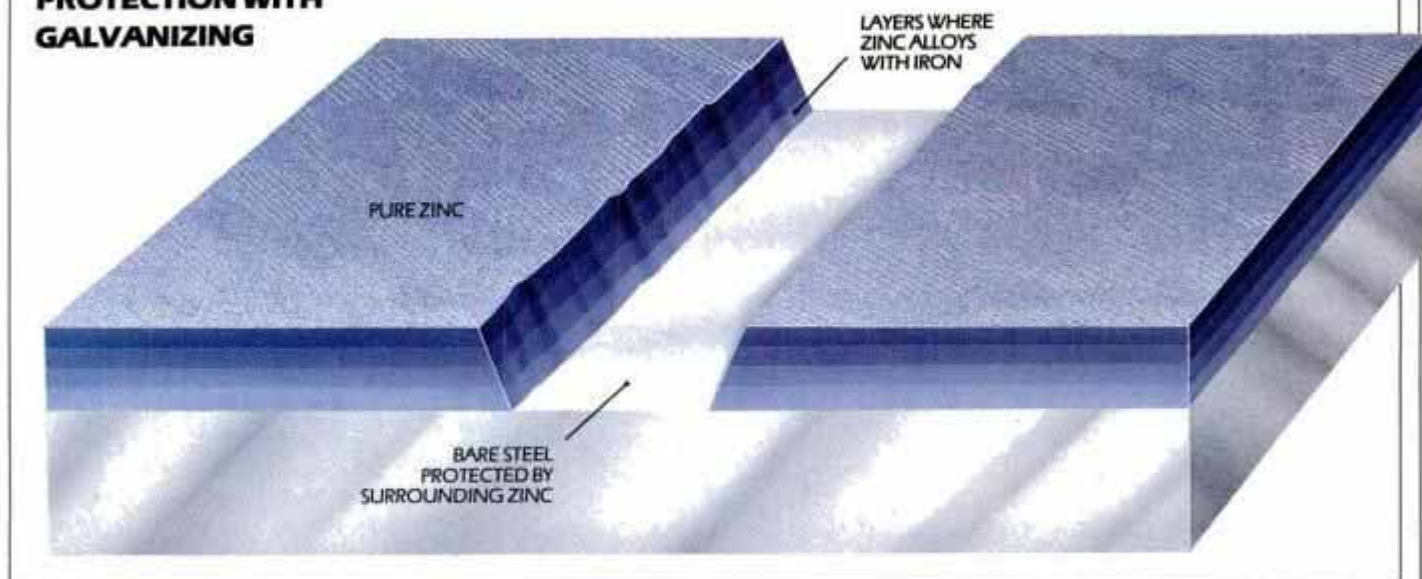
You might wonder why hot-water tanks don't use zinc anodes. The answer: At 120° F and above, zinc loses its effectiveness as an anode. In fact, it completely reverses its effectiveness, causing the steel to become the anode. Early galvanized hot-water tanks, for instance, rotted away quickly. Once manufacturers discovered the problem, they switched to magnesium anodes.

While we're on the subject of galvanizing, take a look at the chart on page 62. This is known as the Galvanic Series. The farther apart metals are on the chart, the greater the corrosion when they come in contact. The separation between zinc and



A scratch or chip through a coating should be repaired as soon as possible. Shortly after water collects on bare steel, the oxygen in the water combines with the iron in the steel and a small amount of iron is dissolved. An electrical imbalance between the solution and the surrounding steel causes a minute current flow. This results in rust and pitting. Rust has greater volume than steel, and this lifts the paint off the surface, which leads to more exposed steel and more rust. Moisture can also penetrate to the steel through pores in the paint film. Multiple coats of paint, with pores misaligned, prevent this.

PROTECTION WITH GALVANIZING



Zinc galvanizing has unique properties that make it valuable as a corrosion-fighting tool. The zinc will corrode before the steel does, sacrificing itself but saving the steel in the process. Even if scratched away, the zinc will protect nearby steel. Also, galvanizing bonds tenaciously to the steel because a metallurgical bond is formed between the two materials. The layers of zinc near the steel form an iron-rich alloy. The alloy layers have progressively less iron as you near the surface of the zinc. The top layer is pure zinc. Although painting will protect a galvanized surface, galvanized steel can be left unpainted. The weathered zinc on the surface forms a protective coating in its own right. Zinc is tough to paint, but we explain how to do it on page 62.

steel indicates how effective zinc is as a protectant when joined with steel.

Now let's take a corrosion tour of a house, starting at the roof.

Flashing

Suppose a piece of flashing works its way loose from your chimney (see illustration on page 62). Ignoring the fact that the flashing was improperly installed, your first idea is to quickly refasten the loose flashing by driving a couple of steel masonry nails into the mortar joints, and then caulking over the nailheads.

Don't do it. Looking at the Galvanic Series, you see that steel and stainless steel are far apart. Galvanic corrosion will result, especially when the caulk breaks down. The steel nailheads that are in contact with the stainless steel will corrode quickly, and the flashing will become loose and fall off. Also, the nails will rust, expand and break apart more mortar, damaging the chimney. Instead, tuck point the joints with mortar where the flashing is loose.

Gutters

If you have old-fashioned steel gutters on your house, clean them well. Tannic acid leaches out of leaves as they lay in your gutters. This acid is corrosive to steel gutters and stains aluminum, so keep the gutters clean.

Don't hold up sagging aluminum gutters with steel nails. Caulking

over the nailheads only buys you a little time. Instead, use aluminum gutter spikes.

Railings

The posts that hold up the handrail will rust from exposure to rock salt, especially where the paint gets chipped by snow shovels. Build up a small mound of mortar or anchoring cement at the base of the posts to ensure that water runs away from the post.

Remember to seal at the base of the post with a good grade of exterior caulk. In case a gap opens up between the masonry and the post, you will need a flexible material to bridge the gap. Silicone and other exterior caulks fill the bill nicely here.

Outdoor woodwork

Galvanized nails are better than non-coated nails, known as bright finish. Countersink nail holes where possible and putty the holes. Screws are also available with weatherproof coatings. If you live in a humid area, or near saltwater, a marine supply store may be able to furnish stainless-steel fasteners. Galvanized hinges, hasps and bolts are likewise preferable to nongalvanized ones.

Plumbing

Avoid connecting copper to steel pipe. Galvanic corrosion of the steel threads will cause plumbing leaks. If

you must join the two materials, separate the metals with a nylon insulation union available at plumbing supply stores. Remember, Teflon tape is not enough to isolate the two metals. Threaded connectors will often pierce the Teflon. And, use plastic pipe when you have a choice, especially with in-ground plumbing, such as sprinkler systems.

Hard water conducts electricity better than soft water. Both copper and steel plumbing will last longer if you install a water softener to deal with hard water. The steel-copper plumbing connections mentioned above corrode more quickly in hard water than in soft water.

Electrical service

Between 1965 and 1973 about 1.5-million homes had aluminum wiring installed. In some early installations, galvanic corrosion occurred at electrical connections where copper met aluminum and moisture was present. This increased electrical resistance and caused arcing. In some cases, it caused electrical fires. Inspecting or repairing aluminum wiring is not a do-it-yourself job. Contact a licensed electrician.

Fuel oil storage tanks

Most homeowners are reluctant to fill the oil tank at the end of the season and would rather keep the money in the bank. But condensation forms

in an empty tank—even one that stores fuel oil. Condensation collects on the tank bottom under the oil and attacks the tank from the inside.

In-ground oil tanks are notorious for leaks. If the tank is more than 15 years old, Dreyman advises to "start budgeting to replace it." Or at least contact your oil dealer to have a zinc or magnesium anode installed next to the tank to extend its life.

Storm doors and windows

Aluminum is not corrosion proof. Brushed-aluminum storm windows and storm doors form "white rust" or oxidation, especially in areas near saltwater. In case you're wondering why the storm windows look better on one side of the house than on the other, oxidation is worse on the side facing the prevailing wind.

There isn't too much you can do here, since it's difficult to paint aluminum. Hardware stores carry an aluminum cleaner that is quite effective at removing the oxidation, though it involves a lot of work. You can also wax and even apply varnish

to brushed aluminum to forestall corrosion. If, however, you're considering replacing storm doors or windows, choose those that are anodized aluminum or factory coated (typically white) because they hold up much better than the older brushed-aluminum models.

This concludes the corrosion tour, but before you get out your toolbox, we have a few more things to say.

Paint: A corrosion tool

It's hard to say too much about paint when discussing corrosion prevention. When painting steel, Dreyman has several words of advice. First, use a primer and topcoat from one manufacturer—that is, don't mix brands on a painting project. To be effective, zinc primers must have at least 84% zinc by weight. Look at the label to determine this or call the paint company's technical service department.

Next, stick with major manufacturers. If you have questions, talk to the store's service people. And remember, most major paint stores have a commercial sales department

that can be very informative.

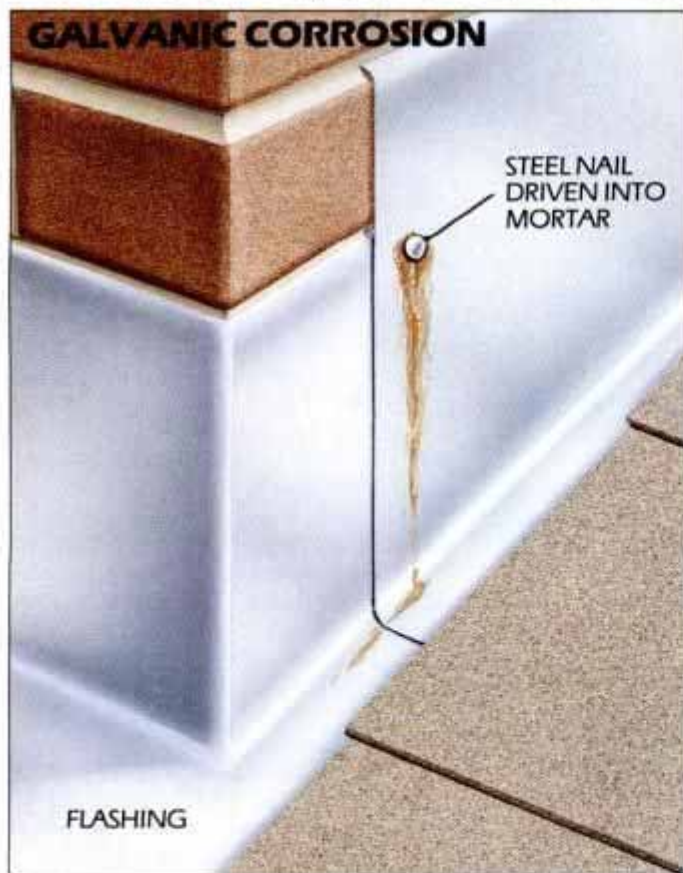
Homeowners can't be paint chemists, but they can rely on trade organizations for good information. For instance, it may be listed on the container if the paint meets Steel Structures Painting Council (SSPC) specifications. And, you can always call the manufacturer and ask if its paint meets SSPC specs.

Military specifications are not easy to meet. The paint can may note that the product within meets certain military specifications. This, too, indicates a high-quality product.

Of course, no matter how good the paint, its success or failure is directly dependent on surface preparation. For some solid tips and techniques on getting ready for paint, please see "Rust Removal," on the next page.

For more information on corrosion, write to:

- NACE International, Technical Activities Group, P.O. Box 218340, Houston, TX 77218-8340.
- American Galvanizers Association, 12200 E. Iliff Ave., Suite 204, Aurora, CO 80014; (800) 788-4258. **PM**



Household galvanic corrosion occurs most frequently from quick and dirty repairs, such as when steel and copper pipe are connected. But the problem can be more subtle than that, and can occur even where steel meets stainless steel—where loose stainless-steel flashing has been tacked down with a steel nail, for instance. The steel nail will corrode badly. To determine which metal will corrode in a galvanic coupling, see the chart at right.



The Galvanic Series is a ranking of metals that tells you which corrode more readily than others. The metals at the top of the chart corrode before those below. That is, the metals above act as sacrificial anodes to the metals below. The farther apart metals are on the chart, the more drastic the corrosion between them when they come into contact. Notice the large distance between steel and copper or steel and stainless steel.

**HOME
 IMPROVEMENT**

**RUST
 REMOVAL**

TEXT AND PHOTOS BY
 ROSARIO CAPOTOSTO,
 Contributing Editor

● Homeowners often deal with rust ineffectively. They often ignore it and paint over it, or they do a poor job removing it. The result is a paint job that doesn't last. However, with a range of inexpensive tools and materials at their disposal, homeowners can fight rust and, in the bargain, produce well-protected metal that gives many years of service, even outdoors.

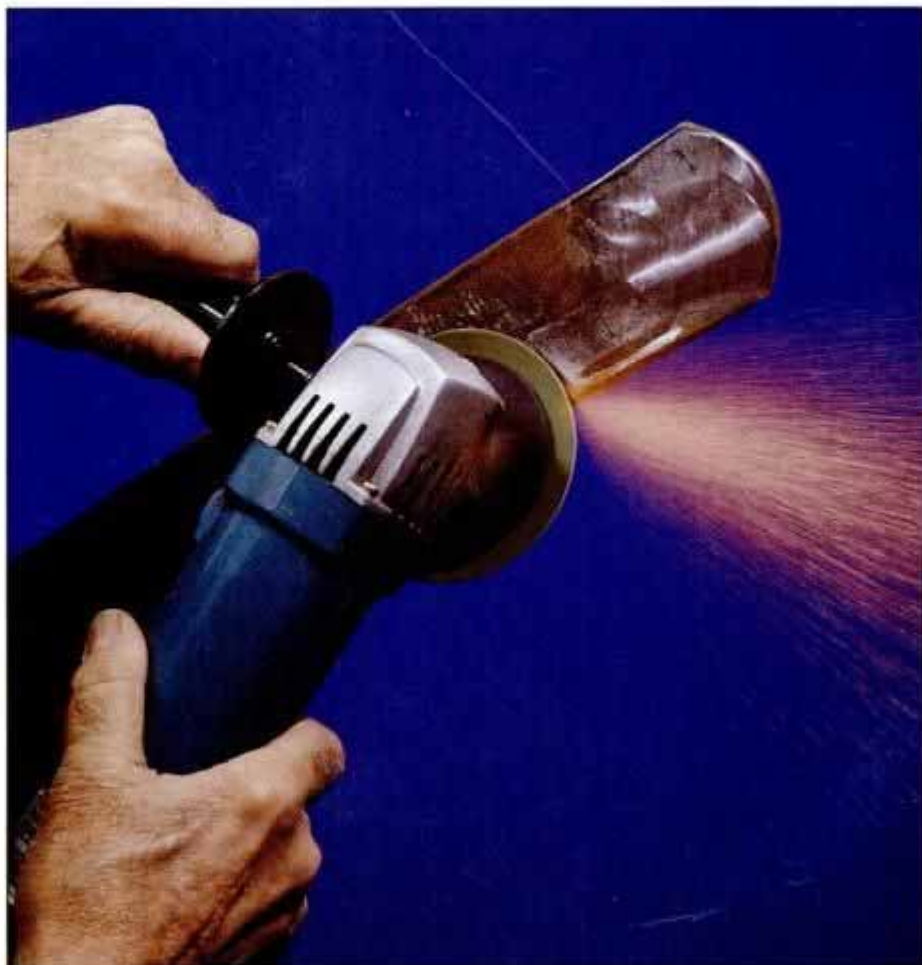
Rust removal

The rust-removal basics are simple. Paint manufacturers recommend that you first clean the surface thoroughly using detergent and water. Let it dry, then remove the rust and deteriorated paint. Finally, wipe off remaining dust with a clean dry rag and paint the metal. Some manufacturers recommend that you use a solvent to clean the bare metal. Check the directions on the can of paint you plan to use. The idea is to start with a clean surface so dirt and oil are not driven into the steel in the process of removing the rust and paint. You should be left with a clean, well-abraded surface that forms a good foundation for the paint.

The most radical rust-removing tool, short of a sandblaster, is a small disc grinder (lead photo). On the other end of the spectrum is the hand wire brush and attachments that chuck into an electric drill (Photo 1). The abrasive wheels and cones produced by Dremel also work well. For example, you can hold a small workpiece in one hand and grind off the rust with a Dremel tool (Photo 2) held in the other hand. If the rust is severe, clamp the workpiece in a vise.

The most versatile rust-fighting tool is an electric drill with a coarse abrasive disc. This is very handy for work on curved surfaces (Photo 3). Often hand tools, such as a wire brush, are teamed with power tools to reach places an abrasive disc can't (Photo 4).

Although not normally thought of as a rust fighter, the belt sander is effective on flat surfaces, especially if



1 A survey of rust-removal products (clockwise from left): abrasive stones in various shapes and abrasive sanding sleeves that chuck into a Dremel motor tool, sander belts, discs that chuck into a hand drill, abrasive strips and pads that you use by hand, wire brushes and chemical corrosion treatments. Don't forget to wear eye protection when using these tools.



2 A Dremel tool can strip rust with a drum and an abrasive sleeve. Small parts can be held while the rust is removed.



3 Use the upper third of a disc sanding attachment when using an electric drill to strip rust on curved surfaces.

the workpiece can be secured to a workbench (Photo 5).

Painting

The best foundation for a rust-resisting paint job is a primer that contains at least 84% zinc by weight.

There are two important things you should know about zinc-rich primers. First, they work best when the surface is well prepared. The zinc must make a good metal-to-metal (electrical) connection with the steel. The other point is that zinc reacts with paint resins, especially alkyds, and forms a crude soap. The process, called saponification, can cause the topcoat to peel away from the primer.

To prevent this, isolate the primer from the topcoat with an intermediate coat. Here, we used Rust-Oleum's Zinc-Sele Primer, followed by Gutter Shield as the intermediate coat and a gloss black alkyd topcoat (Photo 6).

Rusty handrails

Remove the loosest layer of rust and deteriorated paint from a handrail using a wire wheel chucked into a drill (Photo 7). Next, use a stripper (we used 3M's Paint and Rust Stripper) to remove as much of the remaining rust and paint as you can (Photo 8). Work into tight areas with abrasive strips and pads.

After the railing is painted, caulk where the handrail is let into the masonry stoop (Photo 9). This joint is vulnerable to corrosion. De-icing salts attack the base of the post, especially where the paint has been nicked by snow shovels.

Chemical treatments

Rust-treating chemicals don't work well for large and heavy rust-removal jobs, but they're fine on small jobs.

The most common rust-fighting chemical is phosphoric acid Naval Jelly. We demonstrate it here on a sample steel bar that was stripped using the jelly and an abrasive pad (Photo 10). The bar next to it was treated with rust converter. To use this, you scrub off loose rust and apply the converter. It turns the rust into a paint-ready zinc-oxide film.

To clean corrosion off of old-fashioned brushed-aluminum doors and windows, use Aluminum Jelly. Whatever you do, however, don't use a steel-wool pad in this process. Steel-wool particles will embed themselves in the aluminum and form corrosion in their own right. Instead use a cloth or plastic scrubbing pad (Photo 11). **PM**



4 Use a hand wire brush to remove light rust from confined areas, such as the inside rim of a metal chair.



5 A belt sander is an effective rust stripping tool, especially on large flat workpieces clamped to a bench.



6 To stop saponification, use a specialty coating, like Gutter Shield, between the zinc primer and the topcoat.



7 Remove large pieces of loosened paint and loose rust using a wire wheel chucked into an electric drill.



8 Clean off remaining rust with an abrasive wheel. We used the 3M Paint and Rust Stripper with good results.



9 Seal a handrailing's post with a flexible exterior-grade caulk, such as silicone or acrylic latex.



10 Naval Jelly dissolves rust so it can be stripped (left), while rust converters change it into a paintable oxide.



11 Remove corrosion on aluminum using Aluminum Jelly and a rag or plastic pad. Don't use steel wool on aluminum.



SHOP PROJECT

PORCH CLASSIC

An old favorite makes a comeback.

BY NEAL BARRETT

● There are few things in life more restful than sitting in a well-designed rocking chair. It's hard to say whether the relaxation comes from the rocking motion or the gentle, rhythmic squeak of the floorboards. Maybe the enjoyment comes from knowing, as you rock, that you have put business aside for a while. These days, when most of us have so many

demands pulling us in all directions, it's a great pleasure to have a spot dedicated to relaxation.

This chair is built of solid birch, and its construction is a relatively straightforward affair. Since the round back posts are longer than the distance between centers on most home lathes, we shaped the posts using a router table. The front- and

back-seat support rails, as well as the siderails, are cut from $\frac{3}{4}$ -in.-dia. dowels, available at any lumberyard. We chose to paint our rocker, but it would look good if it were simply stained and varnished.

Color photo: J.R. Rost
Black-and-white photos: Neal Barrett
Technical art: Eugene Thompson
Photo stylist: Gabe Herrick

ROCKING CHAIR

26-5/8" WIDE X 35" DEEP X 43" HIGH

DETAIL 1
1/2" DIA. X 9/16" DEEP HOLE

DETAIL 2
1/2" DIA. X 9/16" DEEP HOLE

DETAIL 3
1/2" DIA. X 9/16" DEEP HOLE

DETAIL 4
3/4" DIA. X 5/8" DEEP HOLES FOR RAILS

DETAIL 5
1/2" DIA. X 5/8" DEEP HOLE

DETAIL 6
1-1/4" KERF CLUT IN POSTS
PARE FLUSH

DETAIL 7
EASE ALL EDGES
5/8" PLANE FLAT
GLUE SLATS TO RAILS

DETAIL 8
1/2" DIA. X 1/2" DEEP HOLE ON BOTTOM

FINIAL PATTERN
1-1/8" DIA.
3/4" DIA.
1-3/4" DIA.
3/16" DIA.
1/2" DIA.

BACKREST PATTERN
1-1/8" DIA.
2-1/4" DIA.
1/4" DIA.
1/2" DEEP MORTISE PARALLEL TO TANGENT AT BACK (5 REED.)
20-3/8" RAD.
1-7/8" DIA.
3/8" DIA.
3/16" DIA.
1/2" DIA.

FRONT RAIL PATTERN
1" DIA.
1-1/16" DIA.
TAPER
3/4" DIA.
1-5/8" DIA.
3-1/4" DIA.
5/16" DIA.
8-1/2" DIA.
1-1/2" DIA.

ROCKER PATTERN
7/8" DIA. HOLES AT 90° TO CHORD BETWEEN CENTERS
1-3/4" DIA.
17-1/8" DIA.
EACH SQ. = 1"

SEAT SLAT ASSEMBLY
8-1/2" DIA.
7/8" DIA.
2-3/4" DIA.
1-11/16" DIA.
18-3/8" DIA.
1/4" DIA.
1/4" DIA.
3-3/8" DIA.
11" DIA.
3/4" DIA.

MATERIALS LIST—ROCKING CHAIR

Key	No.	Size description (use)	J	2	3/4"-dia. x 17 1/2" birch (siderail)
A	2	1 1/4"-dia. x 20 3/4" birch (post)	K	1	3/4"-dia. x 23 3/4" birch (seat support)
B	2	1 1/2"-dia. x 41 1/2" birch (back post)	L	2	3/4"-dia. x 18 1/4" birch (back rail)
C	1	1 1/4"-dia. x 23 1/4" birch (rail)	M	5	1/2 x 2 1/4 x 20 1/2" birch (back slat)
D	2	2 1/4 x 2 3/8 x 18 1/4" birch (backrest)	N	2	1/2"-dia. x 1" birch (post dowel)
E	2	3/4 x 4 1/4 x 18 3/8" birch (armrest)	O	4	1/8 x 3/4 x 2" birch (wedge)
F	2	1 1/2 x 6 x 35" birch (rocker)			
G	5	1 1/16 x 2 3/4 x 18 3/8" birch (slat)			
H	2	1 1/16 x 3 3/8 x 18 3/8" birch (slat)			
I	2	1 1/4"-dia. x 2 1/4" birch (finial)			

Misc.: Sandpaper, glue, exterior-grade alkyd primer and enamel.

Making Posts

Begin the project by making two full-size drawings: one of the front post profiles and another showing how the posts and rails intersect. The second should include the rail centerlines.

Cut the blanks for the four posts, but leave the front posts $\frac{1}{2}$ in. long so they can be turned on the lathe. Then, mark centerlines across the post tops and bore the $\frac{1}{2}$ -in.-dia. holes for the finials and dowels.

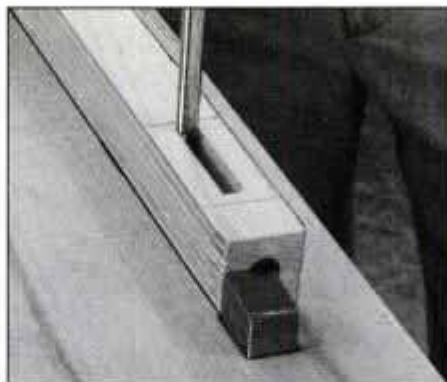
Next, lay out the mortises for the backrests and the front and back rails. Clamp the posts to the workbench, and cut the backrest mortises with a plunge router. Square the mortise ends with a chisel (Photo 1), then move the posts to the drill press. Using an auxiliary fence, bore the front- and back-rail mortises with the posts clamped to the fence.

Round the four posts in four passes using a $\frac{5}{8}$ -in.-dia. rounding-over bit in the router table (Photo 2). Use pushsticks toward the end of each pass to stay clear of the cutter.

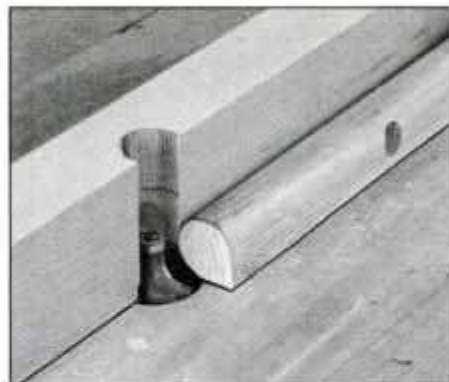
Next, make a template of the bulb on the front posts. Mount a front post on the lathe with a live center in the dowel hole. Transfer the layout from the template to the post (Photo 3), and cut the bulb. Mark the top limit of the $\frac{3}{4}$ -in.-long tenon, and cut the tenon as well as the tapered section above it.

The back posts are too long for the lathe, so shape their tenons and tapers by hand. Mark a $\frac{3}{4}$ -in.-dia. circle on the bottom of each post (Photo 4). Then mark the tenon length, and cut on this line using masking tape on the dovetail saw to mark the depth of cut (Photo 5). Carve the tenon to rough size with a knife. Then smooth it to final diameter with a rasp (Photo 6). Test fit the tenon using a block with a hole bored in it. Then use a spokeshave to shape the taper above the tenon (Photo 7). Turn the post as you work to achieve a uniform taper.

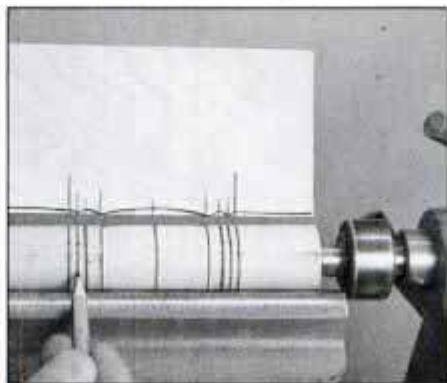
Stand the front posts on the drawing of the posts and rails. Position the posts so their front-rail holes are aligned with the centerlines for the front rails. Now, mark the position of the siderails using these centerlines (Photo 8). Stand the back post on the drawing, and repeat this procedure. Extend these marks along the posts, and then mark across the posts to establish the center of the siderail mortises. Bore the rail mortises with the posts clamped to the fence on the drill-press table. Also bore the mortise for the armrests.



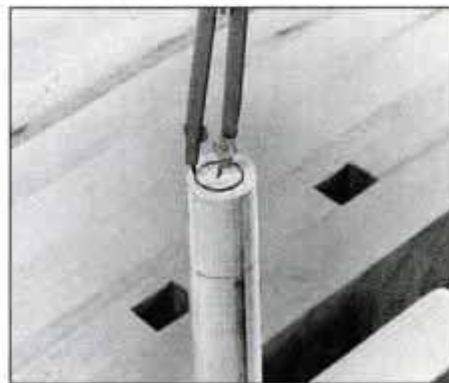
1 Cut the backrest mortises in the back posts with a plunge router, and then chop the ends of the mortises square.



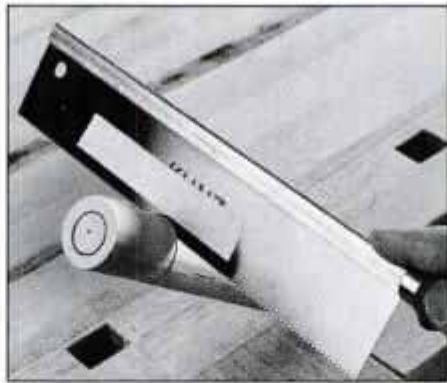
2 Shape the chair posts on the router table using a large rounding-over bit. Make four passes per post.



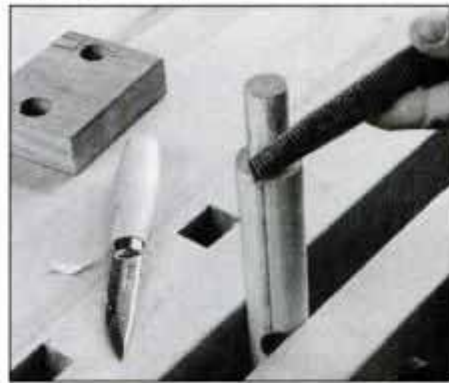
3 Make a template of the decorative bulb. Transfer the shape to the post while it spins on the lathe.



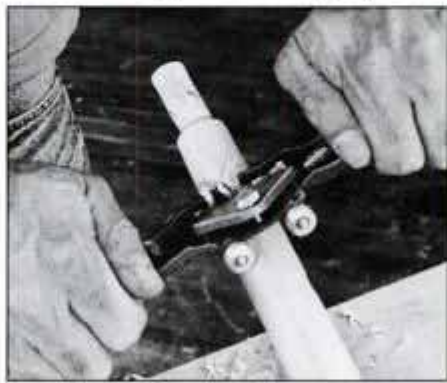
4 The back posts are too long to fit on the lathe, so shape their tenons by hand. Begin by marking the tenon diameter.



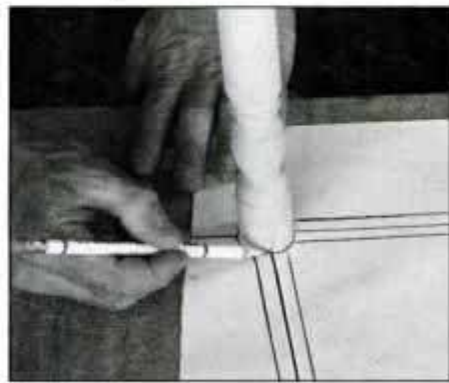
5 Mark the length of the tenon, and then saw on the line. Mark the depth of cut on the saw with a piece of masking tape.



6 Carve the posts to rough diameter with a knife. Then bring them to final diameter with a rasp.



7 Cut the taper on the back posts using a spokeshave. Turn the post as you work to keep the taper uniform.



8 Mark the position of the siderails on the front and back posts using a full-size drawing as a reference.

Making Rails, Slats And Rockers

Rip and crosscut the blank for the front tapered rail about 1 in. over-long. Turn the blank to size, and cut the decorative center portion to shape. Cut the taper on each side of the center. Because the rail is thin and long, use a steady rest when cutting the taper to prevent the workpiece from chattering (Photo 9). Sand the rail on the lathe and crosscut it on the table saw using a miter gauge.

Rip and crosscut a blank that is wide enough to make the top and bottom backrests. Next, lay out the curve on the edge of the backrest, and use the table saw and miter gauge to cut the tenons on the blank (Photo 10).

Cut the outside curve of the backrest on the band saw. Then remove the saw marks, and refine the shape using a plane and scraper (Photos 11 and 12). Cut the inside curve, and use a spokeshave and scraper to smooth it.

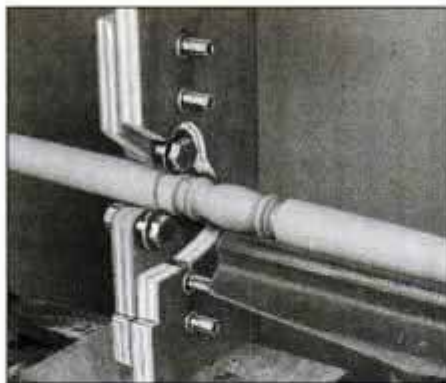
Rip the blank into two backrests, and lay out the back-slat mortises. Remove the bulk of each mortise by boring on the drill press (Photo 13). Then use a sharp chisel to pare the mortise walls parallel and the ends square.

Mark the tenon shoulders at the top and bottom edge of each backrest, and cut the shoulders with a dovetail saw. Then, dry-fit the backrests to the posts, and trace around each backrest on the post. Using this outline as a guide, chisel a flat surface around the rail mortise (Photos 14 and 15).

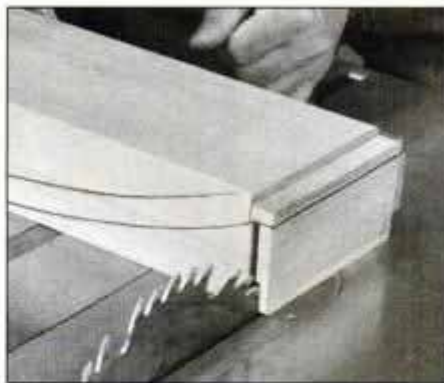
Trace the armrest shapes onto blanks of 3/4-in.-thick stock. Then, use the table saw and miter gauge to cut three sides of each tenon before cutting out the armrest (Photo 16). Cut out the armrests on the band saw. Then finish cutting the tenons with a dovetail saw. Smooth the armrest edges with a plane and a spokeshave. Then shape the corners with a 1/4-in.-rad. rounding-over bit in the router.

Dry-fit the armrests to the back posts and trace the armrest ends on the posts. Cut a flat surface around the post as was done earlier. Then, cut the rockers from a 1 3/4-in.-thick blank using the band saw, and smooth the cut edges with a plane, spokeshave and scraper.

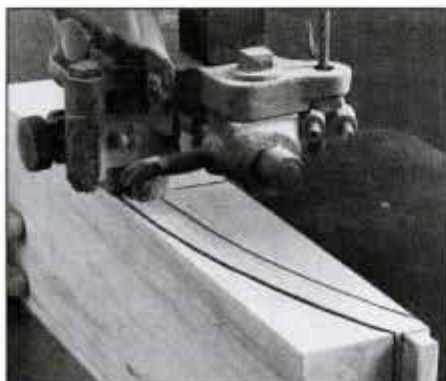
Note that the holes in the rockers that accept the post tenons are perpendicular to a chord that runs between the hole centers. To mark the



9 The bottom rail is too thin to turn without support. Use a steady rest to keep it stable as it is shaped.



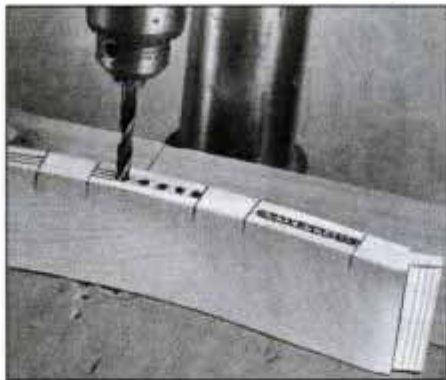
10 Cut the tenons on the backrests using the table saw and miter gauge. Make several passes for each face.



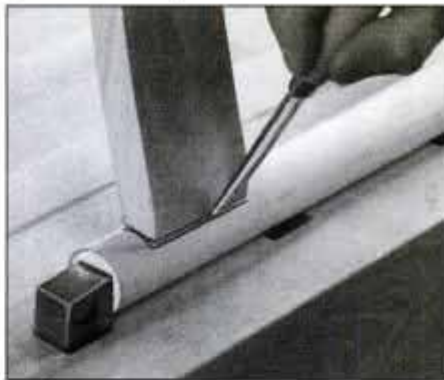
11 Cut the backrests to shape on the band saw. Stay just to the waste side of the line, and feed the workpiece slowly.



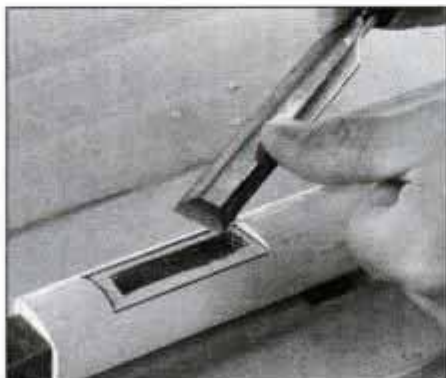
12 Remove the saw marks from the outside of the backrest using a block plane and a scraper.



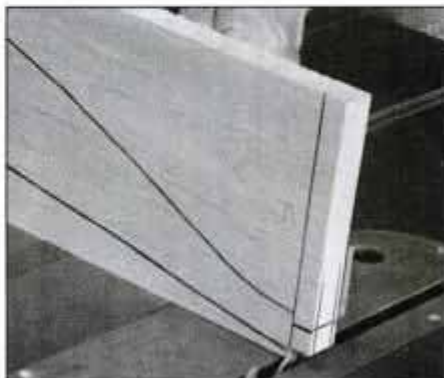
13 Rip the backrest blank in half. Mark the slat mortises on the backrest edge and bore them on the drill press.



14 Press the backrest tenon into the post mortise and trace around it with a knife or sharp pencil to mark the flat.



15 Pare the shallow flat around the mortise using a chisel. This is not difficult, but it does require a sharp chisel.



16 Using the table saw, cut the tenon on the armrest. Hold the workpiece on edge against the miter-gauge fence.

proper angle for the holes, cut a block to $17\frac{1}{8}$ in. long (the distance between these centers). Place the block from center to center, and use a square to mark the angle along the side of the rocker (Photo 17). Cut scrap blocks to support the rocker on the drill-press table at the proper angle, then bore the holes (Photo 18). Different blocks will be required for front and back holes.

Rip and crosscut the chair-seat blanks, and then cut their edge and face profiles on the band saw. Smooth the slat surfaces with a spokeshave and scraper, and ease the slat corners with a rasp and sandpaper.

Cut the wedge kerfs in the bottom of each post and turn the decorative finials for the top of the back posts. Most of the turning can be done with the finial between centers. To complete the finial, mount it in a "pot" chuck. This device is formed by boring a hole in the center of a wood block mounted on the lathe faceplate (Photo 19). The turned dowel on the finial's end makes a friction fit in this hole while the top is completed. Glue the finials to the post tops.

Cut the remaining rails from dowels and plane a flat on the front- and back-seat support rails (Photo 20). Rip and crosscut the backrest slats then presand all parts before beginning assembly.

Assembly

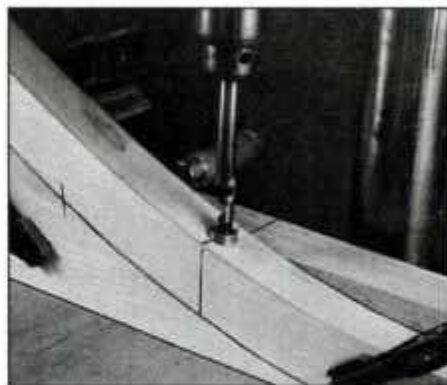
Glue and clamp the front rails to the front post and check the diagonal measurements of the assembly (Photo 21). Then, slide the back slats into the backrests and glue and clamp the back posts to the backrest assembly (Photo 22).

Next, glue and clamp the siderails to join the front and back subassemblies. Then install the short dowels to the tops of the front posts, and glue and clamp the armrests in place (Photo 23). Turn the chair upside down, and apply glue to the rocker mortises, post tenons and the kerfs in the tenon ends. Slide the rockers over the tenons, apply glue to the wedges and tap the wedges in place. After the glue sets, cut the tenons and wedges close to the rocker bottoms. Then trim them flush with a sharp chisel.

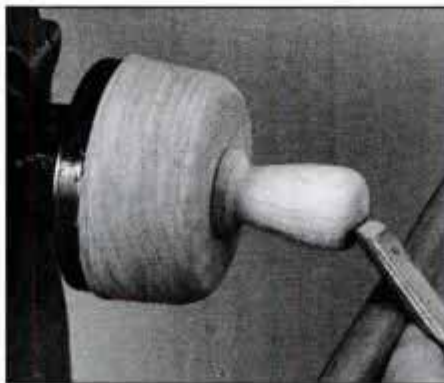
Glue and clamp the seat slats to the seat support rails using a scrap piece of plywood between the slats to ensure even spacing (Photo 24). Finish up by applying a good-quality exterior primer and enamel, following the directions printed on the can. **PM**



17 Prior to boring postholes, mark the posts' positions on the rockers, using a square and a square.



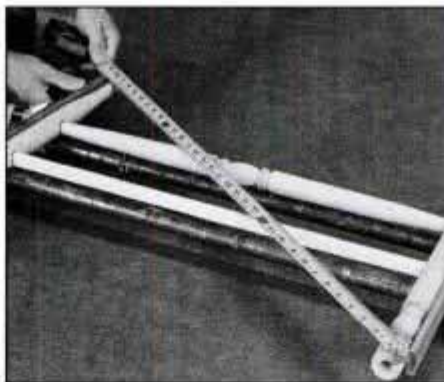
18 Bore the postholes in a rocker on the drill press. Support the rocker with a curved wedge underneath it.



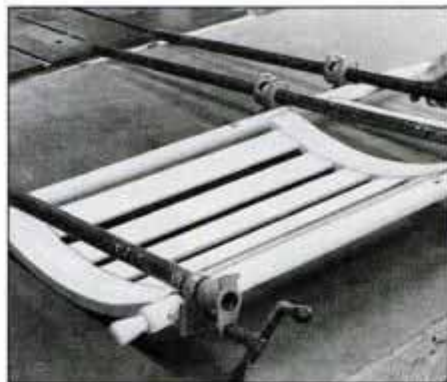
19 Fit the finial's dowel through a block of wood secured to a faceplate. Turn the finial to final shape.



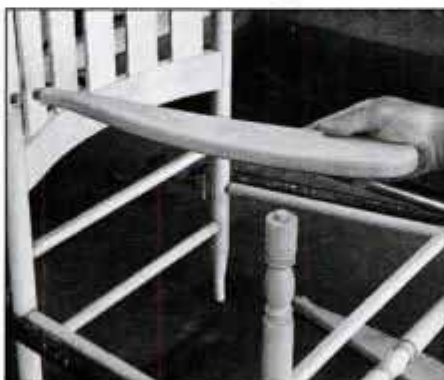
20 The seat support rails are made from birch dowels. Clamp a rail to the bench and plane a flat on one face.



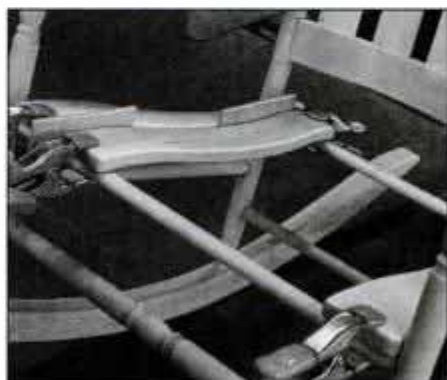
21 Glue and clamp together the front posts spanned by the rails. Check diagonal measurements and let the glue set.



22 Glue and clamp together two back posts spanned by the backrests with slats and the two back rails.



23 Fit the armrests in place after the front and back subassemblies have been glued and clamped together.



24 Finish up construction by gluing and clamping the seat slats to the rails. Use alignment spacers between the slats.

HOME IMPROVEMENT

ETCHING GLASS

BY NEAL BARRETT
PM Illustrations by
George Retseck

● If you've ever stopped to admire an etched-glass door, window or mirror, you know that the effect is both unique and stunning. The combination of clear polished glass with a delicately contrasting frosted geometric or pictorial design enhances just about any setting. What you may not know, however, is that you can etch glass right in your own home or shop with a few simple, easy-to-master techniques.

Glass etching involves frosting or abrading the glass surface to create a dull, nontransparent area. The three most common methods for getting the job done are acid-cream etching, sandblasting and diamond-burr engraving. Each of these techniques can be approached with a modest investment of time, space and cash.

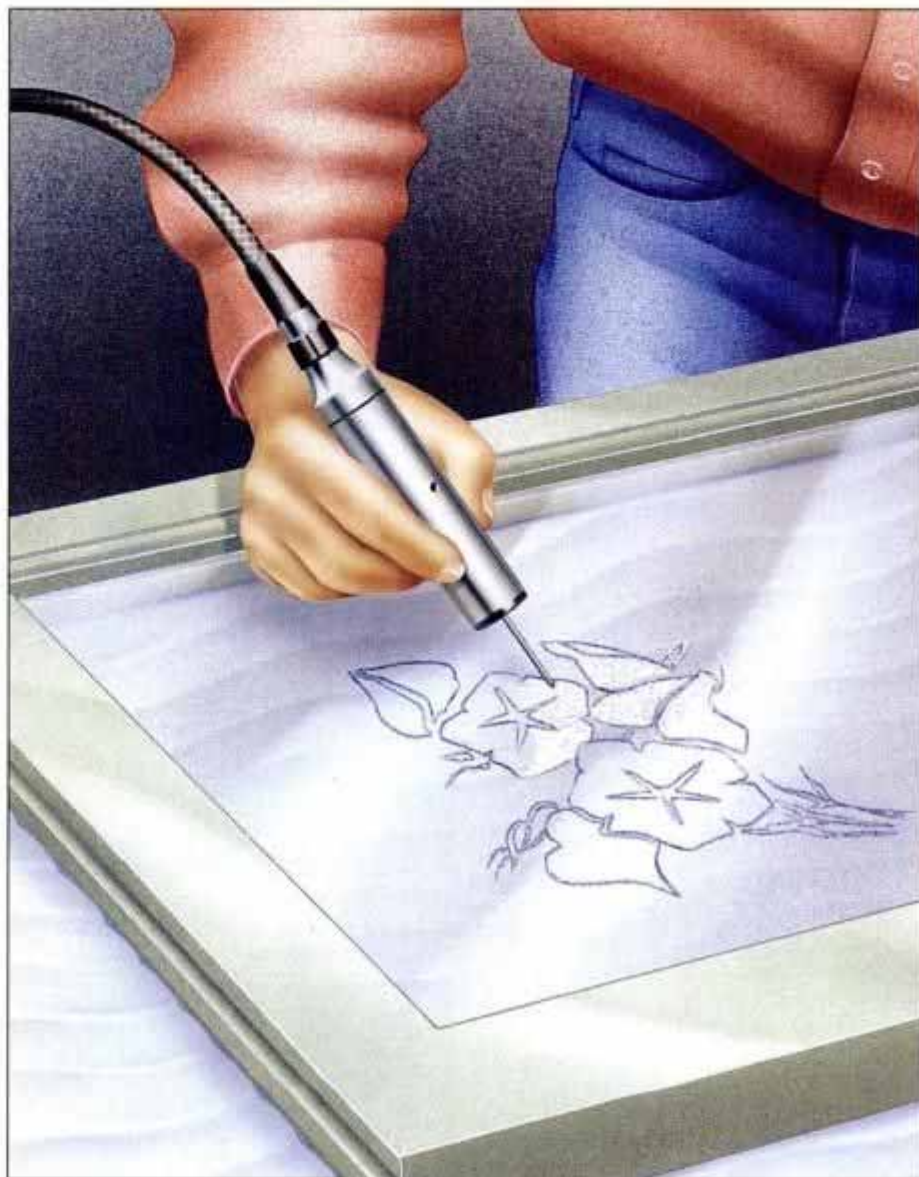
Etching glass not only makes an enjoyable project, but the results add character to your home. Whether you choose to etch an entry door, sidelight panel, bathroom window or mirror, you have the ability to transform ordinary architectural and design features with distinctly personal detailing.

Getting started

When choosing glass to etch, keep in mind that the best material to work with is 1/4-in.-thick plate glass or laminated safety glass. Standard 1/2-in.-thick window glass can be used, but the results will not be as good. And, thinner glass is more apt to break when placed under the mechanical stresses of diamond-burr engraving and sandblasting. If you wish to work with 1/2-in. glass, the best technique is acid etching.

The only type of glass that should not be etched is tempered glass. Tempered glass has been heat treated in a way that creates great tension within the material. When the surface is etched, the internal stresses may cause the glass to shatter. Generally, tempered glass is labeled as such in a corner of the pane.

If you are planning to etch a door



or window with double-glazed panes, you should check with the window manufacturer to see if you will void any warranty by etching. In this case, it might be better to etch another panel and mount it over the insulated pane.

There are many sources of designs for your glass project. Check your local library or book store for books that feature stained-glass patterns and traditional designs. Dover Publications (180 Varick St., New York, NY 10014) offers a variety of books on period and cultural designs in the Dover Pictorial Archive Series. Of course, you can develop your own design to give your project a personal touch. The only limitation to keep in mind is that block designs with broader etched areas work better than thin-line drawings. Regardless of the technique you choose, begin by making a full-size drawing of your design to transfer to the work.

While you're in the planning stage, consider whether the lines and areas you draw will be etched into the glass surface or whether the background will be etched and the design left clear. Often the ultimate use of the panel will be the deciding factor in this regard. When the design is to serve as a decorative embellishment on a window or mirror, the design itself is etched to maintain broad transparent areas. For increased privacy, however, etch the background and leave the design in clear glass. Experimentation is the best way to decide which result you want to achieve.

Acid-cream etching

This technique utilizes an acid to erode the surface of the glass. Because it requires little in the way of special tools, the process provides a relatively inexpensive option for etching glass. The acid is a dilute

form of hydrofluoric acid in a cream-like consistency. It's brushed on the surface of the glass over a vinyl stencil, then washed off to reveal the etched pattern. While this technique is the easiest and least expensive, it's also the most limited in the results that can be achieved—diamond-burr engraving and sandblasting both of-

fer more control over the depth and texture of the etching.

Many arts-and-crafts suppliers offer kits for acid-cream etching. The Woodworkers' Store (21801 Industrial Blvd., Rogers, MN 55374) sells a kit—No. 68544, about \$21—that includes all the supplies you need to begin etching, including cream,

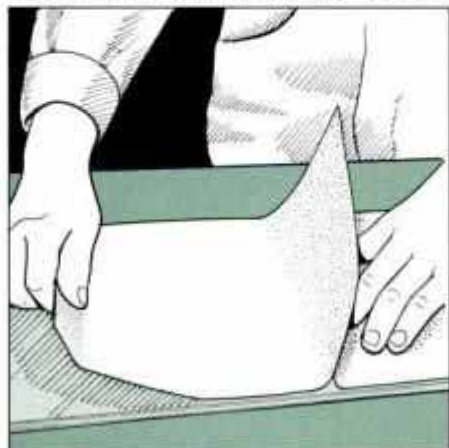
cleaner, brush, gloves and pre-designed stencils. For those who prefer to work with their own designs, individual supplies are available from art suppliers and local stained-glass studios or through the mail from Sunshine Glassworks Ltd., 240 French Rd., Buffalo, NY 14227. You will need the etching cream (we used Armour Etch glass etching cream), an acid-resist stencil material (we used 4-mil acid etch resist), a disposable brush, heavy rubber gloves and eye protection.

Begin by thoroughly cleaning the glass surface with denatured alcohol (Fig. 1). Peel about 1 in. of the backing paper from the vinyl stencil material and carefully adhere this edge to the glass in the desired area. Slowly pull the backing off the vinyl while you smooth the vinyl to the glass with the other hand (Fig. 2).

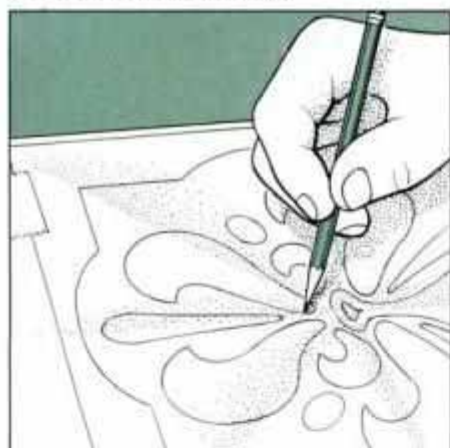
Be sure to eliminate any bubbles or wrinkles in the stencil material as you go. The vinyl should extend beyond your intended design area at least 2 to 3 in. in all directions to ade-



1 To prepare for acid etching, first remove oil and dust from glass by wiping with alcohol. Then, allow to dry.



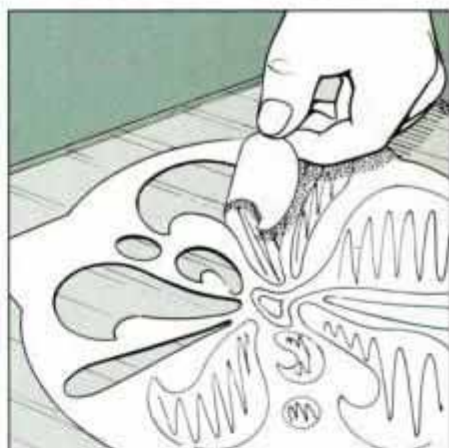
2 Peel backing from stencil material and apply to glass. Apply vinyl slowly while smoothing out bubbles and wrinkles.



3 With your drawing taped in place and carbon paper underneath, trace your pattern with a sharp pencil.



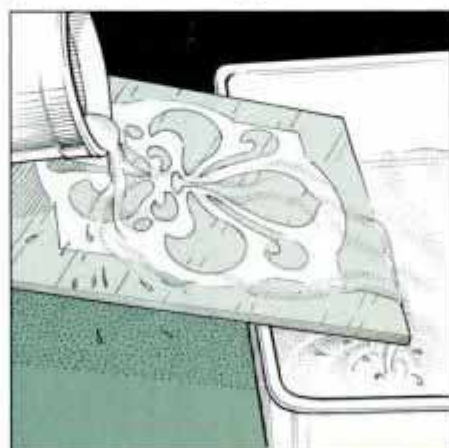
4 Use a sharp razor knife to cut the stencil. A swivel-blade knife is best for patterns that have many curved lines.



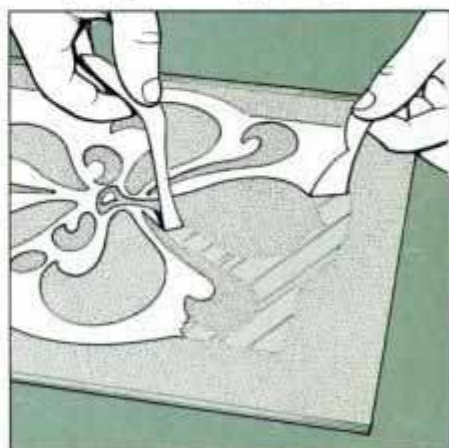
5 Carefully peel away the stencil in the areas to be etched. Examine the cuts and fix any wavy lines or ragged edges.



6 With newspaper or a plastic sheet under the work, apply acid cream to the glass and let it stand for 10 minutes.



7 Rinse away the cream with plenty of cold water. Don't rinse into a porcelain sink to avoid etching the sink's surface.



8 After etching and rinsing, remove the stencil to reveal the finished pattern. Then, clean the surface with glass cleaner.

quately protect the glass. If you are working on a panel within a wood or metal frame, protect the frame from contact with the acid cream.

Use masking tape to fasten your full-size drawing to the glass, with carbon paper (carbon side down) between the drawing and the stencil material. Carefully trace your pattern with a sharp pencil to transfer it to the stencil (Fig. 3).

The best way to cut the stencil is with a sharp razor knife. When your design incorporates straight lines, use a straightedge to guide the knife. For designs that involve many curved lines, the best tool is a swivel-blade razor knife. These knives, available at most art supply stores, allow you to change the direction of the cut without rotating the knife, resulting in a smoother edge (Fig. 4).

After you have cut the stencil, carefully remove the resist material in the areas that are to be etched. Examine the stencil and make any adjustments to fix wavy or ragged edges (Fig. 5).

Place several layers of newspaper or a polyethylene sheet under the work to protect your worktable, and be sure to wear heavy rubber gloves and eye protection when you work with the acid cream.

Use a brush to apply a thick coat of cream on the exposed glass surface, lapping it about 1/2 in. over the cutout stencil edges. Brush the cream over the glass in several directions to ensure complete coverage of the design (Fig. 6). Leave the cream on the glass for about 10 minutes, then wash it off with plenty of cold water. Do not rinse into a porcelain sink as the acid may etch the sink's surface. Instead, wash the cream into a large plastic basin first, diluting it with lots of water (Fig. 7). If possible, use a hose to wash off the cream outdoors.

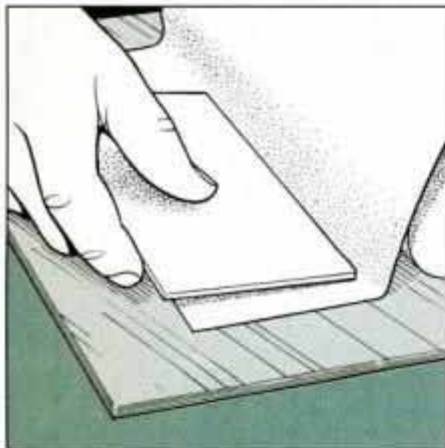
Examine the design to be sure that the etching is even and complete, and reapply the cream if necessary. When you are satisfied with your results, peel off the resist material and clean the panel with glass cleaner (Fig. 8).

Sandblasting

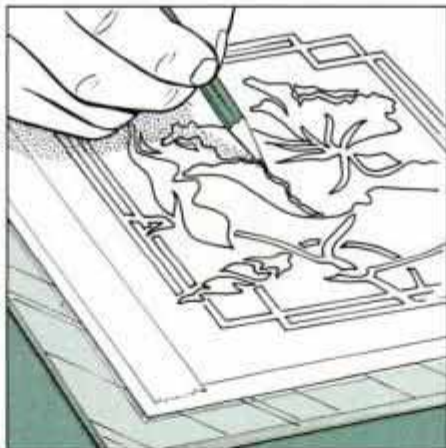
If you already own an air compressor, you're well on your way to having the equipment you need to etch glass by sandblasting. You also need a sandblaster—a spray-gun-type tool that uses compressed air to drive the abrasive particles under pressure. Tool dealers that sell air compressors usually carry sandblasters as well, or check your Yellow Pages under sandblasting to locate dealers for equipment and supplies. If you'd rather not buy the equipment, it's usually available through rental outlets for use on a short-time basis.

The blasting medium used for glass etching is either silicon carbide or aluminum oxide. Different textures can be achieved by using either finer or coarser grits. These materials should be available where you buy or rent the sandblaster.

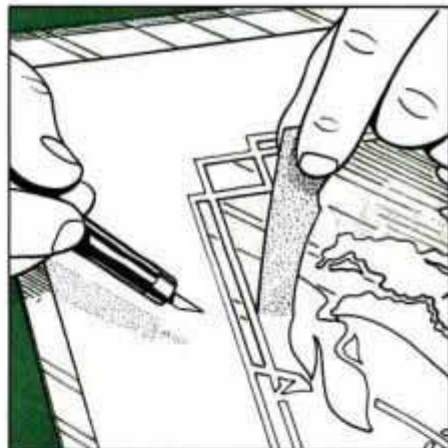
In its preparatory stages, the technique of sandblasting glass has much in common with the acid-etch method. The method of preparing the glass panel is almost identical,



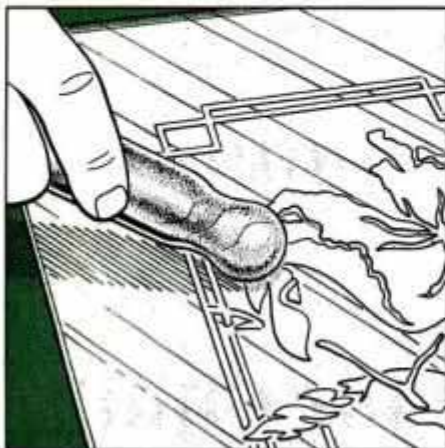
9 Apply the sandblasting stencil material to the glass and use a plastic squeegee to ensure good contact.



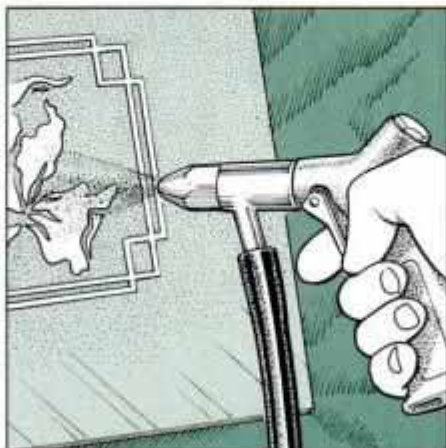
10 Place carbon paper under your drawing, and transfer the design to the stencil material with a sharp pencil.



11 Use a sharp razor knife to cut the stencil material to the lines. Then peel away the areas to be sandblasted.



12 Check that the stencil makes good contact with the glass. Use a rounded screwdriver handle to press edges to glass.



13 Prop up the work and make a series of overlapping passes with the sandblaster. Wear a respirator and goggles.



14 When you're satisfied with the results, remove the remaining stencil material and clean the glass surface.

although the resist medium is different. We used a 4-mil sandblast resist (available from Sunshine Glassworks). This material is sold in 12-in. squares and rolls.

Apply the resist to the glass in the same manner as described for the acid technique. Here, though, it is even more important to eliminate



15 After taping your design over the wax transfer paper, trace your pattern carefully to mark the glass.



16 With the pattern attached at one edge, examine the tracing. Check for missing or incomplete lines.



17 Use a flexible-shaft tool with a diamond burr to engrave the design. Be careful not to smudge the wax lines.



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any bubbles in the material. Use a plastic squeegee to smooth the resist onto the glass as it is applied (Fig. 9). If any bubbles remain, the sandblasting material could tear the resist at those points, ruining the design.

Using carbon paper, trace your design onto the stencil material (Fig. 10). Then, use a razor knife to cut to the lines and remove the stencil material in the areas that are to be etched (Fig. 11). Use the round end of a screwdriver handle or a similar hard, smooth tool to press the stencil along the pattern lines to ensure good contact (Fig. 12).

Sandblasting offers the possibility of quite varied and interesting techniques, such as shading, texture variation and multilevel etching. However, for the beginner, a single-level etching is an appropriate place to start.

Sandblasting is, by its very nature, a messy process, and professionals generally use specially designed cabinets to control the dust and recover the blast media. While this option is beyond the range of the home craftsman, a viable alternative is to work outdoors with a heavy dropcloth behind the work to catch the dust.

It is extremely important that you

use a good-quality respirator that fits properly. Goggles that completely protect your eyes are also necessary. The dust produced by the blasting process is hazardous if inhaled or allowed to contact the eyes, so these precautions are vital.

Once again, if you are etching a design on a door or window pane, protect the frame from the blast stream, as the painted surface can be damaged by the abrasive particles.

To proceed with the blasting, prop your stencil-covered glass panel in front of the dropcloth. Holding the blasting gun about 4 to 6 in. from the glass, and with the compressor set at 30-psi to 40-psi pressure, make a series of passes over the glass. Begin at the top edge of the panel and overlap your blast pattern slightly with each pass to be sure that you cover the entire surface to be etched (Fig. 13). It is usually necessary to go over the entire panel several times to evenly etch the surface.

Wipe the dust off the glass, and carefully examine the panel to see if the etching is even and complete. Repeat the process if necessary. Then remove the resist material and clean the glass (Fig. 14).

Diamond burr etching

The third technique for etching uses diamond burrs to engrave a pattern directly into the glass surface. The burr is driven by a flexible-shaft grinder. These units have a motor of 1/8 to 1/4 hp, connected by a flexible shaft to a handpiece which holds the burr. The most readily available of these units are made by Dremel and Foredom, and they're sold through woodworking and carving supply dealers. The diamond burrs come in a wide variety of sizes and configurations. We found the most useful shapes to start with were a conical-shaped and a ball-shaped tip, each about 5/32 in. in diameter. The best shape to use depends upon the design you are engraving.

The first step in this process is to transfer your design onto the glass surface. If you wish, you can draw directly onto the glass using a thin wax pencil. However, it's best to make a full-size drawing first and then trace this onto the glass. To make the tracing, use a waxy tracing paper such as that used to transfer sewing patterns onto fabric. We used Dritz Trace-B-Gone tracing paper, which is sold at fabric stores. When you trace over this paper, a wax line is transferred to the glass. Tape your pattern to the glass panel with the transfer paper beneath, and trace the design with a sharp pencil (Fig. 15). Then, lift the paper to check that you have a clear pattern to follow (Fig. 16).

Wear a dust mask and eye protection when you engrave. Begin by using the edge of the conical diamond burr to engrave the outlines of your design into the glass surface. Note that the waxy image traced onto the glass is rather delicate, so you must be careful not to smudge the design as you work.

After the outlines are cut into the glass, proceed to fill in the body of the design. At this point, use a sponge or rag to spread water over the glass surface as you work. The water both cools the cutting tip to prolong its life and keeps the glass dust from becoming airborne. The water makes it a little more difficult to see the engraved surface, so periodically wipe the surface dry to check your progress (Fig. 17).

One of the nice features of this technique is that it gives you the ability to manipulate details of the design in terms of texture and depth of cut. After only a short time you will begin to see the wide variety of results that are possible.

PM

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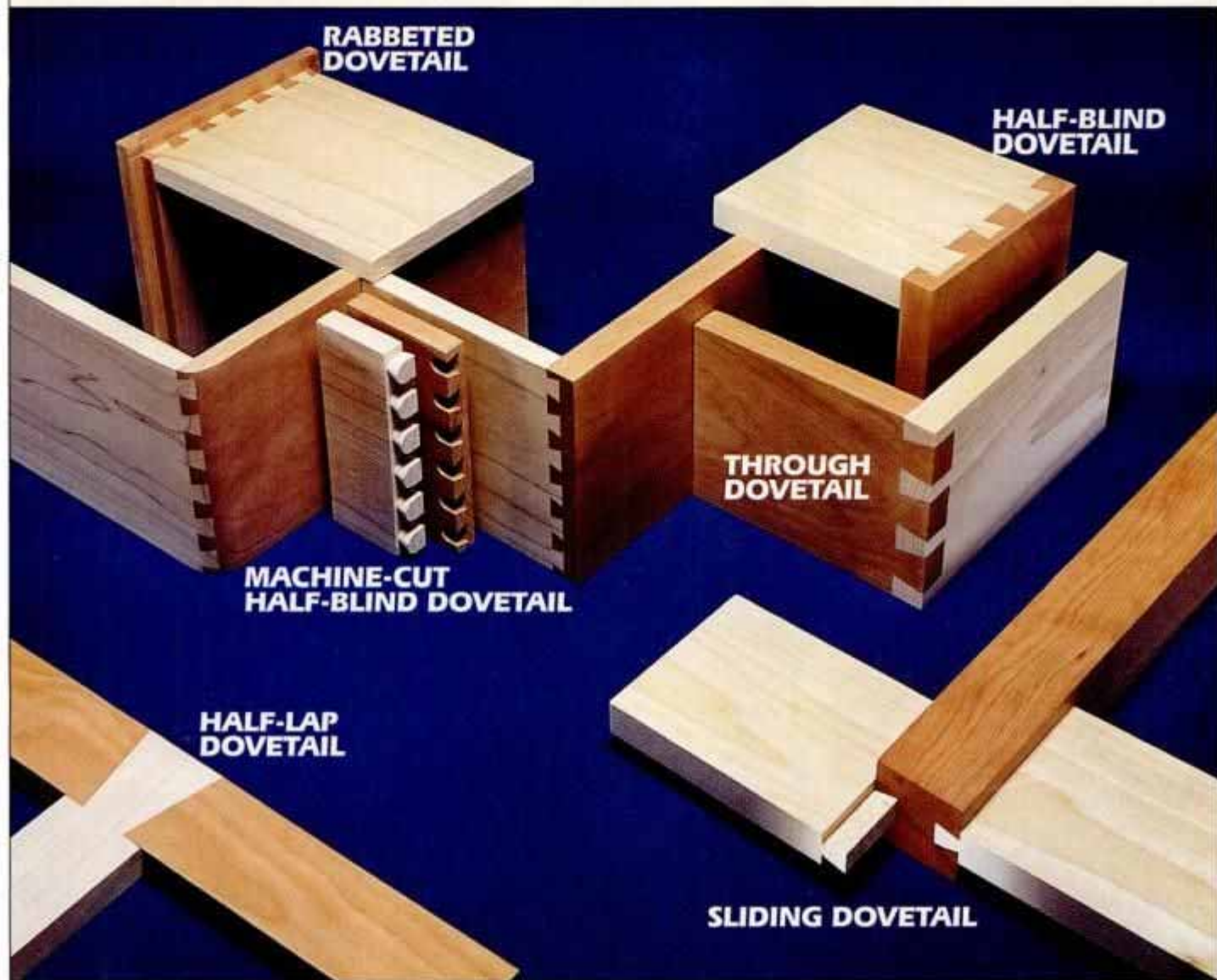
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**SHOP
 TECHNIQUES**
**DOVETAIL
 JOINTS**

TEXT AND PHOTOS BY
 ROSARIO CAPOTOSTO,
 Contributing Editor

● Of all woodworking joints, the dovetail stands in a class by itself. It's not only very strong, but its visual appeal makes it the choice for fine furniture and cabinet construction. Traditional handmade dovetails involve careful layout and painstaking work with a saw and chisel. However, the payoff is in a great sense of accomplishment and pride of craftsmanship. On the other hand, if speed is a priority, the router and a dovetail jig can be used to cut the joints.

Dovetail variations include the through, half-blind and rabbeted dovetails as well as the sliding dovetail and the half-lap dovetail. The through dovetail is a joint that is visible on both surfaces, and the half-blind dovetail is visible only on one surface. The rabbeted dovetail, also half-blind, is commonly used for assembling a drawer that has a rabbeted overlapping front. The sliding dovetail can be used for joining rails to legs or attaching endcaps to breadboard assemblies without glue. The single half lap is useful for assembling narrow-width frame members.

To make the best use of dovetail joints, it pays to know how to make them with both hand and power tools. With the exception of a few sophisticated router accessories, dovetail jigs produce dovetails of uniform size and spacing. The advantage of doing the job by hand is that you can vary the size and spacing of the dovetails.

**Handcut Through
 Dovetail**

The through dovetail joint is comprised of angled pins that interlock with tapered tails cut on the adjoining piece. Although the entire joint is called a dovetail joint, the term tail specifically refers to the angled cuts laid out on the board face. The angled cuts laid out on the end of the adjoining piece are called pins. The first and last pins are called half-pins because they are sloped on only one side. These need not be half the width of the full pin. However, for strength and appearance, the end pins should never be made too small.

Layout

Typically, the slope of the dovetail taper should be within 1:5 through 1:8 in proportion (about 78° to 83°). This and the size and spacing of the pins and tails are variable, as there are no hard and fast rules. As a general guideline, however, use a wider-flare

dovetail for soft wood, and where strength is of prime importance, the pins and tails should be about equal in size. As for deciding which piece gets the tails, make your decision based on the structural requirements of the object. Because dovetails lock in only one direction—parallel to the piece that holds the tails—plan for the tails to be in line with the greatest stress. In a drawer, for example, the greatest stress is on the front panel in a direction parallel to the drawer sides. Therefore the sides get the tails to mechanically resist the stress on the joint when the drawer is pulled open.

The pins are usually made first, and the completed piece is then used as a pattern for tracing the outline for the tails on the mating piece. To simplify designing the joint, first make a full-size drawing on paper. When sizing the sockets (the spaces in between the pins), make sure the width is not smaller than the width of your smallest chisel.

Cut the stock squarely to size and mark a baseline on the face to indicate the depth of the sockets. Make the distance from the baseline to the board end the same as the thickness of the adjoining piece. Use a rule and square to lay out the width of the pins on the outside face of the workpiece. Next, set the T-bevel for the desired angle and mark the angled lines across the end grain to coincide with the parallel pin lines on the face (Photo 1). Follow by continuing the lines, with a square, down to the baseline on the opposite face of the workpiece. To avoid error, mark the waste areas with an X.

Sawing

Use a dovetail saw or small backsaw to cut the sides of the pins. Make each cut on the waste side of the pencil line and stop the cuts just short of the baseline (Photo 2). This can be done freehand, or you can use a simple guide to ensure precise cuts.

The guide we used consists of a small wood block in which a notch is cut that matches the dovetail angle. Cut the depth of the notch to match the pin length. Straddle the guide over the edge of the workpiece and attach two cleats underneath for clamping the guide to the work. You'll need a left and a right guide to serve for both sides of each pin. When all the sides of the pins have been cut, use a coping saw to cut out the bulk of the waste. Saw close to the baseline, but not into it (Photo 3).



1 After laying out the pin spacing on the face of the stock, use a sliding bevel gauge to mark the dovetail angles.



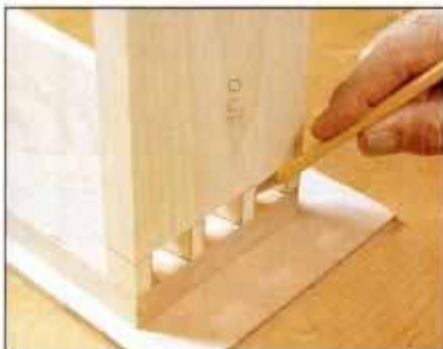
2 Use a backsaw to begin cutting the pins. Stay to the waste side of the line. A shopmade guide block helps accuracy.



3 After the pin sides are finished, remove most of the waste with a coping saw. Cut almost to the baseline.



4 Clamp a guide board at the baseline and use a chisel to trim the sockets. Trim halfway down, then reverse the work.



5 Align pins with the edge of the adjoining piece and use as a template for the tails. Mark with a sharp pencil.

Trimming

When the sawing is done, use a sharp chisel to trim the socket bottoms flush to the baseline. A square-edge board clamped on the baseline will help to guide the chisel for precise cuts. Hold the chisel bevel out against the guide board, and tap with a mallet (Photo 4). Cut about halfway down, and then turn the workpiece over, position the guide board and trim from the other side. If necessary, pare the sides of the pins true to the layout lines.

Cutting the tails

Begin work on the tails by marking a baseline to match the pin-stock thickness on both faces and edges of the workpiece. Position the pin ends



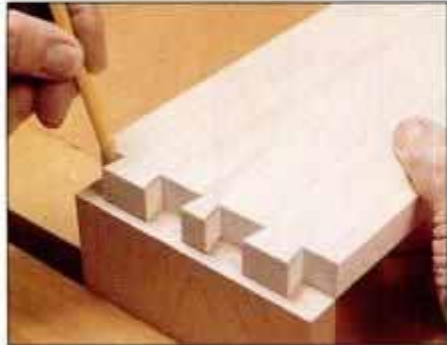
6 Cut to the waste side of the dovetail lines with a backsaw. Remove waste with a coping saw and trim with a chisel.

carefully on the face of the tail board, and trace around the pins to lay out the tails (Photo 5). Use a square to continue the lines across the workpiece end, and mark the waste areas with an X.

Use a backsaw to cut on the waste side of the lines, and stop just short of the baseline (Photo 6). If you wish, you can use a sawing guide similar to the one used for the pins to guide the tail cuts. Instead of angling the sides of the notch, angle the bottom of the notch and the top and bottom edges of the guide to match the dovetail angle. After the cuts are made, remove the waste with a coping saw and chisel. Test fit the pins and tails and pare the tails, if necessary, until a snug fit is obtained.

Handcut Half-Blind Dovetail

The procedure for making a half-blind dovetail joint is essentially the same as for a through joint except here you begin by cutting the tails. Lay out the depth of the tails about two-thirds as long as the thickness of the pin stock, and cut them with a backsaw and chisel.



7 After cutting the tails for a blind joint, position the work on mating piece and use it as a template for laying out the pins.

Mark a baseline on the pin stock to match the full thickness of the tails. Then, lay the tails in position on the end grain, trace the outline and extend the lines to the inside baseline with a square (Photo 7). Mark an X on the waste areas.

With the dovetail saw held at an upward angle, make partial cuts on the sides of each socket, following



8 With pin layout lines in place, hold the backsaw at an angle and follow angled end lines and parallel face lines.

the lines on the end and the face (Photo 8). Chisel out the sockets using alternate cuts with and across the grain (Photo 9). Use a narrow chisel to undercut the waste in the inside corners. Two old 1/8-in. chisels reground with left and right skewers are ideal for reaching into the tight corners. Then, test fit the joint for a snug fit.



9 Remove waste from pin sockets with a chisel. Make alternating cuts—first across the grain and then with the grain.

Machine-Cut Dovetails

A router with a dovetail jig provides an easy method for cutting accurate half-blind or through dovetail joints. The most common type of jig utilizes a comb-shaped template, a guide bushing that is mounted on the router to follow the template and a dovetail bit.

To use a typical dovetail jig, clamp the two adjoining pieces under the comb-shaped template (Photo 10). Offset the pieces to a distance equal to the average of the dovetail-bit cut width at the top and bottom. Then, with the guide bushing and bit installed in the router, follow the template to simultaneously cut the pins in one member and the sockets in the other (Photo 11).

A dovetail fixture of the type



10 A typical dovetailing jig cuts half-blind and through dovetail joints. Clamp stock in jig with pieces offset.

shown provides the capability to cut both flush and rabbeted dovetails. Generally, it is necessary to reposition the template and make a second pass with the router to accomplish a rabbeted dovetail. But some fixture



11 With dovetail bit and guide bushing in router, follow the dovetail template. Both pieces are cut in one operation.

models provide optional accessory finger templates that permit cutting rabbeted dovetails in one operation. Other jigs use a straight bit to cut the pins and can produce joints with variable spacing.

Sliding Dovetail

The sliding dovetail, or tongue-and-groove dovetail joint, is an easy one to make, particularly if you have a router table. Shown here is the procedure for making such a joint for a rail-to-leg assembly. Although a dovetail bit is used to make the cuts on the adjoining members, a straight bit is required as well to make a preliminary cut that removes most of the waste in the dovetail groove.

Begin the sliding dovetail joint by making the groove. When working with a typical 1/2-in. dovetail bit, first install a 1/4-in. straight bit in your router and adjust its depth for a slightly shallower cut than the de-



12 After preliminary groove is cut with a straight bit, use a dovetail bit to rout dovetail channel for a sliding dovetail.

sired depth of the finished dovetail groove.

Adjust the router table fence to



13 Shape mating piece by routing both sides of work with a dovetail bit. Test fence position on scrap stock first.

position the straight bit's cut in the center of the intended dovetail groove. Then, make the cut. Use a

stopblock clamped to the router table fence to limit the length of the groove. Replace the straight bit with the dovetail bit, adjust the depth of cut and make the second pass to form the dovetail groove (Photo 12).

The tongue is cut by making an endwise pass on each side of the workpiece with the bit kept at the

same depth-of-cut position. First, set the fence so that when cuts are made on both sides of the workpiece, the resulting dovetail will slide smoothly into the dovetail groove. Make trial cuts on scrap stock of the same thickness as the workpiece to finalize the fence adjustment.

When the fit is right, make the

cuts on the actual piece (Photo 13). A pushblock is essential to help feed the work safely and accurately. To make the pushblock, cut a notch in the end of a small board. Size the notch equal to the cross-section of the workpiece. The thickness of the block should be greater than the depth of the dovetail tongue.

Single Half-Lap Dovetail

To make this joint with a table saw, first lay out the dovetail by marking the outline of the slopes and shoulders. Next, clamp a stopblock to an auxiliary miter-gauge fence to position the shoulder lines with the edge of the blade. Adjust the blade height and crosscut each edge to cut the shoulders of the dovetail. Readjust the blade height to half the thickness of the stock and make a pass with the work facedown to cut the shoulder for the half lap. With a tenoning jig to hold the work vertically, adjust the blade height so it will intersect the shoulder cut and position the fence to cut the face of the half lap. Then, tilt the blade to the dovetail angle, clamp the stock edge to the tenoning jig and make the angled edge cut (Photo 14).



14 After the half lap is cut, angle blade and cut dovetail sides. Use a tenoning jig to safely hold workpiece vertically.

Rotate the work 180° to make the second angled cut. Use the dovetail as a template to mark the socket on the mating piece. Adjust the blade to the half-lap thickness and set the miter gauge to match the slope angle.



15 Cut the adjoining half lap by making successive passes at the dovetail angle from each side. Clean up with a chisel.

Then, make successive kerfs to remove most of the waste, readjust the miter gauge to the angle of the opposite side and repeat the process. Finish by shaving off the remaining slivers with a chisel (Photo 15). **FM**



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APPLIANCE CLINIC

BY STEVE TOTH,
 Contributing Editor

Flying Ice Cubes

I have a Hotpoint refrigerator Model C.T.F. 18 E. It has a GE icemaker that is now throwing the ice cubes over the container. Any way to get the crazy cubes back to normal?

NATHAN SHAPIRO
 PALM SPRINGS, CA

Assuming that the freezer temperature is okay and the ice-cube flipping just started, I suspect that you have a problem with the amount of water entering the ice-cube mold.

It's likely that the waterflow has become restricted by a partially clogged filter screen in the water fill valve to the icemaker. It's also possible that the saddle valve, installed in your house's plumbing, might be partially clogged with sediment or mineral deposits.

You should check the amount of water in the ice-cube mold after a fill cycle is completed. There should be enough water in the mold to fill each cavity to within 1/4 in. of the top. If you find the water level low, or you suddenly notice the ice cubes have become smaller than normal, then you need to disassemble and clean these valves or replace them to get the cubes back up to size.

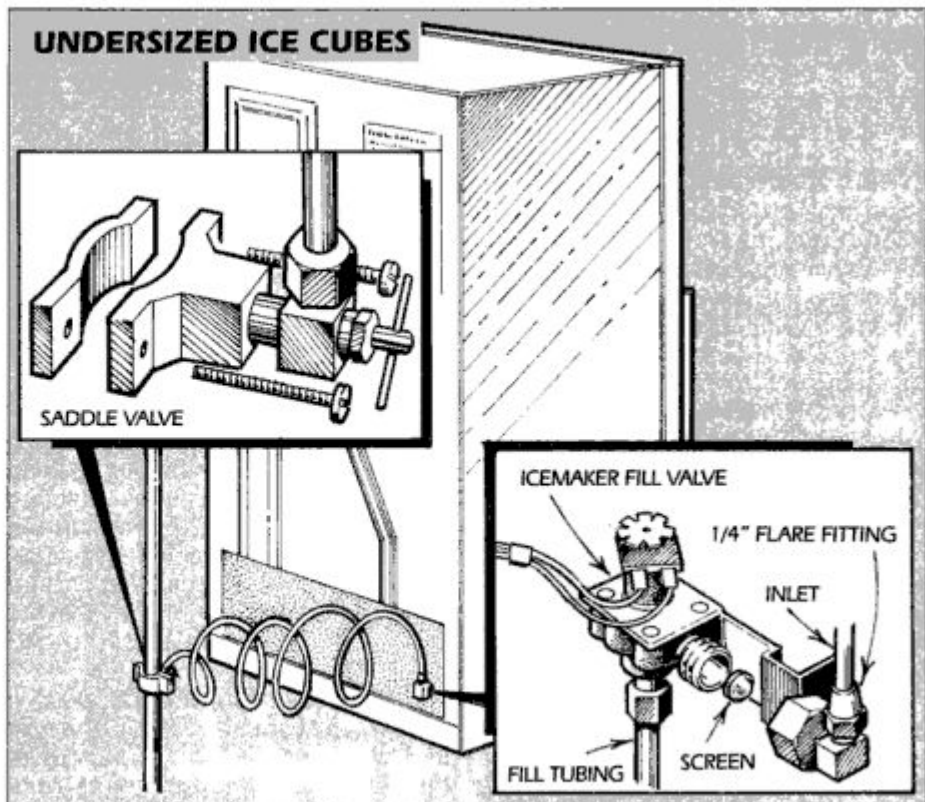
For this repair, you need a repair manual for GE/Hotpoint refrigerators and freezers. You can order the manual by calling GE's national parts center at (800) 626-2002.

Dancing Washer

I replaced a washing machine because it vibrated and danced across the floor. It seemed nothing could stop this. I bought a new washer and the same thing is happening. An appliance service technician said it was the floor. I bought two jacks and braced the beams under the washer, but it still vibrates and moves. What is the solution?

GERALD STERN
 RANDOLPH, NJ

I suggest you put a piece of 3/4-in. plywood under the washer. Cut the wood so it extends away from the washer on all sides, and position the washer in the center. You don't need to secure the plywood to the



Undersized ice cubes can be caused by a clogged screen in the icemaker water valve or a clogged saddle valve. A clog in either device reduces waterflow to the icemaker.

floor with nails or screws.

Also, check the machine for level from side to side and front to back. Adjust the leveling legs so the machine is as close to the floor as possible, and be sure that the locking nuts on the leveling legs are locked down. This should prevent your washer from doing the two-step.

Humidifier Parts

I have a Sears humidifier, model No. 758-743300, roto belt No. 34-7269, that needs a replacement part. Sears informs me it no longer stocks the part, and it is no longer available. Can you suggest another supplier?

FRED THURSBY
 SOUND BEACH, NY

Your model humidifier was manufactured by the Emerson Co. for Sears. I contacted the company and was told that the roto belt is still available under Sears part No. 14916. It's available from Division 42, Source 042, and costs about \$7. You can either call your local Sears repair parts center or call the new Sears national parts order center at (800) 366-7278.

Transformer Is Shot

In June 1971, we had a Climatrol furnace and model No. 53-1-014 electronic air cleaner installed in our

house. The air-cleaner transformer burned out, and I can't find a source for a new or rebuilt one. The furnace manufacturer, Mueller-Worthington, is no longer in business. Honeywell manufactured the air cleaner. I hope you can help.

SHELDON WEXLER
 SKOKIE, IL

For parts and service information regarding your electronic air cleaner, contact Air Cleaning Specialists Inc., 180 El Camino, Milbra, CA 94030; (800) 633-4007.

The manager of the company suggests you send the furnace's power pack. This part may be a small box screwed to the cabinet on top or next to the air cleaner, or it may be on the door.

The company charges \$50 to diagnose the appliance, and will apply this money to the repair charge if the appliance can be repaired.

If you want to replace just the transformer, send it to the company along with model and serial numbers from the appliance. If you can, send the company a copy of the owner's manual. It will try and match the transformer to one it has in stock. There is a good chance that if the air cleaner was manufactured by Honeywell, White Rodgers or Emerson Electric, the company will have a replacement.

HOMEOWNERS CLINIC

BY NORMAN BECKER, P.E., Contributing Editor

Heat Exchanger

I live in a part of the country that has a lot of radon gas. Can you help me find information on an air-to-air heat exchanger? It seems to me that if we change the air in the house without losing too much of the desired temperature, any airborne contaminants would not be a problem.

RONALD GABIANELLI
WILLIAMSPORT, MD

Just because your house is located in a radon belt doesn't mean that your house will have a radon problem. Before you install an air-to-air heat exchanger, test your house to determine radon levels. The Environmental Protection Agency advises taking action only if the radon gas occurs at 4 or more picocuries per liter of air (pCi/L). For more information on radon, contact the EPA's regional office or your state health department.

The EPA booklet, Radon Reduction Methods—A Homeowner's Guide, explains how to correct a radon problem. An air-to-air heat exchanger (also called a heat-recovery ventilator) is one method. It extracts the heat in the air that is being exhausted and uses it to warm the fresh incoming air. If used by itself and if the levels start out above 16 pCi/L, it will not reduce radon

levels to below 4 pCi/L. Radon Control Inc. sells heat exchangers to contractors. To locate an EPA-certified radon-control contractor in your area, call RCI at (800) 523-2084, or write to RCI, 511 Industrial Dr., Carmel, IN 46032.

Do Trusses Sway?

I want to use the attic of my home for storage. The roof has trusses instead of rafters, and I've been told that you cannot put sheets of plywood in the attic because truss roofs must be allowed to sway. Can you clear this up for me?

DICK FINALDI
SALISBURY, MD

Your attic is not suitable for storage because the bottom member of a typical truss (referred to as a cord) is not designed to support a storage load, not because of truss movement. The cord is only designed for a dead load of 10 pounds per sq. ft. The truss will support its own weight, the gypsum ceiling below, insulation and light fixtures. Roof trusses are not normally designed to support the weight of stored objects—although they can be.

Incidentally, trusses move but they don't sway, exactly. Truss movement occurs in a condition known as "truss uplift" or "truss rise." During the winter, trusses

rise because of the different contraction between the bottom members of the truss, which are normally covered with insulation, and the upper truss members, which are exposed to the cooler attic. The bottom members are exposed to warm temperatures and a low relative humidity. Consequently, the lower members shrink and shorten slightly compared to the upper members. This causes the upper members to pull the bottom members upward, lifting the drywall ceiling below. Cracks form where it meets the walls.

Cement Dusting

The concrete walkway around our built-in swimming pool seems to be flaking off. That is, when we sweep around the pool we have a lot of dust. Is it normal for concrete to break down like this?

PETER MORRIS
CHERRY HILL, NJ

The condition you describe is called dusting. It usually occurs within the first several months of when concrete is installed. Several things can cause it, such as using a concrete mix with a low cement content, using a concrete mix that is too wet, allowing the surface to dry too rapidly, exposure to freezing temperatures before the concrete is cured and finishing the concrete while bleed water is on the surface.

Since the concrete is seven years old, I suspect it's caused by pool water that's splashed on it. Chlorine in the pool water may be reacting with the concrete.

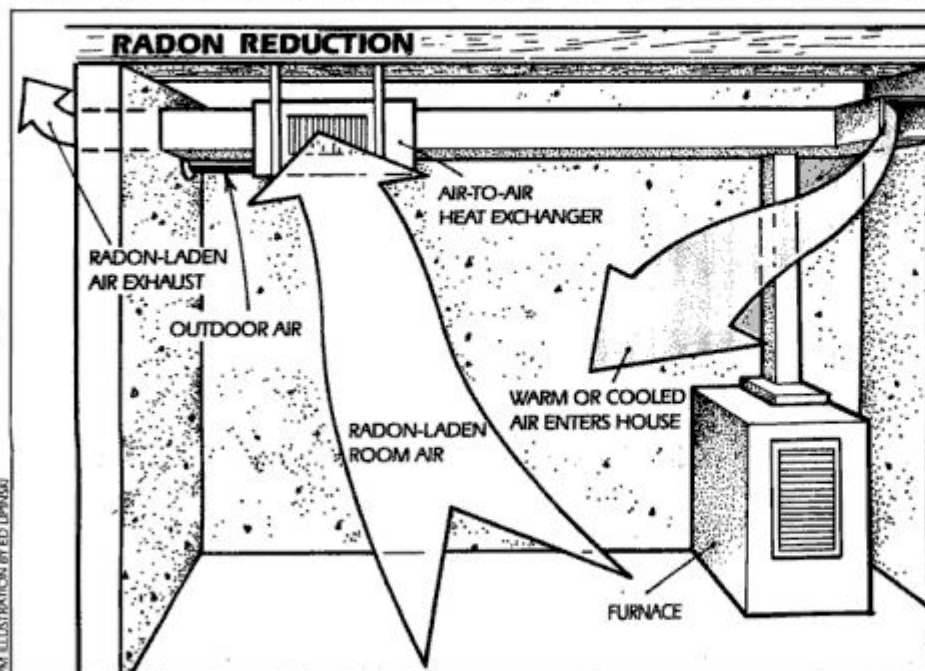
Try the following. Remove the dust and clean the walkway by scrubbing the surface with a stiff-bristle broom and then hosing off the accumulated dust. Let the walkway dry, and be careful not to splash pool water onto it. Next, coat the concrete with a sealer that contains methyl-methacrylate or silane.

One such concrete sealer is Pakmix, sold at home centers and masonry supply yards. For information, write Pakmix Inc., 873 Western Ave., Toledo, OH 43609.

PM

DO YOU HAVE A HOME-MAINTENANCE OR REPAIR PROBLEM?

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



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HOW IT WORKS

FURNACE AIR FILTERS

BY MERLE HENKENIUS
 PM Illustrations by
 George Retseck

● When it comes to a clean, healthy environment, you may have noticed that there's a new concern—indoor air quality. And, when it comes to addressing the problem, many homeowners are focusing their attention on a new family of high-efficiency air filters to get the job done. Combined with a forced-air heating system or central air conditioning, these units are not only gaining popularity in new installations, but retrofit devices of every description can be found on home-center shelves.

High-efficiency air cleaners have long been used to reduce maintenance costs in commercial buildings. But with today's energy-efficient homes, builders and consumers have come to realize that houses that don't allow air to infiltrate also don't allow pollutants to escape. In fact, recent government studies suggest that indoor air can be 10 times more polluted than outdoor air. Allergy sufferers, especially, look to high-efficiency air filters for relief, and some doctors even prescribe them.

It's important to note, however, that air filters can only catch particulates. They cannot filter noxious gases, such as radon and those emitted by synthetic materials. The first step in understanding the new air filters, therefore, is to define what it is they're designed to remove from the air—namely household dust.

The dust mix

What makes up the dust in our homes? Probably more than you'd like to know about. There are soil particles and lint, of course, plus airborne cooking grease, tobacco smoke, pet hairs, pollen, mold spores, bacteria, viruses, skin flakes (human and animal), carbon particles, dust mites, dust mite feces, insect scales—well, you get the point.

These particles range in size tremendously. While some particles (10 microns and larger) are visible, most cannot be seen with the naked eye. A larger share of these particles can be seen only with a microscope. And a few others are visible only



Modern, high-efficiency filters are available in new installations and as retrofits. This ionization unit is spliced into the ductwork to clean the air while the furnace blower is operating.

with an electron microscope.

As an interesting aside, the average person's respiratory system processes more than 2 tablespoons of dust each day. The larger the dust particles, the better the lungs are at expelling them. To a large degree, the same is true of air filters.

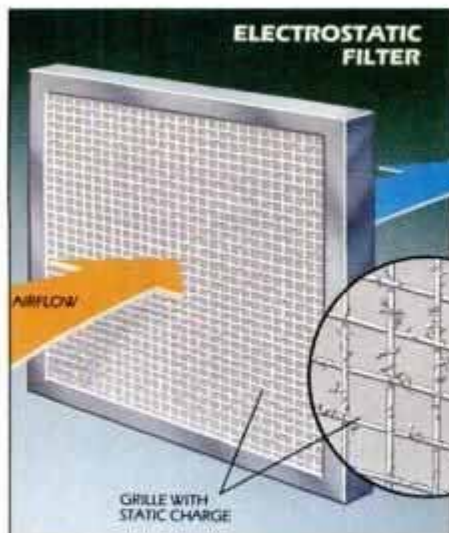
About effectiveness claims

In order to compare the effectiveness of a filter, tests are performed that rate its ability to trap airborne dust. If you do a little research on filter efficiencies, don't be surprised if you find manufacturer's effectiveness claims confusing. The problem has to do with the variety of testing formats in use. While several standardized tests that yield useful and comparable ratings are available, it only

makes good marketing sense for a manufacturer to tout its product's highest rating. As such, you'll find that most products claim 80% to 95% efficiency.

What the rating doesn't tell you is that a filtering device might be nearly 100% efficient in catching one particle size, while it's only 10% efficient with a smaller size. What's more, actual efficiencies change throughout the period of operation and vary with the age of the filter and the level of maintenance. To keep things manageable, we'll only consider overall efficiency, as defined by the ASHRAE (American Society Of Heating, Refrigerating And Air-conditioning Engineers) Atmospheric Dust Spot Test.

Do these ratings mean that 90%-



Electrostatic filters use a static charge to collect dust particles. These filters replace standard, disposable fiberglass filters.

efficient filters will catch and hold 90% of the dust in your home? Not at all. They can only filter the dust that is pulled through your furnace. Not all dust particles, however, remain suspended in the air. The larger, heavier particles settle out unless disturbed. Many of these heavy particles include the most common allergy triggers.

Electrostatic media filters

Electrostatic replacement filters have immediate appeal as they are designed to fit standard return-air carriages made for disposable, fiberglass filters. They are also a good deal less expensive (and less effective) than the two options that follow.

How are they an improvement over disposable filters? The difference lies in the filtration media, which is usually a densely woven, petroleum-based material such as polyester. You'll find a variety of models on the market, but they all use a combination of filter media and static electricity to attract and retain dust.

An electrostatic filter does not require a power source. Rather, air drawn across the media fibers gives dust particles a negative charge. As a result, the particles are attracted to the media, much as they would be to the statically charged surface of a TV screen. After a month or so, you remove the filter, wash out the dust and return the filter to its carriage. Most units will withstand at least five years of washings.

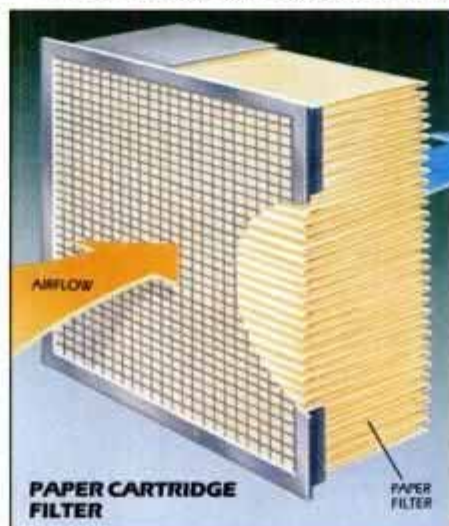
Lab tests rate these filters at up to 20% efficiency as compared to the 3% or 4% offered by disposable fiberglass filters. In the home, however, that figure can be quickly eroded. A

loose fit easily reduces efficiency, and loose fits are common in standard filter carriages. Poor maintenance also yields lower efficiencies.

Paper cartridge filters

Next on the list is the replaceable cartridge filter, which usually consists of a paper-like media in a loosely folded configuration. If stretched out, these filters would extend nearly 30 ft. As such, paper filters have enormous surface area and an operating life of roughly one year. Moreover, the dirtier the filters get, the more effective they become—up to a point. The reason is that the dust accumulation actually increases the surface area of the filter.

While overall efficiency for this



Paper cartridge filters are installed in a carriage spliced into the ductwork. They are effective at removing larger dust particles.

type of filter starts in the 25% to 30% range, it can be nearly 100% efficient in arresting particles in the 6- to 10-micron range. This size includes many of the common allergy triggers, such as pollen, mold spores and tobacco-smoke particulates. Unlike electrostatic replacement filters, paper cartridge filters require a carriage that's spliced into the ductwork by a qualified specialist.

Two-stage ionization filters

The final, most efficient and most costly alternative is the electronic ionization filter. These devices must also be spliced into return-air ductwork by professionals. In fact, furnace manufacturers recommend this type of filter over all others, partly because it does the best job of keeping equipment clean.

A two-stage ionization filter con-

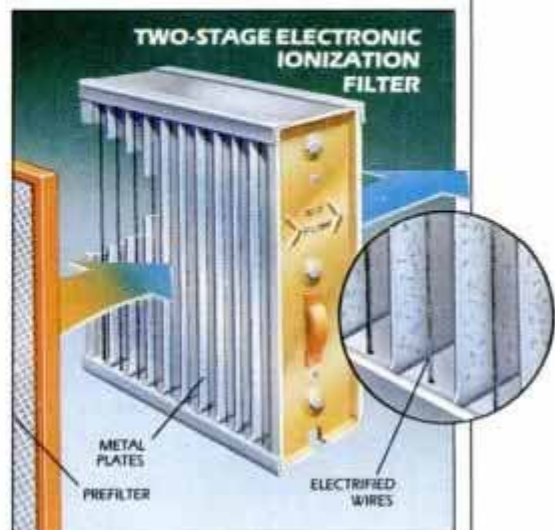
sists of a coarse metal mesh that ensnares only the largest particles. Particles that make it through the mesh move past a series of light-gauge electrified wires. Upon passing these wires, the particles are ionized, or charged, so that they impinge on a network of metal plates mounted just behind the wires. This charge is given to the full range of particle sizes, so that an extremely high efficiency rating is possible, even for microscopic particles. A clean filter cell can have an overall efficiency of 90% to 95%.

As with all filter types, only a portion of the story is told in the product literature. Efficiency ratings fall off dramatically when the filter is not kept clean. As with electrostatic filters, regular maintenance is a must.

Some owners also object to the occasional popping noises issuing from these devices. The noise occurs when larger particles of dust stray into the electrified wires. When this happens, the ionizer acts like a bug zapper, exploding the particles and, in the process, releasing ozone. Ozone yields the faint but familiar odor of an electrical fire, and is a lung irritant to some people. Still, no other air cleaner can claim efficiency levels as high as these for a broad range of particulates.

A final consideration

Because furnace-mounted air cleaners can only trap dust particles that pass through the furnace, you get the cleanest air by running the furnace blower continuously. This is especially true in spring and fall, when allergy triggers are most numerous and when a furnace or air conditioner is not likely to start automatically. **PM**



Ionization filters have two stages for trapping large and small particles. This type claims the highest overall efficiency.

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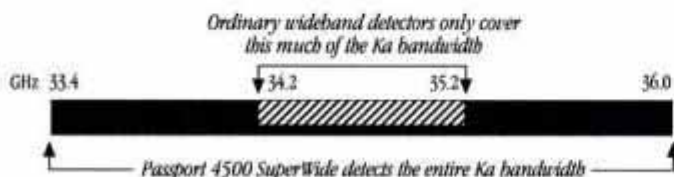
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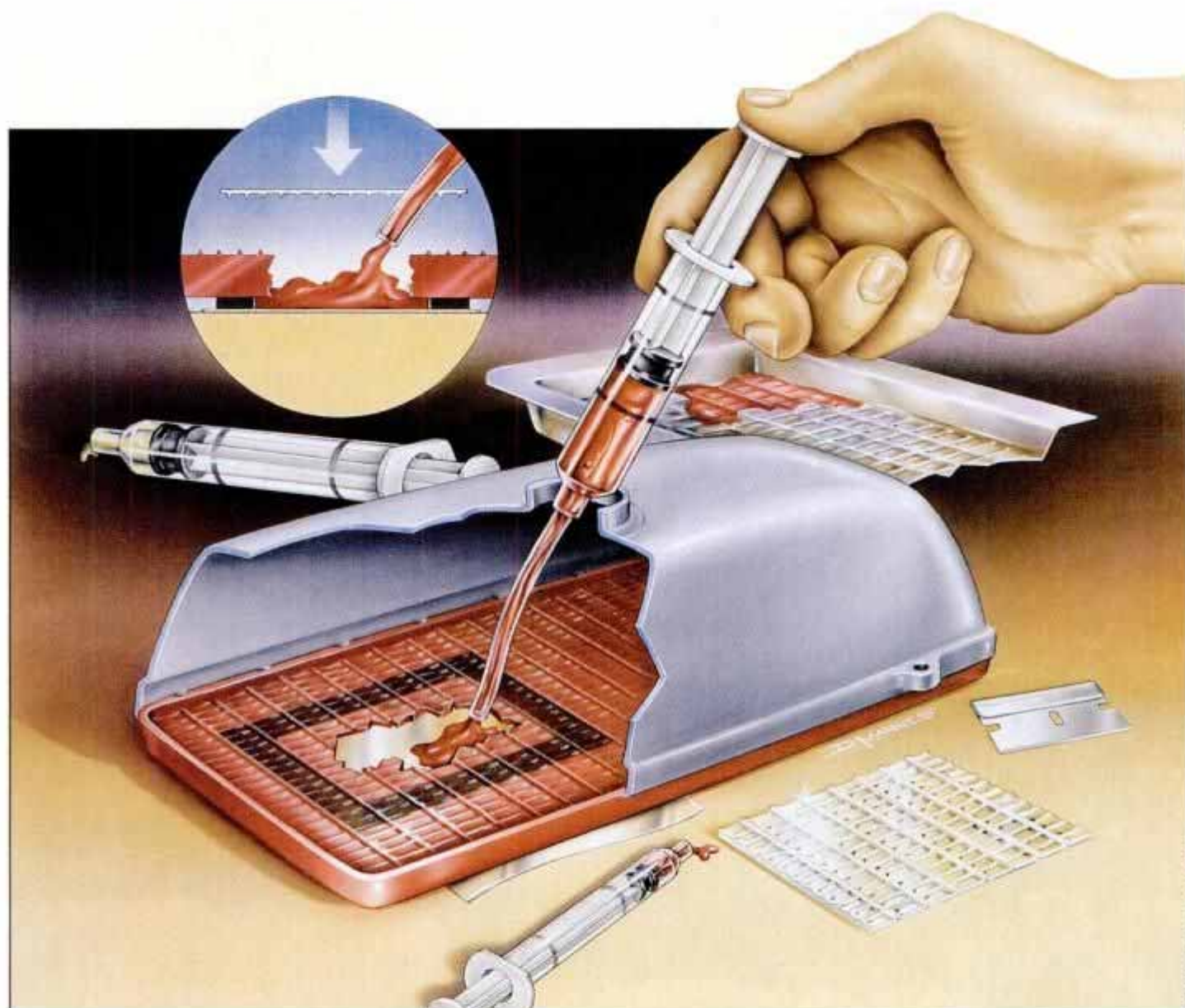
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CAR CARE



CAR CLINIC

BY MIKE ALLEN,
Associate Automotive Editor

Rolling Your Own

I have an old, old car. One of the tail-light lenses is cracked, and the other lens is so bleached out that it has turned yellow. I've been looking for replacement lenses for a long time—and now I can't pass the state inspection. I tried using red plastic film inside the lens to change the color, but the inspection station wouldn't accept that. Do you have a source for these lenses?

JOHN CHANGIRA
MORRISTOWN, NJ

The bleached lens you can just dye with red fabric dye. Clean the lens thoroughly with detergent, and soak it in a warm, concentrated dye solution. Too hot a solution will warp the lens—be careful. It may take several hours of soaking.

The cracked lens can be repaired with a kit made for—surprise—repairing cracked or broken lenses.

I've seen the kits at places like Wal-Mart and Sears in the automotive section. Auto parts stores often have them as well. Inside the kit, you'll find some casting resin, often in a syringe dispenser, some clear tape and some adhesive-back cardboard templates.

Remove the lens from the vehicle, and clean it. Cover the outside of

the crack in the lens with the tape and, if necessary, add a template to contain the resin to the appropriate area. If the inside of the lens is jeweled, you can cut up the plastic blister pack from the kit to fit the template. This plastic has a pattern to replicate the jewelry in the resin.

Mix the casting resin per the instructions, and flow it into the crack. Press the plastic blister pack into the resin, and let the assembly sit overnight.

I've found that if the area has a compound-curve shape, it's better to do several applications of the resin rather than trying to do the job all at one time.

This won't win you any prizes at car shows—but it will be legal.

CAR CARE

Collision Course

I managed to scrape and slightly ding one of the wheels on my Vette one rainy night. I wondered if there's any way to touch up the wheel. The tire store I went to said I'll have to replace the wheel—and wants about a month's salary for it. I sure hate to live with the cosmetic imperfection, but they're telling me that there's a danger of the wheel failing structurally at any minute. I have a hard time believing that.

WAYNE SUDBURY
VICTORVILLE, CA

Normally, alloy wheels aren't repairable. Well, you can repaint them if the paint is peeling.

Paint? Yup, many alloy wheels are actually painted with a silver metallic paint and clearcoat over the aluminum alloy to keep them from corroding. Careful, nondestructive removal of the paint can be followed by respraying. Chemical strippers are okay—sandblasting is out.

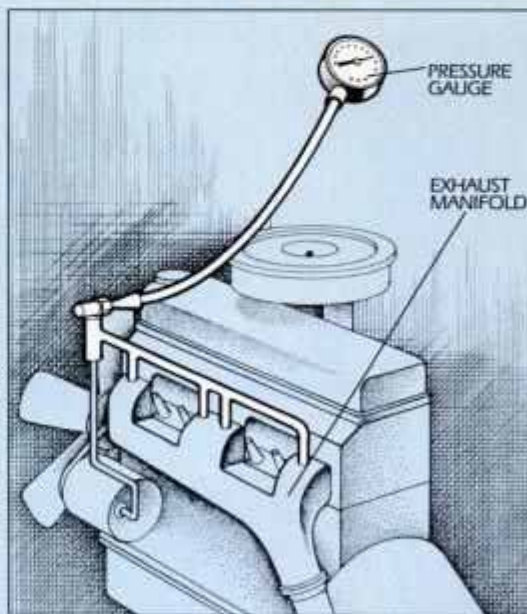
But for a wheel that's dinged? As in the bead is bent? Normally you'd have to make a coffee table out of it—

An Engaging Opportunity

● Once in a great while you get one of those cars you can't get a handle on. This one acted as if a potato had been stuck up the exhaust pipe. It idled okay, but any application of throttle caused a lot of wuffling and noise—and little forward motion. The owner said it began all at once, but the car was running poorly for a month or so.

A slugged catalytic converter plugging the exhaust was consistent with the symptoms, but I was in no mood to wrestle with the corroded exhaust just to see if the converter was plugged.

So I unhooked the manifold to the air-injection system from the air pump. The EGR pipe would have worked just as well. With a pressure gauge hooked up, it was obvious that high backpressure was corking up the engine. Sure enough, a new converter fixed it.



FOR ILLUSTRATION BY ADOLPHINE BRITZMANN

**Lots of plugs can
This one started a**

CAR CARE

as much as you'd like to believe that the tire dealer is really just trying to separate you from about \$900.

Try contacting Wheel Collision Center in Bath, Pennsylvania, at (800) 292-RIMS. They can actually straighten beads, weld up cracks and retrue your wheel, as well as refinish it to factory specs. The price depends on the extent of the damage, but probably will be less than a quarter of the price of a new wheel.

Wipe-Out

The windshield wipers on my car have a major problem with streaking and skipping. I've tried replacing the blades, and I've cleaned the glass 100 times. I recently tried adding spring tension to the arms, and just replaced both arms with brand-new ones. Nothing seems to help.

JOHN EPSTEIN
KANKAKEE, IL

Start by thoroughly cleaning the glass with alcohol and then with ammonia. Avoid glass-cleaning products that claim to leave a protective film on the surface. Clean

the inside of the washer reservoir as well—there may be something oily in there contaminating your fluid.

If there's no contamination, and the wipers work okay for a day or two, then you're probably getting tree sap or industrial fallout on your windshield. Clean it again, and cover the windshield when you're not driving the car.

You've already replaced the wiperblades and arm, but I've found that the bargain-basement blades are not nearly as good as the premium brands—not to say you have to buy them at the dealer and pay top dollar, but the more expensive spread seems to work better and last longer.

Unsolicited testimonial: Get a bottle of a product called Rain-X, available in auto departments all over. This stuff is so good that most of the time you don't even need windshield wipers. Honest. **PM**

DO YOU HAVE A CAR PROBLEM?

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

SERVICE TIPS

● If your sohc-engine Saturn has a misfire or stumble, or your dohc Saturn has higher-than-normal oil consumption, you may need to replace the valve-stem seals. There's a procedure to verify the oil consumption rate or to validate the cause of the misfire. If the engine meets the criteria, it's possible to replace the valve-stem seals without removing the cylinder head.

● If your Saturn has failed a state inspection sniffer test, the vehicle still may be within legal specifications. Extended idling while waiting in line for the test may cause the engine computer to drop back to open-loop mode. Bring the idle to at least 2500 rpm for 2 minutes, and then let the idle drop back to normal just before the test.

● Ford suggests that orange rust dots in the paint may be caused by iron particles from iron railroad wheels or tiedown chains when the vehicle is being transported. The TSB details a procedure for removing the iron without repainting.



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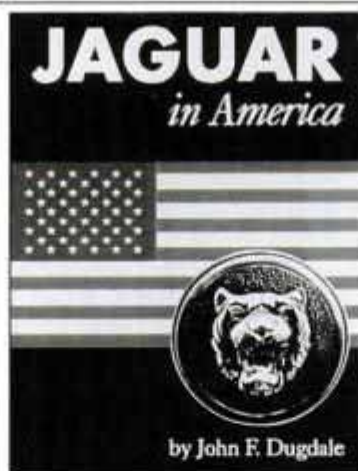
As an engine is lifted from a car, it usually must be raised at specific—and frequently changing—angles. The Tilt Lift Engine Sling lets you change the tilt of an engine as you lift. The Tilt Lift features a steel cable, with a lifting eye at each end, which runs through a drum. The drum has a lifting eye to attach to the engine hoist. Your 1/2-in. drive ratchet or breaker bar fits on the drum's drive socket, allowing you to alter the tilt of the engine by about 30° initially and up to about 45° total. The 2000-pound-capacity Tilt Lift costs about \$55. From Yankton Intl. Products, 3366 N. Torrey Pines Ct., Suite 210, La Jolla, CA 92037; (619) 450-9936.



The Corvette Of Car Vacs

What would you name a high-powered, high-speed vacuum for your car? The Eureka Vacuum Cleaner Co. has Chevrolet's blessings to use Corvette. This Vette is a potent handheld vacuum designed for cleaning automotive interiors. Its motor turns at 19,000 rpm and drives a roller brush in the vacuum's head. The brush features an adjustable visor to facilitate vacuuming vertical

surfaces, as well as horizontal ones. An attachment kit comes with a hose and various tools, allowing the Corvette to clean variously shaped and hard-to-reach spaces. A mini-attachment kit for cleaning computer keyboards, cameras, electronic gear and other household items is also included. Suggested price is \$79.99. From the Eureka Vacuum Cleaner Co., 1201 E. Bell St., Bloomington, IL 61701; (800) 282-2886.



A History Of Jaguar

It may be difficult for some people to appreciate, but at one time the dominant forces in the imported auto industry were not the Japanese, nor the Germans. Most imported cars here were either French and, to an even greater number, British. In the early 1950s Jaguar was creating an indelible image in motorsports and on our roads as an exotic, luxurious and fast car. *Jaguar In America*, by John Dugdale, gives an interesting and enlightening account of the evolution of the U.S. auto market and Jaguar's place in it. This 10 7/8 x 8 3/8-in., 310-page book is available for \$49.95, plus \$4 shipping. From BritBooks, P.O. Box 321, Otego, NY 13825; (607) 988-7956.

Air-Filter Monitor

Many people replace their car's or truck's air-filter element when it looks dirty. However, looks can be deceiving. For a more accurate reading on how plugged your air filter is, install the Filter Minder. This taps into the airstream between the intake manifold and the air cleaner to indicate what percentage of the filter element's capacity has been used. Its maker claims that air-filter service life can be doubled or even tripled. Price for the Filter Minder is \$24.95, plus \$3 shipping. From Engineered



Products Co., P.O. Box 1615, Waterloo, IA 50704; (800) 765-1641.

Battery Care Kit

Sooner or later, your car's or truck's battery will run down and have to be replaced. To help ensure that this happens later rather than sooner, Berryman Products has introduced a 3-Way Battery Maintenance System. The kit cleans and neutralizes corrosion on the terminals and the battery case while retarding further corrosion. The system consists of an aerosol cleaner, with an adjustable spray nozzle and scrub brush built into the can's cap, as well as treated felt washers for the terminals. A PH color tester in the cleaner automatically pinpoints any acid leaks as you clean the battery. The kit costs \$3.98. From Berryman Products Inc., 3800 E. Randol Mill Rd., Arlington, TX 76011; (800) 433-1704.



SATURDAY MECHANIC

REPAIRING YOUR POWER WINDOWS

BY DON CHAIKIN, Contributing Editor

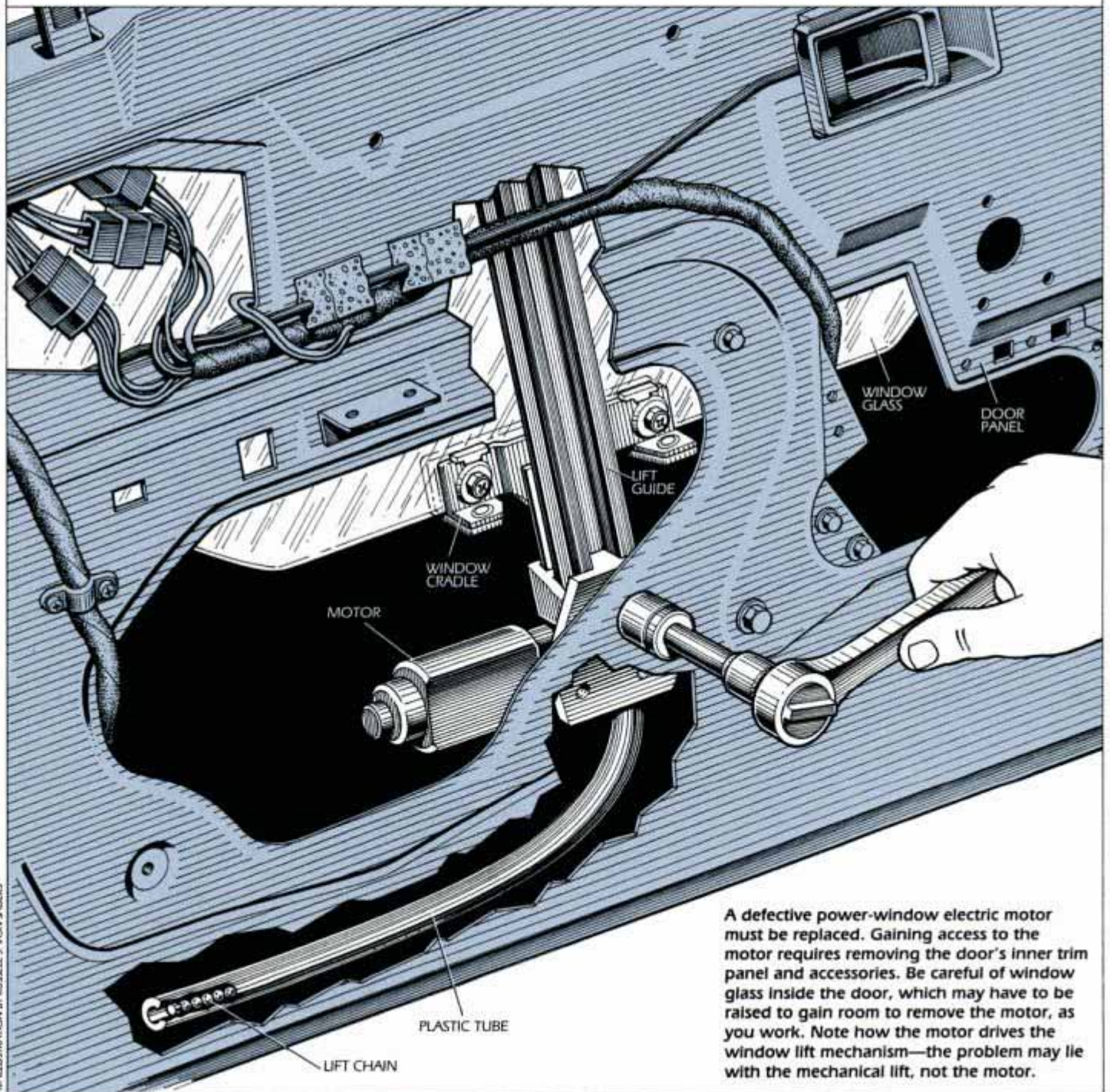
● It may be no more than an annoying inconvenience for you to open your door to pay tolls or collect those Big Macs from the drive-through window because your car's power

windows won't go down anymore.

Or, it may be a cold, wet and noisy pain in the keister because one or more of the electrically operated windows will not go up all the way—if at

all—letting all manner of weather into the car's interior.

Maybe you're faced with the worst-case scenario—you can't park your car unattended because one or



A defective power-window electric motor must be replaced. Gaining access to the motor requires removing the door's inner trim panel and accessories. Be careful of window glass inside the door, which may have to be raised to gain room to remove the motor, as you work. Note how the motor drives the window lift mechanism—the problem may lie with the mechanical lift, not the motor.

more of the windows always stays wide open, no matter how you play with the buttons and switches that are supposed to operate them.

In any case, power windows are meant to be a convenience item on a car or truck. And chances are that you paid several hundred dollars for that convenience. You should enjoy it.

Fortunately, tracing and repairing problems with a power-window system are tasks well within the ken of the average Saturday mechanic. The time and effort spent on curing the problem makes living with it foolish.

Power to the people

Electric power windows work the same way as manual windows, except for the fact that with power windows an electric motor inside the door, rather than a handle on the door panel, turns the window crank to raise and lower the window glass.

Each door-mounted motor has its own switch, usually on the door near the window or on a center console. In addition, there are redundant switches for the passenger windows at the driver's position so the driver can operate any window when driving alone. The driver's switch panel also has a safety lock-out switch, which can shut off power to the passenger windows to keep small children from opening or closing them.

The system is protected by a fuse or a circuit breaker, and power for the system goes through an ignition-key-activated relay as well.

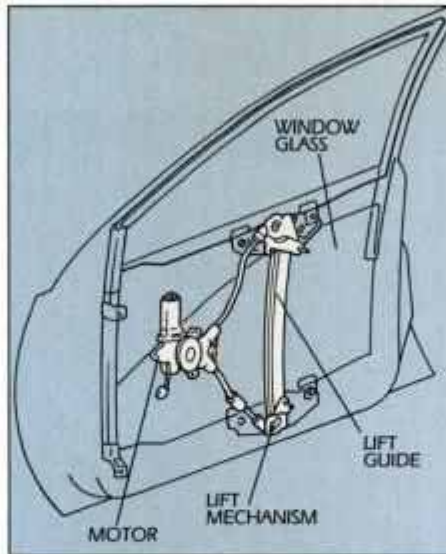
The individual electric motors either drive a gear, which meshes with a large sector gear to operate the glass-lift assembly, or it runs some variety of cable, chain or tape through a drive gear to move the window glass.

Begin with the basics

There are two elementary types of power-window problems—localized and universal. Localized problems affect only one or two windows or switches. Universal problems involve the whole system.

If none of the windows operates at all from any of the switches, assume there is a simple electrical problem. The trouble lies with the fuse or circuit breaker, relay, wiring or possibly the driver's master switch.

Begin by checking the fuse or circuit breaker. If the fuse



Typical system has electric motor, lift mechanism and window cradle and guide.

is blown, replace it. Reset a tripped circuit breaker. It may have been just one of those things. If the fuse blows again or the circuit breaker trips, there is either a short circuit or an overload caused by a problem with one or more of the electric motors or the glass lift mechanism.

If one of the electric motors is beginning to fail, it may draw enough current to burn a fuse or trip a circuit breaker. And, if one of the window lift mechanisms is sticking in the door, it can create enough of an overload on its motor to blow the fuse as well. If this is the case, the fuse or breaker will fail only when the suspect window is being operated.

A simple way to check is to replace the fuse and operate each window in turn, isolating the window that is causing the trouble.

If the fuse blows regardless of which window is being operated, the trouble probably lies elsewhere in the windows' electrical system.

If the fuse is good, double check that it is getting current. Either probe the fuse with a grounded test light or with an electric meter. Make sure that the ignition switch is turned on for this check.

If the fuse is not getting any current, locate and test the relay. Check your owner's manual for the location of the relay—it may be at the main fuse block or in a separate secondary fuse and relay bus. Remove the relay by pulling it straight out. Use a volt/ohm/ammeter to check the relay by testing the continuity across its terminals according to the sequence in your shop manual.

If the relay is bad, replace it.

If it tests good, verify that it is getting power—again with the ignition system turned on. If not, check your owner's manual to see if there is a second relay—possibly from a factory-installed antitheft system—which may feed the power-window relay. Check that relay's operation.

Otherwise, trace the wiring from the relay to its power source from the ignition switch for an open circuit.

If the relay is getting current with the ignition switch on, check the windows' master switch at the driver's control panel.

One switch serves all

The passenger-window lock-out switch at the driver's master switch passes current on to the individual window switches. If the driver's switch fails, none of the windows will operate from any position.

Before taking apart the door panel or center console to get to the driver's switch, consider cleaning the switch's contacts. And, depending on the specifics of your car's or truck's system, you may be able to do that without removing anything. Spray some aerosol electrical contact cleaner (sold as radio- and television-tuner cleaner) through the gaps around the switch's rocker. Operate each of the rockers back and forth as you clean. Naturally, start with the separate button or rocker



Electrical contact cleaner can remove current-blocking dirt and corrosion from contacts with the switch in place.

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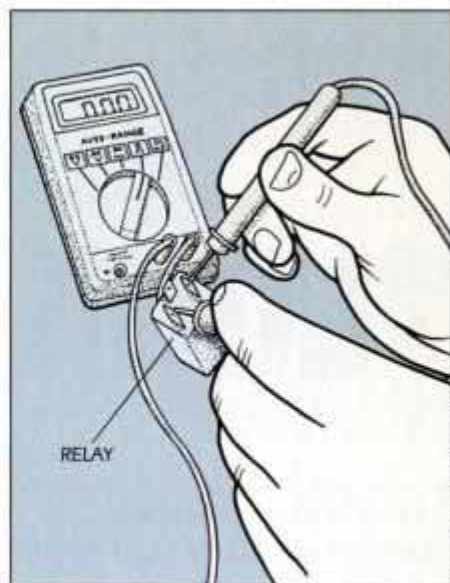
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TM ILLUSTRATION BY RON CARBON

**Check the operation of the relay by testing
the continuity across its various terminals.**

that locks out the individual window
switches.

If cleaning does not help, check the
operation of the driver's master
switch. On some cars, you may have
to remove a door inner trim panel or
part of the center console for access.
On other cars, you may be able to
simply depress a couple of locking
tabs and lift out the switch assembly.
Unplug the switch from its wiring
connector.

Use an ohmmeter and follow the
testing sequence in your shop manu-
al, checking for continuity between
the terminals on the switch.

If the switch assembly—or any of
the individual switches—fails the
test, replace it.

If the switch is good, check the
wiring connector for current. Use a
grounded test light or ammeter with
the ignition turned on. If there is no
current to the driver's switch, you
must trace the wiring back to the
fuse panel looking for a broken wire
or another open circuit.

If there is current getting to the
driver's master switch, there must be
an open circuit between the switch
assembly and all of the window mo-
tors. Check the switches' wiring con-
nectors for good contact. Use a pair of
pliers—which have some tape on the
jaws to pad them—to gently squeeze
tight a loose connector. Clean any
corrosion from the connector using
the same electrical contact cleaner
you used on the switch. If these steps
don't cure the problem, you must
check the continuity between the
driver's master switch and each of
the individual door switches, using an
ohmmeter to find the open circuit.

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Motorized actuation

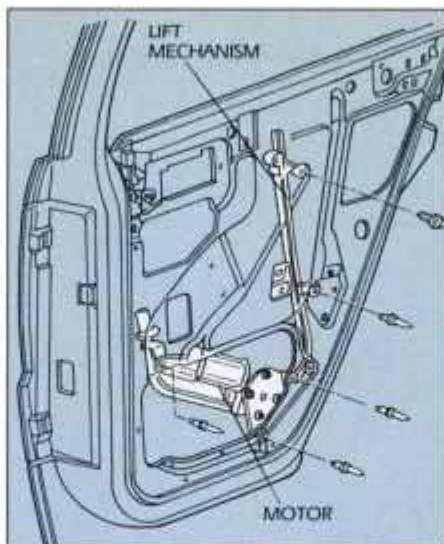
If the problem is a local one—only one window does not operate—begin by checking that the motor is getting power. First check the window's switch—trying to clean it as you did the driver's master switch. Remove the switch and check it using an ohmmeter. If the switch is defective, replace it. If the switch is good, use a grounded test light or ammeter to verify that it is getting current with the ignition on.

If the switch is good and there is power to it, the next step is to check the motor.

To gain access to any of the window motors, or the glass lift mechanism, you have to remove that door's inner trim panel.

This means first removing the door-latch lever and possibly an armrest. You may also have to disconnect wiring for a courtesy light or stereo speaker from the back side of the door panel after you have removed all of its retaining screws and pins. Make sure that you have taken out all of the panel's retaining screws before trying to pry the panel off the door metal. Look carefully for screws hidden inside armrests and under trim pieces. Slide a thin, wide tool—either a door trim removal tool or a putty knife—between the trim panel and the door metal to find all of the retaining pins or clips. Gently pop out the pins or clips as you go.

With the door trim panel off, you may be faced with a plastic liner held

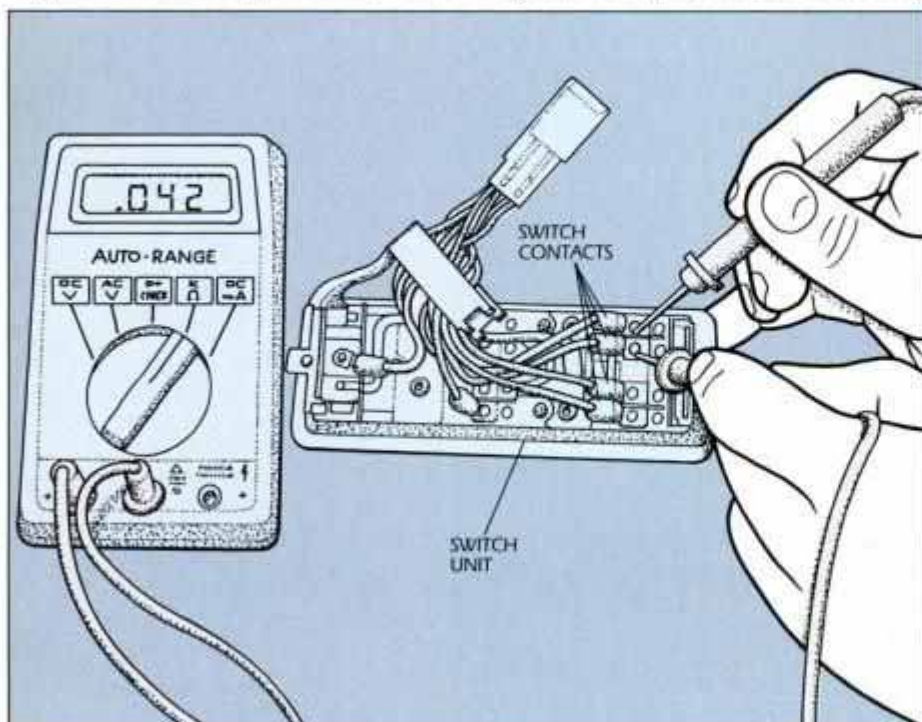


Space confines of smaller rear door may require a different lift arrangement.

by sealer, gently peel back the liner taking care to not tear it or fold it back on its sealer.

Locate the window's electric motor, and disconnect its wiring connector. With the ignition switch on, operate the window switch and check that power is getting to the motor's connector. If not, there is an open circuit between the door switch and the motor, replace the wiring.

If power is getting to the connector, make sure that the connector is clean and making good contact with the motor. If the motor still does not operate but the fuse has not blown, double check that the motor's ground is good. If it is, the motor is defective,



Use an ohmmeter to check operation of each switch, starting with driver's master switch.

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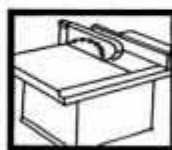


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and you need to replace it.

If the motor operates sluggishly or if the fuse blows when you operate it, either the motor or the window glass itself is binding. To determine which, you must remove the motor from the door, disengaging it from the window lift mechanism.

If the motor simply drives a spur gear, which meshes with a large sector gear on the window lift mechanism, unbolt the motor from the door panel and take it out.

If the motor passes a cable, chain or tape drive through it, you might have to remove the lift assembly along with the motor—which may mean supporting the window glass while you remove the drive mechanism. Or, depending on your car, you may be able to separate the motor from the drive drum or mechanism that moves the cable, chain or tape.

In many cases, you may need the window in the fully up, closed position to get the necessary clearance inside the door to remove the motor. If the motor has failed with the window open and down, you will have to manually raise the window. If the motor has actually seized, you will first have to disengage the motor from the lift-mechanism drive to move the glass.

For a quick test of a disconnected motor, simply attach it directly to the battery. The motor should spin. Reverse the polarity of the connections and the motor should spin in the other direction. For a more accurate test, attach an ammeter to the spin-

ning motor to check its current draw. Compare that with specifications. Typically, a draw of more than about 15 amps, however, indicates internal drag in the motor. Replace it.

If the motor checks out properly—spinning freely in both directions and not consuming so much current in the process that it is going to blow

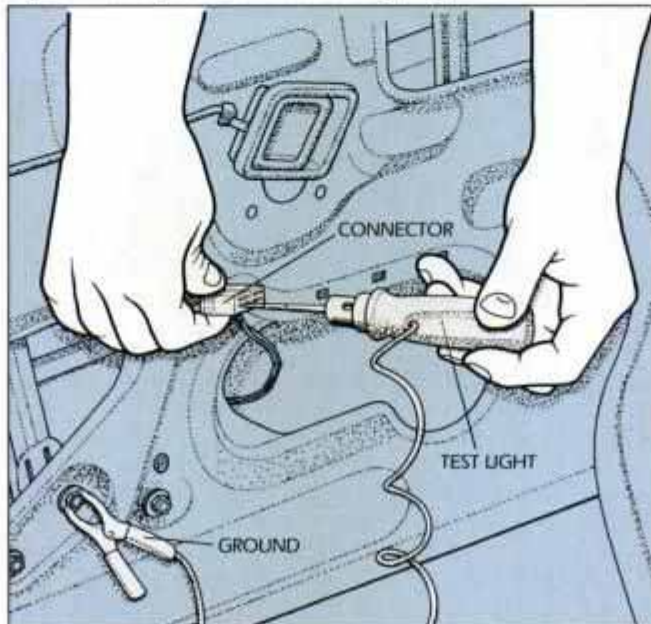
due to a bent link, twisted or folded plastic tape, frayed cable or mangled chain—it can put enough of a strain on the window's motor to cause an electrical overload. Likewise, if the glass itself is not properly aligned in its channels—front or back—it can create a serious problem. Also, verify that the glass is not getting hung up on some loose or torn weather-stripping.

Inspect the lift mechanism—as much of it as you can see through the access holes in the door's metal panel—looking for obvious physical damage. You may be able to make a quick and simple repair by straightening or reattaching a piece. You simply may also be able to replace the defective component of the lift mechanism.

If the window lift mechanism is defective, you may be able to find a replacement for it at a scrap yard.

To check the alignment of the window glass itself, remove the inner panel of the door on the opposite side of the car. Compare the movement and alignment of the glass of the two windows, making adjustments to the balky window in small increments and rechecking its alignment.

Check that the lift mechanism is not corroded or dry—clean and lubricate the linkages as per your shop manual. Then reinstall the motor and reconnect its wiring. Replace the plastic door inner liner, reattach any courtesy light or stereo speakers and reinstall the door trim panel. **PM**



With the ignition switch on, use a test light or meter to check for current to each window switch at its wiring connector.

the fuse—the problem lies in the mechanical components of the window, not the electrical components.

Before reinstalling the motor, check the operation of the window lift system. Various carmakers use different types of arrangements to raise and lower the window glass. They also employ various systems to guide the glass as it moves up and down.

If the lift mechanism is binding—

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performs in cold weather like a 5W-30 oil and in hot weather like a 20W-50 weight oil. Conventional motor oils can't do that.

Q. I put your synthetic motor oil in my car and would like to know when I have to change the oil.

C.K., Newark, DE

A. Automobile manufacturers do not recommend extended oil drain intervals for synthetic motor oils. But we believe this may change in the future. In the meantime, follow the oil change interval recommended in your owner's manual. This protects your new car warranty.

For more information on motor oils, lubricants and engines, write to Don Johnson, Pennzoil Products Co., P.O. Box 2967, Houston, TX 77252-2967.



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BEFORE



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DETROIT SPY REPORT

BY JIM DUNNE, Detroit Editor



Reskinned S-10 Pickup

● Both the small Chevy pickup and its GMC cousin, the Sonoma, get fresh-new sheetmetal for 1994. As with previous models, the S-10 and Sonoma share chassis, drivetrains and interiors, as well as their looks.

that grille as a '94 option—a premium engine based on the 32-valve dohc V8 in the Mark VIII.

Chinese Cherokee

Those of you who get to travel abroad may know all about buying



News for Cougar is not only a new grille, it's the optional 32-valve dohc V8 behind it.

Three engines will be offered—a 2.2-liter Four and standard and “enhanced” versions of the 4.3-liter V6. Both V6 variants should be smoother than before, thanks to a new balance shaft. And, as before, both 2wd and 4wd (shown) will be available with 5-speed manual or 4-speed automatic.

Freshened Cougar

The grille distinctly wearing the Mercury logo on this Cougar is part of the freshening that the coupe gets for 1994. While the new front-end treatment continues the familiar Cougar theme, it offers more depth of dimension. Of at least equal, if not more, note is what is going on behind

knock-off designer purses, bags and shirts. They're bargain copies sold at open-air markets. Now in China, you'll find knock-off Jeep Cherokees. These full-size sport/utility vehicles are almost duplicates of the Cherokee. But they are based on a 4wd truck chassis that's widely available in China. These Cherokee bodies are hand-built—even to the point of hand-forming the sheetmetal

panels. Ironically, because labor costs are so low, these knock-offs can sell for less than the real thing, the Chrysler-blessed Beijing Jeep.

Four-Door APV

Chevrolet has plans for a 4-door version of the new APV front-wheel-drive minivan due as a 1995 model. The fourth door is an optional sliding door on the driver's side. This door is in response to current owners' requests for the double sliding doors to facilitate loading and unloading. While the four doors will

help the APV stand apart from its competitors, its body will more closely resemble them. Reports are that the new minivan will have body panels made of sheet steel, unlike the current model's plastic ones.

The Sedan Division Of General Motors

Oldsmobile's master plan is to offer only 5-passenger sedans in the future. No more large 6-passenger models. No more 4-place sporty coupes. By 1995, the Olds lineup will consist of 4-door sedans, with the sole exception of the 2-door Achieva, which still will be sold alongside the sedan model. This is all part of Oldsmobile's aim to establish a narrower image for itself—one separate from Buick and Cadillac. Management at Oldsmobile sees the division's future in the mold of foreign makers, which do not offer 6-passenger seating.

PM



Imitation Jeeps are confusing the Chinese market.

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LIGHT SPEEDSTERS

BY ABE DANE, Science/Technology Editor



● Disciplined, conservative, relentless—not the first words that come to mind when I think of college students. But the University of Michigan's Maize & Blue team displayed exactly these qualities last June when they held off 33 contenders to win America's premier interscholastic solar car race. Despite poor weather, they averaged 27.29 mph over Sunrayce 93's 1100-mile course, edging out the second-place car by 90 minutes, and proving the value of their unswerving levelheaded race strategy. They're now 2-for-2 in the biennial event, which had its inaugural running in 1990.

With a couple of small but important rule changes to limit costs, and a shortened 7-day schedule, the Sunrayce concept itself is also proving its merit. The technical challenge of eking the greatest go-power possible out of 8 sq. meters of sunlight, combined with stiff competition, has brought a blossoming of creative engineering ideas. Principal sponsors the U.S. Department of Energy and General Motors appear to be getting a good educa-

tional return on their investment.

First over the Arlington, Texas, starting line this year was the California State University-Los Angeles Solar Eagle II, which held the pole position by virtue of a 50.04-mph qualifying speed. Sixty seconds later, Virginia Polytechnic whirred out of the gate. The University of Michigan started 10th, but had the lead by the time the pack reached the first overnight stop. Second was California State Polytechnic-Pomona's Intrepid, Michigan's toughest challenger throughout the race.



Second-place Cal. Poly-Pomona's detachable solar array sped recharging (above), but Michigan (top) once again was unbeatable.

In the days to come, about the only setback suffered by the Maize & Blue was a 20-minute penalty for running a red light (observers gave no slack on traffic violations). Other than that, Michigan left nothing to chance. Resisting the temptation to go for victory on every leg, their strategist determined optimum speeds based on a computer model and information from the team's meteorologist. The driver followed orders exactly, regardless of what the others did. As a result, the car's batteries always had power when needed, and Michigan was the only team not penalized for failing to complete a leg by the end of a race day.

It took an estimated 70,000 hours of work by the more than 100 mostly undergraduate team members to create the Michigan car. Like most in the race, it showcased high-tech electronics, refined aerodynamics and Space-Age materials. But more important, the event as a whole demonstrated the talent and ambition of those who'll develop the technologies of tomorrow.

PM

from a bridge-like truss, rather than the usual one-piece box spar, and radar components will be mingled with this internal bracing. The last time a structure like this was used in a large aircraft's wing was probably back in the biplane days. But tests so far have found it to be surprisingly light and strong. Also, as Gilbert points out, the load-bearing elements are distributed throughout the wing, so taking an anti-aircraft hit in any given spot is unlikely to cause a total collapse.

To quench the array's transmit/receive modules, liquid-coolant lines will be weaved into the structure. Wiring weight will be kept low by using a web of fiberoptic cables to carry data back to processors in the fuselage. The wings will be sheathed with protective fiberglass fairings that hinge out of the way for repairs. Underneath that lie the copper antenna elements—150 sq. ft. of them on each wing—contoured to follow the shape of the airfoil.

According to Gilbert, this airfoil will be much closer to the aerodynamically optimal than they had first thought. Theory says that a radar array's performance is in part determined by its capture area—the square footage presented to the target. That's why phased arrays like

those on the Patriot Missile system and Aegis combat ships look like barn doors pointed at the sky.

The EX's radar would mostly look horizontally, so Gilbert's team naturally worried that they would need to use a very fat airfoil with questionable aerodynamics. But the end-fire effect, the same phenomenon that enables TV aerials to pick up signals running parallel to their elements, proved stronger than expected. "We learned you can have capture area in the horizontal too," he says. That meant a conventional airfoil could be used. Not only did the joined wing take the place of a separate rotodome, but it apparently did so without compromising its own aerodynamics.

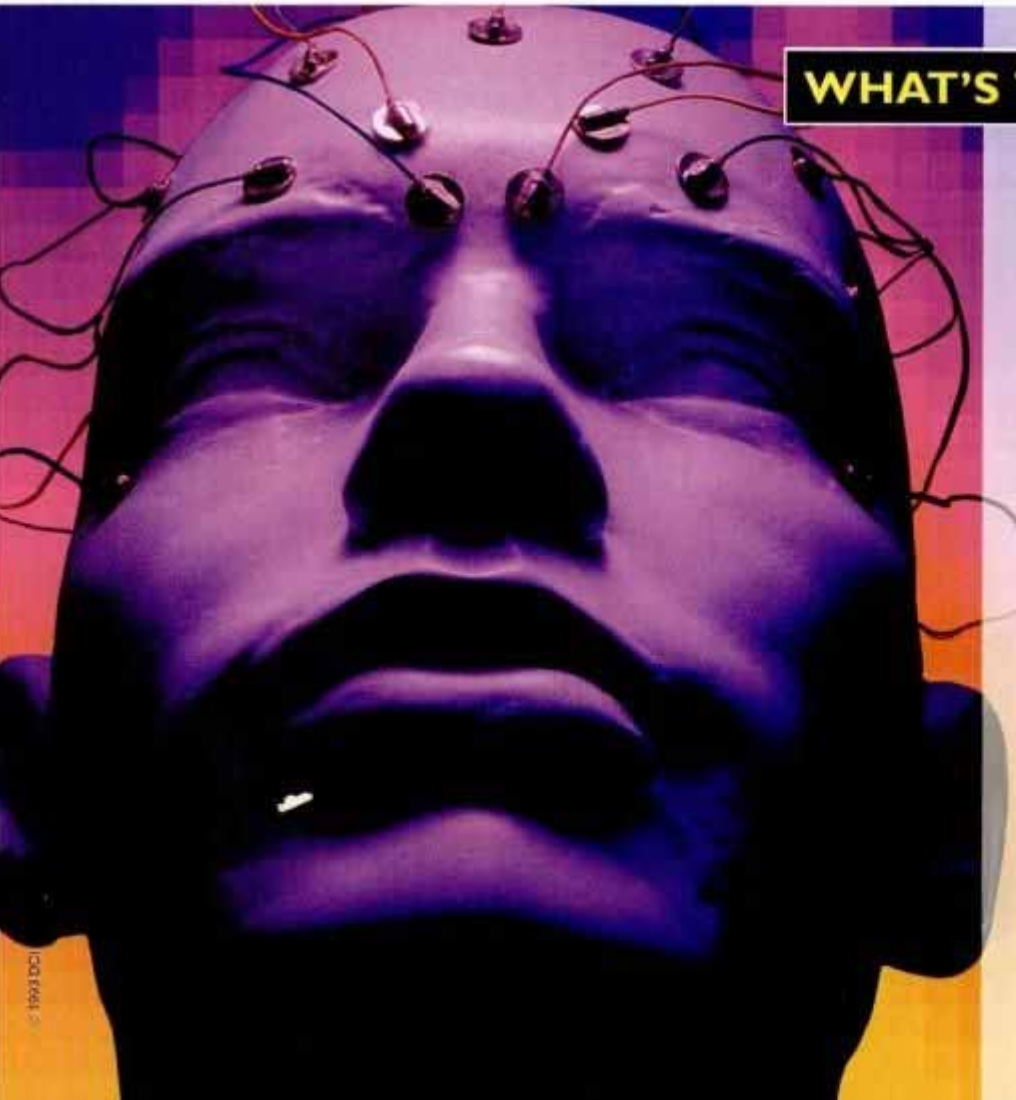
Partly as a result, Boeing's estimates so far indicate that the EX will outperform its predecessor by just about any aeronautical measure. With two 9275-pound thrust turbofans like those in the current S-3 Viking antisubmarine warfare craft, the EX will have a top speed of Mach .76, compared with Mach .48 for the E-2C. If endurance is the goal, the EX can slow to Mach .38 and loiter for up to 4 hours at a location 600 miles from the carrier.

As for handling—vital in any plane that has to make carrier landings—

fly-by-wire, or possibly fiberoptic fly-by-light, flight control systems provide designers wide latitude. "We can make the flying qualities whatever we want," says Gilbert. Their first thought was to have it mimic the behavior of the S-3, but they learned the Navy was not entirely happy with that plane. "The Navy said it flies like a feather," says Gilbert. For carrier landings, it's better to be able to fly like a rock, so there's no doubt when and where the plane will touch down. Control surfaces were added accordingly.

The one facet of the flying diamond that must really shine, however, is the performance of its radar. Gilbert predicts that the detection range for a small target will be 2½ times that of the new E-2C Group 2. Scuds should be visible beyond 400 miles, and airbreathing targets with cross sections down to 1 meter should be visible 400 to 600 miles off.

It may not be so simple to see into the future of naval warfare and determine whether the EX is the answer to tomorrow's threats. But a decade or so into the next century, today's Hawkeyes will be reaching the end of their design life, at which point Boeing's diamond may be an aircraft carrier's best friend. **PM**



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PM AT THE INDY 500

BY JEREMY SHAW



● Raul Boesel came oh-so close to winning this year's Indianapolis 500 for Team PM and Dick Simon Racing. With a little luck on his side, the 35-year-old Brazilian might well have been up there on the victory dais, sipping the traditional bottle of milk.

tory for both himself and team owner Dick Simon. It would have been entirely deserved, for Boesel's Duracell/Mobil 1/Sadia Lola T93/06 Ford-Cosworth XB had been among the very fastest cars.

That fact alone says much for the talents of Boesel and the resilience of Team PM and Dick Simon Racing. Their car is certainly not one of the most lavishly sponsored in the field, yet Dick Simon has lived up to his growing reputation for total commitment and thrifty management.

This year, the jovial, balding former IndyCar driver invested a significant portion of his budget into com-

missioning freelance engineers Mike Bowron and Mike Clark to conduct an exclusive 5-day wind-tunnel test in England. The pair devised several modifications to the standard Lola aerodynamic package, including a slightly different engine cover, revised sidepods and a reprofiled underbody. Each change might have represented only an infinitesimal advantage over the off-the-shelf equipment, but in the ultracompetitive world of IndyCar racing, that's all it takes to turn a good car into a winner. That and driver talent, of course.

Enter Boesel. The 35-year-old had been truly a force to be reckoned with in the first three races of the season, while the team's confidence received an extra boost when teammate Scott Brayton posted some very competitive speeds during a promising test at Indianapolis in



Scott Brayton ran a solid top-10 race all day, finishing sixth.

Instead, of course, another Brazilian, Emerson Fittipaldi, claimed the spoils of victory after a faultless performance in his Marlboro Penske-Chevrolet—although he, unwisely, opted to eschew the chalky-colored beverage in favor of a flagon of orange juice bottled on his own plantation in South America. One week later in Wisconsin, the heart of dairyland, Fittipaldi was greeted by a round of boos from the packed grandstands. But that's another story.

Back at Indianapolis, Boesel came within a couple of controversial calls of securing a first-ever IndyCar vic-



Jimmy Vasser, the least-experienced Team PM driver, came home in the lucky 13th spot.

PM PHOTO BY DAN E. BOWD

PM PHOTO BY RON MCGUIRENEY

PM PHOTO BY RAY ALTENGHULTE



PM PHOTO BY ROY D. QUERY

Well-founded high hopes for Team PM/Dick Simon Racing before the Indy 500—Jimmy Vasser, Raul Boesel and Scott Brayton (l. to r.).

April. Things were looking good.

But auto racing is a fickle sport. The test had been conducted in cool weather. When the track opened for official practice May 8, temperatures were considerably higher. Try as he might, Boesel was unable to match Brayton's earlier speeds.

"When we started, we were nowhere," acknowledged race engineer Julian Robertson. "We had a diabolical push in the car. Everything we had learned in the test was useless. With the hot weather, the car doesn't have nearly as much downforce."

Robertson also confessed that the famed 2½-mile superspeedway had taken on a new demeanor this year—the result of changes made over the winter in the name of safety. The most significant difference from a year ago was the fact that the old as-

phalt apron on the inside of the turns had been replaced by a grass verge, bounded by a rippled curb. The track effectively had been narrowed by a significant amount.

"The thing is," continued Robertson, "the track is so different this year, you really need a perfect setup to go quick. In the past, even with a rookie driver, you could get them up to speed and then take some of the downforce out of the car and go faster still. Because they could run all four corners flat out. They can't do that anymore. You have to finesse the car more."

Undaunted, the team knuckled down to finding an effective setup for the cars. It wasn't long in coming. Boesel soon began to pick up speed. On Day 5, Wednesday, he posted the fastest time at 224.461 mph. Two

days later, he again topped the time sheets with a best lap at 225.592 mph. Only Indy specialist Arie Luyendyk had gone faster. As the team prepared for qualifying, no question about it, Boesel was a contender for the coveted pole position.

"The car's feeling good," declared Boesel. "We had some problems early in the week but we're over that now. We have a good setup. The car is fast. We'll see what we can do."

Teammate Scott Brayton also lapped in the 223-mph bracket with his Amway/Northwest Airlines Lola/Ford-Cosworth, while the third member of Team PM, Jimmy Vasser, showed distinct promise after car owner Jim Hayhoe traded his regular Chevrolet/A-powered '92 Lola for a Ford-Cosworth XB version.

(Please turn to page 108)



PM PHOTO BY RON MCGUINNEY

Starting from the front row, Boesel led the race until his first pitstop on lap 17—a stop that resulted in a stop-and-go penalty.

"I was a little bit concerned about being able to qualify for the race good and solid with the old Chevy/A engine," explained Hayhoe, "especially with all the Fords and new Chevy/Cs around. So when this opportunity came up to run the Ford-Cosworth, I jumped at it. Even though it cost a lot of money, I feel it puts us on a whole different level."

Vasser was severely restricted on the number of miles he could put on the tired XB motor, yet he qualified solidly enough on the first weekend—19th among the field of 33. He would have a fresh engine for the race.

Brayton was disappointed to manage no better than 11th on the grid, having struggled with a very loose car on his qualifying run, while Boesel professed to mixed feelings after turning four excellent laps at an average of 222.379 mph—good enough for the outside of the front row.

"My car was perfect," he said. "I think we had a shot at the pole, but we were slower than I hoped because it was hot. But what should you do? In one way, I am disappointed because I think we had a car good enough for the pole. That's what we came here for. On the other hand, the

car is good, it's very consistent, and I think we will have a good car for the race. And for sure, the race is a lot more important than qualifying."

The prospects for race day, then, were good. All three drivers were optimistic. There had been virtually no mechanical problems during the long buildup to the race. Everyone was confident of a strong performance.

And so it proved. Boesel, in particular, felt he had a point to prove from qualifying. He made it as soon as the green flag flew, charging past pole-sitter Arie Luyendyk on the outside line into Turn 1. Team PM was leading the Indianapolis 500!

Boesel hammered home his advantage early, turning some of the fastest laps of the race as he pulled out as much as 5.5 seconds over a battling Luyendyk and Mario Andretti.

Then came disaster. Following his first pitstop, made under caution on lap 17, Boesel was called in for a stop-and-go penalty. But no one knew why. One official said the penalty had been assessed for passing Mario Andretti on the way out of the pits. Another said it was for exceeding the 100-mph speed limit in pit lane. In any event, the penalty stood. And once an angry Boesel had made his way in and out of the pits, he was all the way back in 27th place.

From there it turned out to be a long afternoon. Gradually, though, Boesel worked his way back into contention. Then Lady Luck turned against him again. On lap 168, the three leaders—Mario Andretti, Emerson Fittipaldi and Nigel Mansell—all made routine pitstops. Boesel, running fourth, was due in next time around. But, cruelly, the yellow flags were flying as Boesel made his way toward pit lane, because Robby Gordon's car had expired out on the course. And under USAC rules, the pit lane is automatically closed when the yellow is shown—as a safety measure, no pitstops are allowed until the entire field has bunched up behind the pace car. The penalty for pitting too soon? You guessed it, a stop-and-go.

Boesel, though, already was committed to making his stop when the yellow came out. One more lap and his fuel would have run dry.

"What were we supposed to do?" queried an irate Robertson, "Run out of gas in Turn 2?"

The team protested its innocence but to no avail. Boesel would have to stop again. He did so on lap 173—out of 200—falling from third place, behind Andretti and Fittipaldi, to seventh.

The final irony came 10 laps later when the caution lights flashed on

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again. By this time Mansell had regained the lead in what was turning out to be a classic encounter. The Englishman was followed by Fittipaldi and Luyendyk. Right ahead of them was young rookie driver Stephan Gregoire, who was obviously overwhelmed by the situation and, in his confusion, beckoned all three leaders to go past. Next in line was Boesel, having made up a couple of places following his earlier penalty.

"I saw them go past the slower car," related Boesel. "It was right in front of me. But you can't pass under yellow. They broke the rules."

Boesel immediately informed his pit crew of the apparent infraction. To everyone's astonishment and dismay, no action was taken.

"It was crazy," said Boesel. "The officials were very inconsistent. When the green flag came out again, the leaders all took off. I had to wait for the slower car to get out of the way. By that time, the leaders had gone. I was about a half-straightaway behind."

In the dramatic closing stages, Fittipaldi drafted past Mansell to take the lead, holding on for a famous victory in what had been one of the most exciting and competitive Indianapolis 500s ever. Luyendyk followed closely



PHOTO BY LINDA MCCUE/NET

Raul Boesel making one of his two costly stop-and-go penalty pitstops.

in second place, pursued by Mansell and an irate Boesel. Brayton also drove a fine race for Team PM, running strongly in the top 10 all day, and finally finishing sixth, while Vasser belied his relative inexperience by claiming a worthy 13th, two laps behind the leaders.

Boesel, though, was adamant that the race should have been his.

"We worked hard and we had the car to win," he said with great emotion soon after the race was over. "I think we would have won if not for the officials. This race, I think, would have been mine." **PM**

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MERC'S SEA POWER

BY JIM YOUNGS



• If it seems like there's a lot of emphasis on offshore fishing by marine engine companies lately, you couldn't be more right. The offshore angler is being inundated with high-tech products designed to make blue-water trips more enjoyable, reliable and comfortable. New offerings from the big three outboard manufacturers (OMC, Mercury and Yamaha) fall into this category, and the fiercest competition is in the high-end of the market—the 225-horsepower range. The most recent engine to debut in this class is by Mercury.

The new Mercury/Mariner 3.0-liter 225 V6 is an impressive piece of machinery. It should be. Engineers at the roll-out in Florida told us the big Offshore 225 was seven years in the making. Not surprisingly, it bristles with advanced features. Chief among these is a new lost-foam cast 60°-V block with 185 cu. in. of displacement. It also has loop charging, a 1.64:1 gear ratio, a 60-amp alternator and 20-in., 25-in. and 30-in. shafts.

The lost-foam casting process that Mercury uses on these engines provides tremendous benefits through the elimination of gaskets, bolts and add-on parts. Exhaust and intake manifolds, heads, exhaust pipe and idle-relief systems are now integral parts of the block.

A good example of the benefits derived from forming complex shapes through lost-foam casting is in the

heads. The new Offshore 225 features O-rings instead of gaskets, which helps keep cylinders within better tolerance. Also, it eliminates gasket creep and the tendency to set up a galvanic cell among dissimilar metals.

The Offshore 225 does not have electronic fuel injection—high cost is cited—but it does have a micro-processor-controlled, digital-ignition system that provides some of the desirable functions of an EFI system. Mercury's onboard ECU (Electronic Control Unit) monitors and adjusts spark timing, coolant temperature, throttle position, engine speed, overheating, startup, sensor failure, rev limiter and oil level for optimal performance. The digital ignition is shielded to allow the use of standard spark plugs and prevent interference from stray radio-frequency emissions.

A nice operational feature of the 225 is turnkey starting controlled by the ECU. The system incorporates a fuel-enricher system that precludes throttle fiddling and choking, which is typical of cold-starting an outboard. It worked well in tests.

As a part of the ignition, Mercury incorporated a modular system that features separate charge coils under the flywheel and a CDM (capacitive discharge module) for each cylinder. This feature improves reliability by ensuring that if one of the components fails, it only affects that cylin-

der and not the whole bank or engine.

To keep internals cool, Mercury uses a floppy-vane water pump mounted in the lower unit. It can tolerate sand or dry running far better than competitive units. Mercury has also included a plug-in fitting adjacent to the pressure-relief outlet on the tower housing so that a garden hose can be hooked up for flushing the saltwater out of the engine.

To accomplish its performance goals, Mercury engineers settled on big cylinder ports to improve breathing. There are two big transfer ports and two big boost ports.

The most graphic demonstration of the Offshore 225's low-end power came during a test on a twin-engine Wahoo 26-footer. We were easily able to stop one engine and let it drag in the water while the other engine planed the boat. That's dramatic get-home grunt power.

Mercury included many other nice features on its new V6 as well. The new styling and color scheme, on the Mariner model in particular, are stunning and the bucket cowl is a welcome addition. The new cowl has a simple, single-lever latch, and features a cowl-within-a-cowl design for quiet operation and effective routing of water and salt spray. These engines also sport a new gearcase—one that shares the same internals with the MerCruiser Alpha One drive unit.

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TV'S NEW PICTURE

BY FRANK VIZARD, Electronics Editor

● If you're thinking about buying a new television, right now is about as good a time as any. The number of new models available from manufacturers is the largest in recent memory. And, for the most part, they all have something new to offer.

This avalanche of new TVs is partly precipitated by a new government regulation requiring that closed captioning be a feature on all new TVs. Closed captioning is likely to benefit more than just the hearing impaired since there is an opportunity to present a variety of textual information ranging beyond program dialogue to services like stock quotes.

What you'll probably notice immediately, however, is a sharper picture. These new TVs are the end product of an internal industry debate going back many years. The issue, put simply, is one of artifacts versus contrast. TV engineers were initially hellbent on removing any artifacts from the screen that stood in the way of a film-like picture. The problem was that the removal of some artifacts often adversely affected picture quality.

It soon became apparent that while many engineers were chasing a Holy Grail, most of the artifacts



Black glass translates into greater realism.



Sony brings more contrast to TVs (above) and offers a slim 61-in. projection model.

they were trying to remove weren't really visible to most people anyway.

What most TV viewers really wanted, even if they couldn't articulate it, was more contrast. TV viewers are finally getting their wish thanks to a new picture tube which, while marketed under a variety of names, can be described generically as black glass. A special dye is added during the manufacturing of the picture tube so that the screen is darker. This dye effectively makes blacks richer and leads to more vivid colors and brighter whites. The improved contrast—defined as the difference in magnitude between black and white elements—makes the picture look more realistic.

How do you spot a TV with black glass? Just turn it off. TVs with black glass will have a darker tint than those without. Black glass TVs are already available from RCA, Sony, Hitachi, Toshiba, JVC and others in a variety of screen sizes.

Another innovation concerns projection TVs. While projection TVs were once objects of gargantuan proportions, a newly designed short-focus lens assembly is making pro-



jection TVs much slimmer. Since the internal electronics and optics require less space, companies are now approaching projection TVs with more flexibility. Sony, for example, is going bigger, offering a 61-in. model that has a depth of only 31 in.

Mitsubishi, meanwhile, is going the other way, developing a 45-in. tabletop projection TV that has the same footprint as current 27-in. direct-view models. List price for the Mitsubishi tabletop projection TV is \$3299, however.

Another new feature is an electronic program guide available this fall in TVs made by Zenith and Mitsubishi. Called "Starsight," this program guide is available to subscribers for about \$5 per month. "Starsight" presents program information in grid form and offers detailed descriptions of each show.

Programming information also can be customized in ways most convenient for individuals. Programming can be accessed by genre, for example. Select "Sports" and a list of sporting events for the next seven



Ghostbusting: California-based Zoran plans to wipe ghosts off the screen.





The wristphone: No time, lots of talk.

days will appear. "Starsight" also makes recording shows on your VCR a one-touch operation since day, time and duration of the program are instantly entered into memory when the program is selected. Programming information is transmitted over the vertical blanking interval of PBS stations. Other TV makers are likely to incorporate "Starsight" circuitry in future models.

Other new features for TVs are visible on the horizon. Perhaps the most promising is circuitry that will eliminate ghosts. Philips says its 1994 Magnavox and Philips TVs will have such circuitry. Competing against Philips in this area will be a company called Zoran, a California chip maker. Zoran says the Philips chip only eliminates nine ghosts, while its chip gets rid of an unlimited number of ghosts. Who you gonna call? We'll have to wait a few years to know for sure.

Calling Dick Tracy

Like other cordless phones, the Panasonic KX-T9900 has a base station. But unlike others, the phone wraps around your wrist like a watch. The wristphone features a built-in microphone, speaker and keypad. Up to 10 numbers can be stored in memory for instant access. There's even a one-touch redial feature. Up to four wristphones can operate from one base station, and users can talk to each other using the intercom feature.

The Panasonic wristphone operates on the new 900-MHz frequency. While cordless phones using this frequency have an operating range of over a half-mile, the Panasonic model has an effective range of only about 150 ft., says the company. This is about the range of the older cordless phones operating in the bandwidth between 46 and 49 MHz. The wristphone's limited range is due to the small size of its antenna, which is itself wrapped around the wristphone. List price is \$999. The only drawback to the product is that it doesn't tell time as well, so you need a pocket watch to go with it.

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NEW CARS

**New Mercedes C-Class**

• Mercedes C-Class sedans, the replacements for the 190 line, are completely new automobiles—new styling, a new engine and increased size.

Behind the steering wheel, the driver sees and feels the Mercedes tradition. The 3-pointed star on the hood and the full-disclosure gauge pack are the visible clues. Drivers sense the added power, the precision steering and the overall strength of the body construction.

On the German autobahn, the car settles down to 100-mph cruising without a murmur of protest. Predictable handling, dual airbags, ABS and enhanced side-impact crash protection are Mercedes standard features.

C-Class cars are bigger inside and out. Compared to the 190 series, the 177.4-in. overall length is 2.3 in. longer, and the wheelbase is 1 in. longer—105.9 in. Front-seat passen-

gers have more space in the C-Class.

Two models are offered: the 4-cylinder C220 and the 6-cylinder C280. As in the past, designations are based on engine displacement. A 4-speed automatic is the only transmission.

Thanks to greater horsepower from a dohc 4-valve design—147 hp for the Four, 194 hp for the Six—and carefully chosen gearing, 0-to-60 times are quicker by a couple of seconds. The 2.8-liter Six will push the new sedan to 60 mph in about 8 seconds.

While prices for the C-Class won't be available until November, you can expect them to begin at about \$30,000 for the C220, and about \$4000 more for the C280. —*Jim Dunne*

Alfa's Enhanced 164

Although there have been small styling tweaks, there's no mistaking the latest update of the Alfa Romeo 164 sedan for anything else.



Mercedes C280 has a dohc inline Six with variable intake tuning and direct ignition.

But its performance promises to be a pleasant surprise. Thanks to new dohc 24-valve cylinder heads, the 164's 3.0-liter aluminum 60° V6 hustles these sexy front-drive sedans down the road with more authority than their predecessors.

Available in LS and sporty Quadrafoglio trim levels, the new 164s both offer improved horsepower and torque over the previous editions—15% more hp, 7% more torque.



New dohc 24-valve cylinder heads give Alfa's 3.0-liter alloy V6 a 15% boost in horsepower.



New Lola T93/20 chassis will carry Firestone Indy Lights racers through the '95 season. Race-prepared stock-block Buick V6 engine produces 425 horsepower.

The LS version produces 210 hp, the Quadraflorio 230 hp.

Both models are offered with 5-speed transmissions. Automatics are available with LS versions only. Other standard equipment includes a driver's airbag and 4-wheel disc brakes with antilock. —Tony Swan

It's Definitely Not Your Father's Buick

Okay, so it's not exactly what you'd call practical. Seating is limited, there's no place to stow any luggage, air conditioning has to do with wing settings and the sound system, located just behind the driver's shoulder blades, plays the same tune all the time. Plays it loud, too.

Most of all, though, it plays it fast.

It's pretty obvious that this is a car intended for weekend driving. Specifically, weekends devoted to the 1993 Firestone Indy Lights racing series.

But there's a stock-block Buick V6 engine at the core of this critter, so

when the opportunity came our way, we naturally felt it was our duty to assess the car's performance.

This occurred at Portland International Raceway, courtesy of Oregonian Ray Richter, who owns the car shown above. A self-made trucking and warehousing magnate, Richter was tuning up for Portland's Indy Lights round and invited us to share the day. It was an instructive experience.

But first a word about the car. The carbon-fiber/aluminum honeycomb chassis is made by Lola, in England, model No. T93/20, and sells for \$129,000 per copy. It's dimensionally similar to last year's IndyCar Lola, but with a flat bottom—no ground effects. The Lola is the first new Indy Lights car since the original March chassis of 1986, and it's clearly well suited to its role as an IndyCar trainer. Indy Lights lap times this season have been very impressive, even quicker than many of the IndyCars at some venues.



Naturally, the engine contributes a great deal to this performance. But even more important, its stock-block origins help keep costs in line. All the Indy Lights engines come from the shop of George Montgomery in Dayton, Ohio. The teams lease the engines for the season at \$40,000 per copy, which includes 1000-mile rebuilds.

Montgomery starts with GM's 170-hp port-injected 3800 V6. When he's through, displacement expands to 4.2 liters, compression is up from 9.0:1 to 12.0:1, intake and exhaust valve sizes are increased, solid roller lifters replace the stock hydraulics, there's a steel crank in place of the nodular iron stock unit, a dry-sump lubrication system replaces the 3.8's wet sump and the Delco engine management system has had a fair amount of massaging.

The net result: 425 hp at 7200 rpm, 342 ft.-lb. of torque at 5500 rpm. That may not sound like much compared to the 750 to 800 hp of today's IndyCars, but in a 1400-pound car it performs well beyond the experience of most drivers.

How far beyond? Well, even though I spend lots of weekends on race-tracks, the Indy Lights car is so far beyond my normal racing realm that I found myself downshifting into survival mode almost immediately. The guiding ethic: Don't wad this thing up.

Even so, Portland's long back straight gave me a chance to experience the heady rush that goes with 1 hp for each 3.3 pounds of car. Your shoulders flatten out against the seatback, and the scenery gets blurry in a hurry. Even in survival mode, we saw speeds upward of 160 mph.

It's obvious that this isn't an everyday car. But it's a design that won't change for two more seasons. How many other new cars will still be new two years from now? —T.S.



PHOTO BY LEE BECK

A Perfectly Modern Packard

● At a glance, it looks like a 1934 LeBaron-bodied Packard roadster. And even up close, this all-new classic from the Packard-Bayliff Co. of Lima, Ohio, painstakingly preserves the glorious past.

The car really is entitled to the Packard name. Company founder C. Budd Bayliff, who also sells new Pontiacs, Buicks and Cadillacs, secured rights to the Packard brand name in 1978.

This car, Bayliff's prototype, uses a Packard straight-Eight engine. However, production versions will get Ford's 4.6-liter V8, to go with the Crown Vic chassis. The body is high-quality fiberglass, and there are certain modern amenities, like power windows. But the classic era is preserved in the 18-in. Zenith wire wheels, the faithfully reproduced interior and the superb craftsmanship.

The price: About \$130,000.

the selected shift points to help catch the driver's eye as he negotiates a 7-second, 195-mph run.

Transmissions are either Lenco planetary units, which carry each gear in a separate case, or one of several clutchless 5-speeds controlled by a pneumatic pushbutton system that has eliminated the actual shift lever.

Successful fuel delivery and oiling are vital, but difficult during the forces of a 7000-rpm launch. Every Pro Stock car, regardless of engine make, utilizes a dry-sump oiling system. And some teams have separate fuel filters and pumps for each carburetor.

Some cars even have separate fuel-pressure gauges for each line.

Underneath, Pro Stockers use sophisticated 4-link rear suspensions and minutely adjustable coil-over shocks and carbon-fiber 4-wheel disc brakes. Stopping is again aided by dual parachutes.

Drag racing is more popular than ever, with racetracks in virtually every corner of every state. Amateurs race for the thrill of victory and a trophy to show to the family. And at every moment of every day, someone, somewhere is flooring it at a stoplight to beat another guy to merge. **PM**

(Continued from page 56)

range because of the low-traction Goodyear Invicta GL tires. We had already become disenchanted with these tires before the mud incident. They're quiet on the highway, not too good in the rain and totally useless off pavement. Anyway, two tow trucks, 200 ft. of steel cable and a winch later, we were out. Cost: \$200.

Next came the Blizzard of '93, the worst snows in 20 years. Once we were out of the deep stuff, our Jeep Grand Cherokee was a delight, tracking us safely through whatever Mother Nature threw our way. But once again, the Invictas were not up to the job. Then one blew out. When was the last time you had a blowout with a modern tire? Rather than just buy one new tire, we went to a local Goodyear store and replaced all four with a set of 225/75R15 (stock size) S4Ss, which have a much more aggressive tread design and should fare better with the way we drive the vehicle. Cost: \$352.20.

On a long haul from New York to Detroit and back by our publisher, the Grand Cherokee was a delight, except for the \$145 ticket courtesy of the Pennsylvania State Police. In fact, the more we drive it, the more we like it. We also like the compliments and attention our Jeep gets wherever we go. —J.O.

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Mercury Villager LS

The odometer has just clicked past 10,000 miles and our test vehicle continues to hum along. The first thing we liked about the Villager is still the thing we like best about it. You drive this van like you drive a car. Steering, acceleration and transmission smoothness match a first-rate sedan's performance in these categories. They should. Villager, built by Ford, uses the Nissan Maxima 3.0-liter V6 and 4-speed automatic.

The engine is rated 151 hp and 174 ft.-lb. of torque and makes the Villager feel light and nimble on its feet.

Add the very quiet cabin with a flat floor and high seating position and you have the necessary ingredients for a first-rate driving experience.

The Villager has developed only one glitch thus far. The left-door window came partially loose after an ice storm sealed the glass to the frame. Our local dealer quickly took care of the problem under warranty.

Our fuel mileage has been 21.5 mpg for the 10,000 miles of driving. EPA rates this vehicle at 17/23.


So far, we'd rate the Ford/Nissan collaboration on the Mercury Villager as very successful.

—Jim Dunne

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the torso. The arm simply allows these accelerators to work without resisting it. If the arm is stiff and you try to muscle the serve, you might actually lose power. Sampras is very loose in his arm when he serves."

Racket tech

Has racket technology had anything to do with the proliferation of big serving in the modern game? The answer appears to be that the impact of the livelier rackets on the market today has been more meaningful on the recreational level of the game rather than in pro tennis. Players like Sam-

pras and Jim Courier continue to compete with rackets that were introduced nearly a decade ago and are no longer sold in stores.

According to Ram Ramnath, Ph.D., professor of aeronautics and astronautics at MIT and technical advisor for the ATP Tour, players like Sampras stay away from popular widebody rackets used by most club players because they don't have time to make the adjustment to the more modern equipment. In turn, with their already accomplished styles of play and with their inordinate power off the ground and on the serve, they

don't necessarily need the benefit of a more-potent racket. Ramnath believes the next generation of top-notch competitors—the junior players moving up through the ranks right now—will use the widebody racket and will benefit from it in terms of power because they will have played with it throughout their young lives.

In any case, both Ramnath and Fox salute the efficiency of the widebody frames, which are 25 to 29mm in width compared to 16mm for the old Jack Kramer Wilson wood frame—the most popular racket of the 1960s and most of the 1970s.

As Fox states, "The velocity of a serve comes from how fast the racket is moving at contact and how energy is transferred to the ball. The new rackets probably move at the same speed as older ones, but there is greater energy transfer to the ball with the newer rackets. The widebody is stiffer. In the old days, the racket flexed backward and then the ball left before it flexed forward. Therefore, energy was wasted in flexing the racket. These new rackets don't flex as much so more energy is transferred to the ball."

Rising sweetspots

Ramnath makes another important point when he talks about how the changing sweetspot relates to the fast-paced serving in the game today. "With the newer rackets," he points out, "the sweetspot is being raised all the time. Companies like Wilson are trying to make the sweetspot higher and higher on the racket's strings. For very good servers, the high sweetspot, combined with the high head speed of the racket, can result in great power. They make contact with the ball slightly higher on the strings for maximum power."

The racket industry began shifting away from the standard wood frames in the late 1970s, but the original composites, which entered the marketplace back then, were identical in size to the wood-frame rackets—75 sq. in. The explosion of new products saw some of the oversize frames enlarged up to 120 sq. in., but eventually it all balanced out with midsize frames measuring 85 sq. in., midsize-plus coming in at 95 sq. in. and oversize frames settling down at 110 sq. in. According to Frank Garrett, director of technology for Wilson, the original widebody frames made by his company were 39mm or 1½ in. in width. The current widebodies have come down in size to 25 to 29mm or approximately 1¼ in. The wider the racket, the stiffer it will play.

The most recent development in rackets relates to weight. The con-

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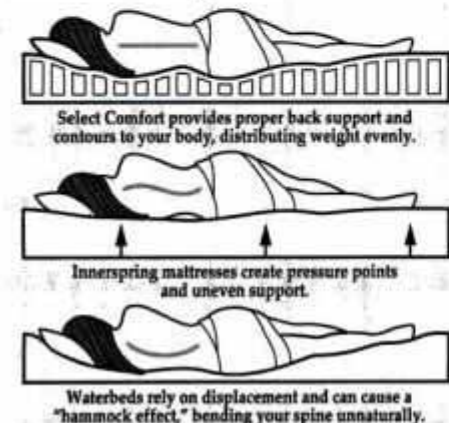
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ventional weight of most rackets until now has been 12.4 ounces, but the trend in some of the newer widebody frames is to make them about 20% lighter, or 10 ounces. If these lighter rackets are balanced properly, they have the capacity to contribute to a larger sweetspot—a movement which could only be a positive step for the power server.

And what of the future? Will the server gain too substantial an advantage, take on too dominant a role? Although innumerable veteran observers of the sport are apprehensive about the growing legions of big servers, reaching the conclusion that the power trend has gone too far, the recent evidence seems to lead in the other direction.

Return of serve

The advancements in rackets are benefiting players in other aspects of the game. There may well be more great power servers around than ever before, but on the other side of the net is the rapidly growing number of players who can return serves with increasing effectiveness. How else can you explain how Andre Agassi could defeat Becker six consecutive times between 1990 and 1992, including a stunning triumph on the grass courts at Wimbledon where Becker's booming serve has blasted so many players off the court in the past?

Fox presents an interesting point of view on the topic. "I would have to say," he begins, "that the big servers do not enjoy as much of an advantage as they used to have. It used to be worse for the receiver. Fred Stolle would play John Newcombe in the 1960s and there would be no points to watch. The server in matches like the Stolle-Newcombe battles was dominant in a way then that I haven't seen since. The counterattacker gets a fair shake today because there are few grass-court tournaments and the ball is heavier than it used to be."

This informed comment might be debated by some authorities, but it cannot be discounted. Clearly, there is encouraging diversity in the playing styles of the top men and, as a group, they are more well rounded in all facets of the game than most of their predecessors. Courier attacks primarily from the baseline and works his way admirably through tough matches, boosted by his big serve. Sampras overflows with talent beyond the serve and is capable of glorious play off the ground and on the volley as well. Becker is a gifted shotmaker. And Stefan Edberg picks apart his opponents with a persistent attack from all parts of the court that

is not based on power but rather on agility and anticipation.

Clearly, the serve will remain a critical weapon across the entire spectrum of the men's game. And it will take on increasing value among the women as well with players like the renowned Jennifer Capriati and the lesser-known Dutchwoman Brenda Schultz, showing the propensity to release serves traveling nearly 110 miles per hour.

In the final analysis, all that is certain is that nothing is predictable when it comes to power on the serve. Surely, the widebody rackets will be

seen with dramatically more frequency over the next decade. Certainly the number of first-rate players will increase steadily. Perhaps the game will grow too fast for its own good.

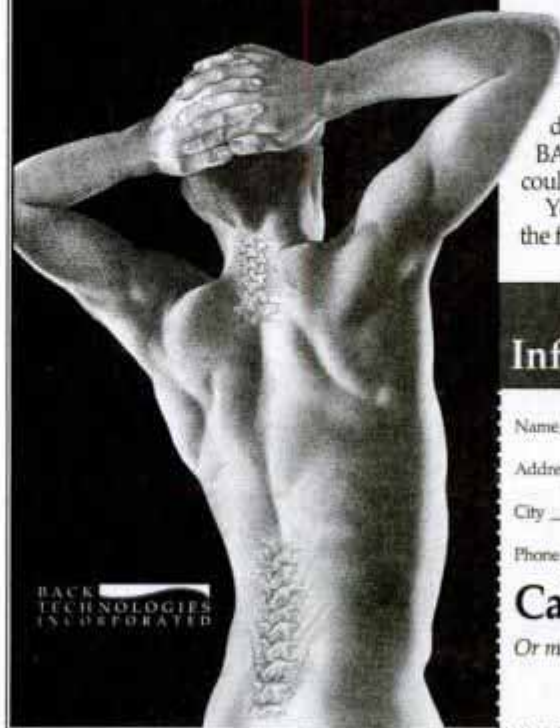
But, as Fox projects, "It is very questionable as to what will happen. The widebody will change the equation at some point down the road, but I am not sure how yet. Servers may become more powerful, but it will certainly make it easier for guys to hit groundstroke winners. Who knows? Maybe the volley will become almost obsolete." **FM**

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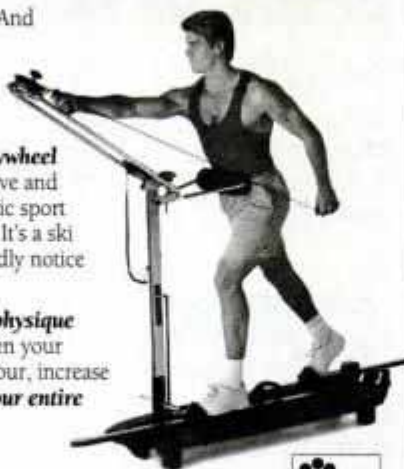
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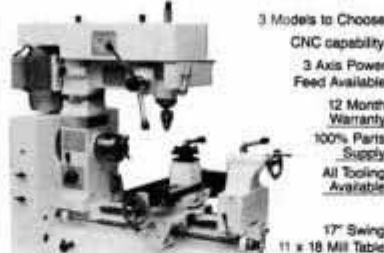
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