Upgrades for the Lycoming O-320

As good an engine as the Lycoming O-320 is, many 172 and Cherokee owners would love to indulge in a little firewall-forward customization. Cherokee 140, Warrior I, and Cessna 172I-M owners would like to be able to convert from 150-hp to 160-hp. (Owners of older, Continental-powered Skyhawks would in many cases like to *convert* to an O-320.) Owners of O-320-H2AD Skyhawks would like to convert to something—anything—else.

It turns out that all of these things are possible (and legal) with STCs by RAM Aircraft Corp. of Waco, Texas.

Of course, RAM isn't best-known for its O-320 mods; the company is best known for its close-tolerance overhauls of (and power upgrades for) the TSIO-520 Continentals used in the Cessna T310, 340A, 402, and 414, and also lately the Baron 58P and 58TC. In addition, RAM offers winglets and gross weight increases for the 414A and 421C. But they also offer some worthwhile upgrades for O-320 owners—including a very inexpensive STC to upgrade the O-320-E2D from 150 to 160 horsepower.

By now, almost everyone knows that the low-compression, 150-hp O-320-E2D differs from the high-compression, 160-hp O-320-B and -D series engines primarily in the choice of piston. The -E2D's P/N 75413 piston gives a compression ratio of 7:1, while the O-320-B and -D use either P/N 71594 or 75089 pistons, with 8.5:1 C.R. (The P/N 75089 uses a half-wedge compression ring, while the P/N 71594 piston uses a full-wedge ring design.) It doesn't take a high school education to figure out that if you put the 8.5:1 piston into your -E2D Lycoming in the course of a normal top overhaul, you're going to gain 10 horsepower overnight.

RAM's STC allows just that. As currently written, the RAM 160-hp STC allows the owner of an O-320-E2D to install P/N 75089 (half-wedge, 8.5:1) pistons in place of the old 7:1 pistons, and in so doing convert the engine to a 160-hp, 100-octane powerplant. Cost of the STC: $400.

The 150-hp Piper Warrior can be converted to 160 horsepower by installation of a RAM-overhauled O-320. Piston swap cannot be done in the field in this case, however.

"It actually consists of two STCs," RAM marketing chief Chuck Morrow explains. "There's the engine-conversion STC, which is a list of cookbook instructions for topping the engine with 160-hp parts, and then there's the STC authorizing *installation* of the engine in a 150-hp airframe. You've got to have both. We sell them separately, for $250 apiece, or together as a package, for $400."

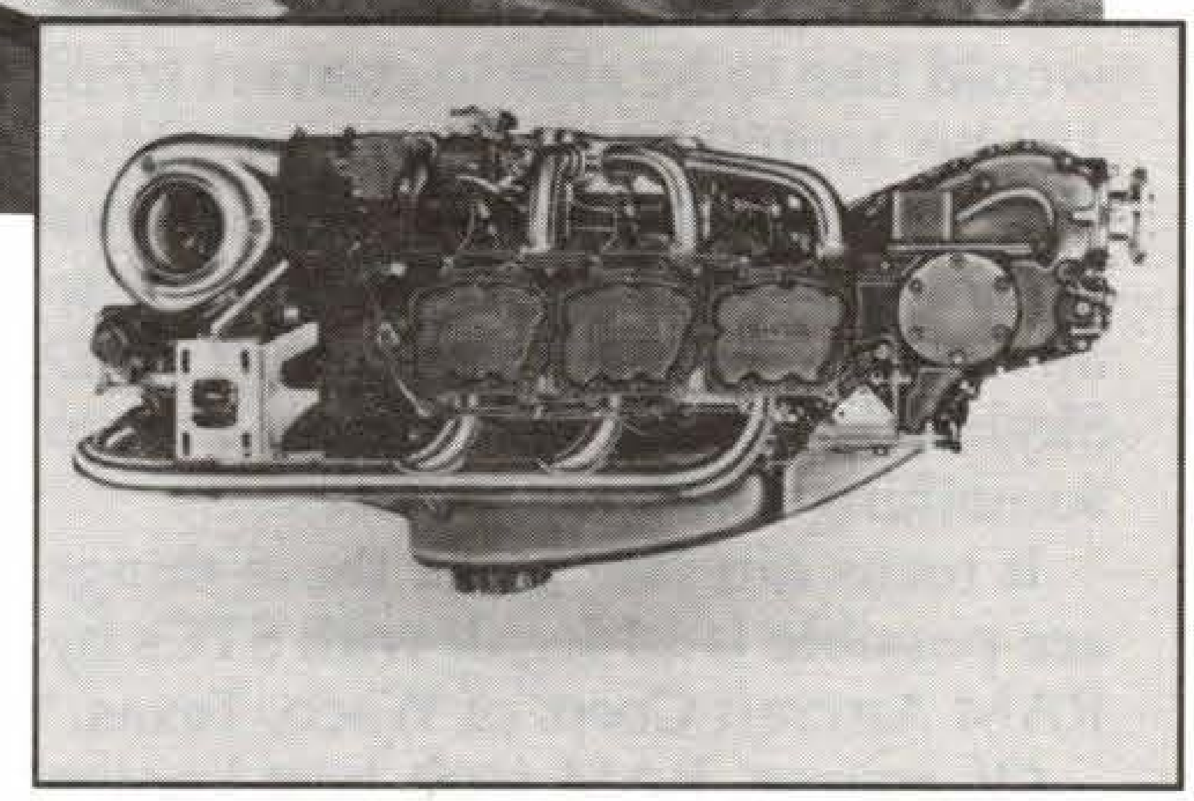
It's important to note that the $400 covers STC paperwork and instructions only; the customer must secure parts himself. The pistons, however, are cheap: Genuine Lycoming P/N 75089 pistons (brand new) can be bought for $44.63 each from Linda Lou Inc. in Memphis; phone 1-800-824-9912 for details.

RAM also performs close-tolerance, new-limits overhauls of O-320-E2D engines to the 160hp specs; the RAM-rebuilt, dynamically balanced engine costs $7,500 uninstalled (FOB Waco, TX), or $8,500 if installed in Waco by RAM. Engines installed by RAM in Waco are eligible for prop repitching (wherein the existing McCauley 1C160/CTM75-53 propeller is repitched to a cruise pitch of 57 inches) as well as the installation of RAM's special red-silicone cooling baffle material.

The latter comes as a separate STC'd kit: Pre-fabbed cooling baffles for the O-320 (made of RAM's proprietary high-temp red-silicone baffle material, same as used on the 400-series twins) are available in kit form for $200.

Important Caveats

The piston-swap mod is not without its caveats. For one thing, the STC as presently written applies only to -E2D engines (not the Cherokee's -E3D), even though the two engines are virtually identical. It may be possible to persuade an astute FSDO (Flight Standards District Office) to accept RAM's paperwork as the basis for approval of a Form 337 on an -E3D mod using the P/N 75089 pistons, but this is something owners will have to take up on their own. At present, RAM can't offer a pre-approved "cookbook style" horsepower upgrade for the -E3D, although it *can* install the 160-hp engine in your



The 425-hp Lycoming TIGO-541-E (above) that powers the Piper P-Navajo (lower left) is aviation's most expensive piston engine at $48,780, reman-exchange (close to $90,000, new-outright). It features Bendix injection, crossflow cylinders, Continental-style lifters (along with a beneath-the-crank cam), and a poppet-valve wastegate (very unusual in aviation). An ungeared, 380-hp version of the engine is used in the Beech Duke (upper left). Parts are expensive, support erratic, experienced shops few. Only 288 P-Navajos (and 596 Dukes) were built.

601P is not a particularly attractive P-plane on any basis other than sheer speed. The P-Aerostar boasts a nightmarishly tight engine installation (you can't top the rear cylinders while the engine is still mounted in the nacelle), with engine-driven hydraulics and dual Rajays (one turbo under each bank of cylinders). There are no cowl flaps. The Rajays blow non-intercooled air into jugs having 8.7:1 pistons—a sure invitation to detonation. The 1,800-hr TBO was Lycoming's official recommendation for the IO-540-S *before* Ted Smith jury-rigged the electric-wastegate Rajays into the exhaust. (The Machen 350-hp conversion, incidentally, doesn't make the engine compartment any easier to work in.) Don't count on making it to TBO without some valve and turbo work. (The Rajays crack every 400 hours or so.) Even then, be prepared to spend $20,000 a side.

Piper P-Navajo: A notorious gas-guzzler (90 gph in climb), the P-Navajo has a surprisingly devoted (if small) following, its admirers claiming it to be the best cabin twin ever built. The last one (No. 288) rolled off the assembly line in 1977. Many can now be had—loaded, and in good condition—for $60,000 or so. The catch: Those 425-hp Lycoming TIGO-541-E1A engines (although said by many to be capable of running to the 1,200-hr TBO with no problem) are hideously expensive to overhaul. Most shops want $25-30,000 per side; Lycoming gets $48,780 for a factory-reman (each, exchange). If a crankcase cracks or jugs need to be replaced, budget thousands more. This is a truly imposing airplane, maintenance-wise. (Even the vacuum pumps cost megabucks. Ever heard of the 840-series Airborne?) Think twice, three times, five times, before buying one of these planes.

Rockwell Commander 685: The Grand Commander's 435-hp GTSIO-520-K Continentals (the most powerful opposed engines ever hung on a production twin) are not to be confused with the 375-hp GTSIO-520s used on the Cessna 421. Problems with the -K (and earlier -F) are legendary, and stem from too much boost (44.5 inches) and rpm (3,400). The main problem is piston and ring failure (and subsequent metal dispersal throughout the engine), but even assuming you *could* make it unscathed to the 1,200-hr TBO (which is doubtful), a major overhaul requires cash infusions worthy of Fed intervention. (A factory reman lists for $33,156, exchange.) All in all, an engine worth avoiding.

A different set of rules apply when shopping for a plane in this category. Low time SMOH isn't necessarily good. A cheap field overhaul on a TIO-541 or GTSIO-520 can spell real trouble. Ideally, you want to see *factory remanufactured* (or Lycoming factory overhauled) engines only, in this class of airplane, preferably with some warranty coverage still in effect. It simply doesn't make sense to fool around with anything less. If the factory rebuilt the engines, you know that all the latest mods and updates were done. If somebody else rebuilt the engines, you don't know what you've got. (Logbooks often lie, or omit the truth.)

Ironically, *high time SMOH* can be a positive selling point in the case of, say, a P-Navajo or Duke. If the engines made it to 1,000 or 1,200 hours without problems and are running strong, take it as a sign that somebody knew what they were doing (in the cockpit, and in the overhaul shop). The very best way to know what you've got, of course, is to buy a plane with runout engines and start from scratch.

Obviously, a detailed consideration of each of the above "cabin cruisers" could end up being quite lengthy indeed. (For more information, I suggest you consult the *Aviation Consumer Used Aircraft Guide*, pp. 255-261; $21.95 from Belvoir Publications. Also, watch for the Cessna 414 used-plane evaluation coming up soon in *The Aviation Consumer*.)

In any case, the fellow who asked me for a simple opinion got an earful over the phone. But it turned out not to matter. About two weeks after the first call, the man called me back. His friend—the one who wanted to know which pressurized twin was "best"—had made a deposit on a King Air.

Cherokee 140 or 151 Warrior in the course of a major overhaul. (Contact RAM at 817/752-8381 for details.)

Another caveat: The -E2D STC, as written, requires installation of chrome cylinders. This is an outcome of RAM's own use of chrome jugs in its overhauls of O-320 engines. The specimen engine used for STC approval had chromed jugs; therefore, FAA expects everyone using the STC to use chromed jugs. Again, this is something that individual FAA offices may allow some leeway for, since there are no engineering reasons why standard steel (or nitrided) cylinders can't be used on a 160-hp O-320. (RAM is looking into getting the STC reworded to allow non-chrome cylinder assemblies. It may take awhile, though. FAA has been obdurate on several of RAM's approvals.)

The Skyhawk's 150-hp Lycoming O-320-E2D can be converted to 160 horsepower relatively economically through RAM's piston-swap STC.

H-Engine Mods

There is only one foolproof cure for the O-320-H2AD's tappet troubles, and that's to install a different-model engine. RAM, recognizing this, has obtained STC approval for installation of the O-320-D2G, O-320-D2J, or RAM-upgraded (160-hp) O-320-E2D in 1977-80 model Cessna 172N aircraft.

This is not something that has to be done in Waco. Basically, you can buy a new or used -D2G or -D2J yourself (or buy a RAM-rebuilt -E2D), obtain RAM's STC and installation kit, and have the installation done by your favorite local shop. The RAM STC and conversion hardware kit is $1,750 for 1978-79 model aircraft, or $1,575 for 1980 models (the former get a new battery; 1980 aircraft already have the Gill 241-style battery).

If you want to bring your 172N to Waco, RAM will do the firewall-forward conversion for the cost of the replacement engine ($7,500), the hardware kit ($1,750), labor ($1,380), and core difference ($5,200). You can then sell your old O-320-H yourself; or RAM will credit you with $1,000 toward the installation cost, if you give the old core to them (bringing total cost to $14,830).

The H-to-D (or H-to-E) mod is a total firewall-forward facelift and results in a 172P engine compartment when all is said and done. Considering the many under-the-cowl changes that need to be done, $1,750 is an eminently reasonable price (we feel) for the STC and installation kit. The only glitch is finding a way around Lycoming's $5,200 core charge (which is a marketing maneuver aimed at getting more overhaul business for the Williamsport factory).

PARTS REQUIRED FOR 160-HP UPGRADE

PART NUMBER	DESCRIPTION	QUANTITY
75089	Piston	4
LW-14077 or	Piston Pin	4
LW-14078	Piston Pin	4
73938	Valve- Intake	4
LW-19001	Valve-Exhaust	4
74230	Valve-Guide-Exhaust	4
60028	Valve Guide-Intake	4
72057	Seat-Intake Valve	4
72058	Seat-Exhaust Valve	4
LW-13659	Carburetor-Marvel-Schebler MA4SPA	1
1061	Supplemental Data Plate	1
74673	Piston Ring- Compression	8
73998	Piston Ring-Oil Control	4
LW-12419	Cylinder Assy.- Chrome	4

O-300 Swap

RAM also holds an STC (No. SA2375SW) authorizing the installation of an O-320-D2G or RAM 160 engine in place of the O-300-D Continental used in 172D through 172H aircraft. The conversion isn't cheap, but that's because it includes a new cowling, new propeller, exhaust system, engine mounts, baffles, etc., updated to the 172M configuration (but with a 160-hp motor instead of 145-hp). The conversion is done on-site at Waco for time and materials plus the cost of the engine. RAM estimates "time and materials" at $8,000; the engine can easily run $12,700 ($7,500 plus the $5,200 core charge). By comparison, Continental demands $14,532 (plus $5,800 core charge) for a factory-remanufactured O-300-D.

For more information on any of RAM's modifications, contact Chuck Morrow at RAM Aircraft Corp., P.O. Box 5219, Waco, TX 76708 (phone 817/752-8381; Telex II 910-894-5248).

Overhauling the S-1200 Magneto

by Fred Mackerodt

NOTE: Back in December, we talked about how a magneto works and why it's designed the way it is (see "Understanding the Aircraft Magneto," Dec. '87). At that time, we promised a closer, hands-on look at the inner workings of the magneto. This article is a followup to our previous discussion. We encourage all owners to read it—even those who own something other than Bendix S-1200 magnetos.—Ed.

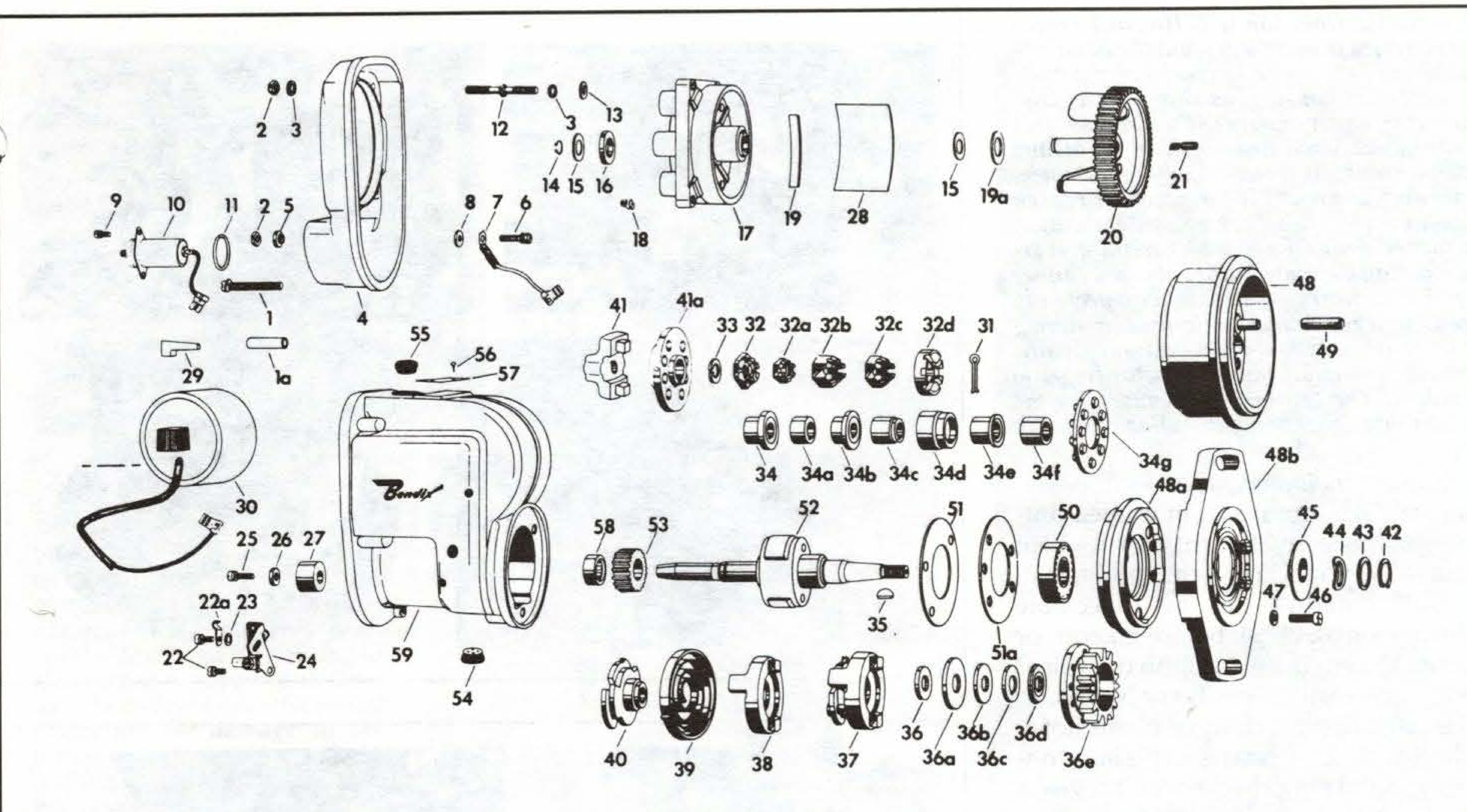
Aircraft Systems, Inc. occupies a neat hangar on the Greater Rockford Airport in Rockford, Illinois. The company specializes in rebuilding magnetos, alternators, generators, starters, fuel pumps, prop governors, and other accessories (even starter-generators for turbine aircraft). The firm is owned by Terry Norris and his two sons, Jerry and Terry, Jr. The elder Norris got his start in aviation in 1956 with Schneck Aviation, where he ran the famous engine shop's accessory-rebuild division. He also worked for Woodward Governor for several years before striking out on his own in 1970 with Aircraft Systems.

Most of Aircraft Systems' work comes from FBOs and engine overhaulers, but—as I found out recently—the company will also take on accessory rebuilds for aircraft owners. When I visited the firm last September, I brought with me a boxful of Bendix S-1200 magnetos out of a Turbo Aztec. All four needed 500-hour inspections.

An increasing number of the mags that Terry Norris sees, it turns out, come in for 500-hour inspections (i.e., routine look-sees) and not because they're giving trouble. While magnetos don't carry a formal TBO (recommended Time Between Overhauls), they do have published inspection intervals (500 hours for most models), which owners are generally ignorant of. Most pilots will only think of having their mags inspected under two circumstances: when it's Underwear Time at Altitude, or when the mag drop falls into the low four digits during pretakeoff runup. Otherwise, the "if it ain't broke don't fix it" system of maintenance prevails.

Unfortunately, while aircraft magnetos are marvelously simple and (for the most part) trouble-free devices—and seem to have the potential of going to the engine's TBO without much trouble—the experts we checked at Continental, Lycoming, Bendix, and Slick concur on a figure of 500 hours as the maximum time between IRANs (inspect and replace as necessary). This is especially true for pressurized mags and mags on turbocharged engines. (The former are subjected to more heat flow than most, and the latter have critical duty-cycle demands in that high-altitude flying brings with it a risk of ionization and crossfire.) In some cases, the 500-hour inspection is mandated by A.D. to check impulse couplings.

In any case, a 500-hour inspection is a good idea (for *any* kind of mag) not only to reaffirm the mechanical integrity of moving parts (rotor, distributor electrode, gearing, impulse couplings, cams, points, cam follower) but also to check for cracks in housings and coils, clean up dirt and grease, and in general assure that everything is as it should be. It's also an opportunity to make electrical checks of the capacitor (condensor) and coils, perform any updates that need to be performed (in accordance with service bulletins), replace worn bearings, oil the cam follower, and—of course—set the internal timing (adjust E-gap). *[If any of this terminology sounds unfamiliar to*



1.	Screw w/	16.	Washer	30.	Coil	44.	Washer
	lock washer	17.	Block	31.	Pin	45.	Slinger
1a.	Tubing	18.	Spring	32.	Nut	46.	Screw
2.	Nut	19.	Strip	33.	Washer	47.	Washer
3.	Washer	19a.	Washer	34.	Bushing	48.	Flange
4.	Cover	20.	Gear Assy.	34g.	Grommet	49.	Stop Pin
5.	Bushing	21.	Brush	35.	Key	50.	Bearing
6.	Screw	22.	Screw	36.	Washer	51.	Plate
7.	Lead	22a.	Clip	36e.	Gear	52.	Magnet
8.	Washer	23.	Washer	37.	Impulse Coupling	53.	Gear
9.	Screw	24.	Contact Assy.	38.	Body	54.	Ventilator
10.	Capacitor	25.	Screw	39.	Spring	55.	Plug
11.	Packing	26.	Washer	40.	Cam Assy.	56.	Screw
12.	Stud	27.	Cam	41.	Plate	57.	Plate
13.	Washer	28.	Strip	42.	Ring	58.	Bearing
14.	Ring	29.	Wedge	43.	Washer	59.	Housing
15.	Washer						

EXPLODED VIEW OF THE BENDIX S-1200 MAGNETO

you, be sure to read "Understanding the Aircraft Magneto," LPM, December '87.—Ed.]

Needless to say, these checks are not considered pilot-performable "preventive maintenance" under FAR Part 43; but they *are* worth taking a personal interest in. After all, this is your *ignition system* we're talking about.

Sources of Misfiring

Offhand, you might not think magnetos would get very dirty inside, being as well encapsulated as they are. But mags *do* suffer from contamination, both from moisture and other atmospheric glop, *and* from oil. *[The atmosphere inside the magneto is also high in ozone and other ionization products, which is why they must be vented.—Ed.]* Oil mist inside the mag comes from moving parts which have to be lubricated—and from the engine itself, if crankcase pressure is high (due to, for example, broken rings)—and this mist gets "fried" by the spark jumping across the distributor electrodes, turning into carbon dust in the process. Now as you know (if you've ever looked at what commutator brushes in motors and generators are made of), carbon is a fine conductor of electricity. A problem arises if a coating of carbon dust is allowed to build up on components like the distributor block, since such a coating could easily provide a different, more favorable route for current to follow rather than its appointed one. Air tends to insulate electrode fingers from distributor towers, and at altitude, where atmospheric pressure is low, crossfiring can happen as electricity seeks a path of lesser resistance across the block. The crossfir-

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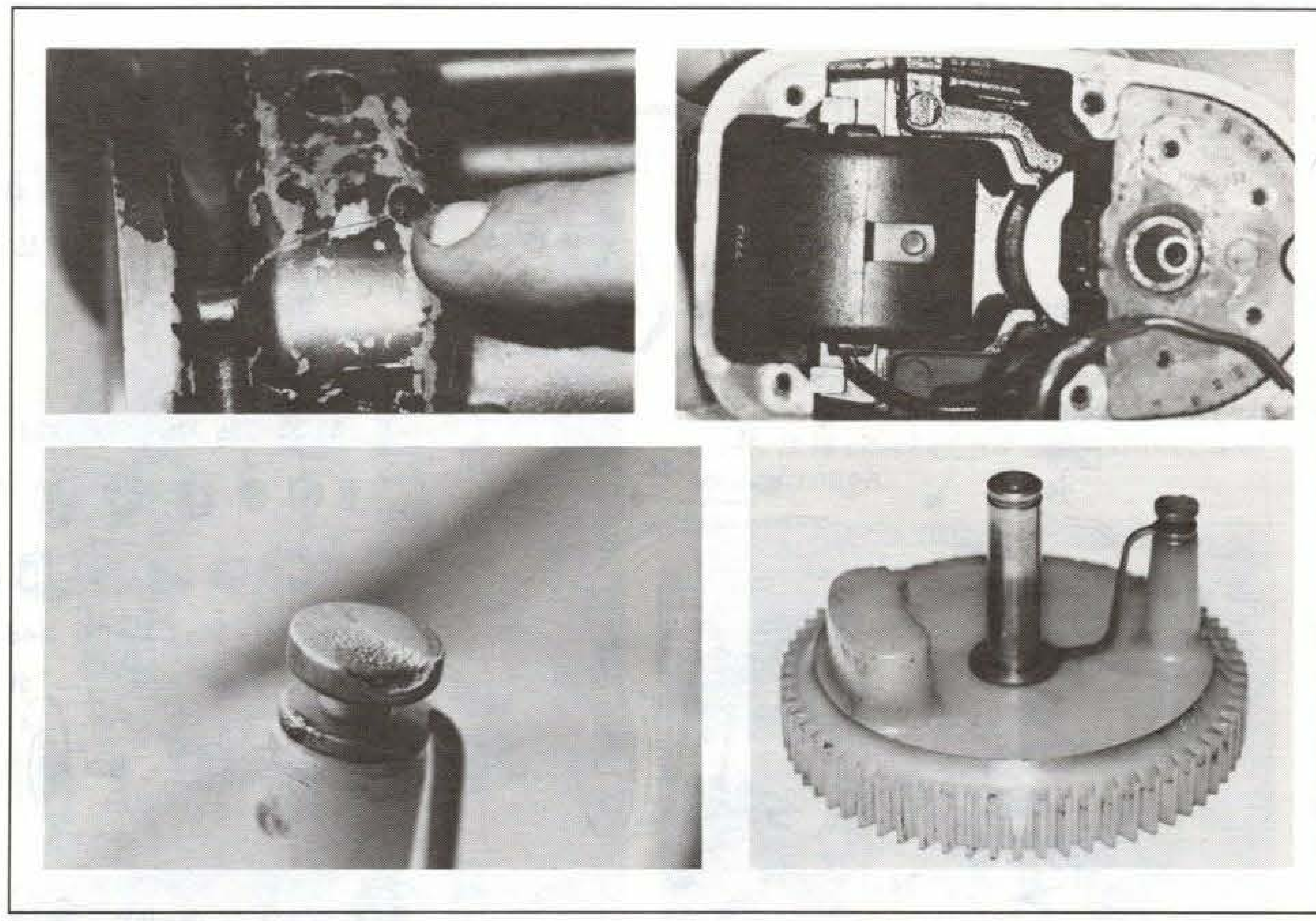

Clockwise from top left: Housing cracks are a rarity in most mags, but the Bendix S-1200 series is prone to cracks of the cast-magnesium housing, as shown here. Distributor end removed, it's obvious this mag has accumulated considerable oil and carbon dust inside. (A 500-hour housecleaning is needed if for no other reason than to keep this sort of contamination under control.) If you look carefully at six o'clock on the distributor gear, you can see that a tooth is gone; this was probably caused when a mechanic used a timing lock to install the mag. In the final picture, severe erosion of the distributor finger is evident. The erosion was caused by the distributor gear being installed one tooth off.

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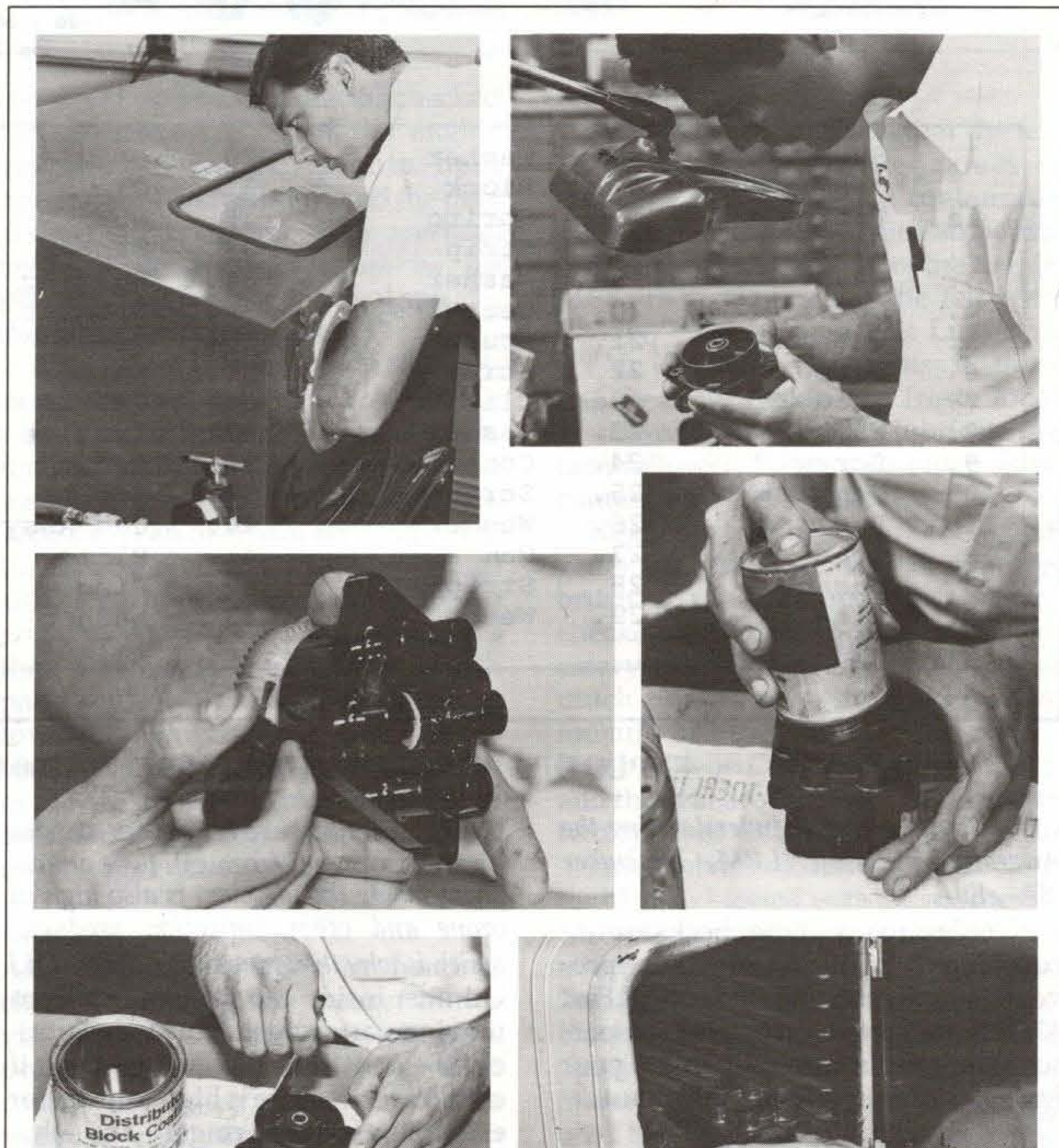
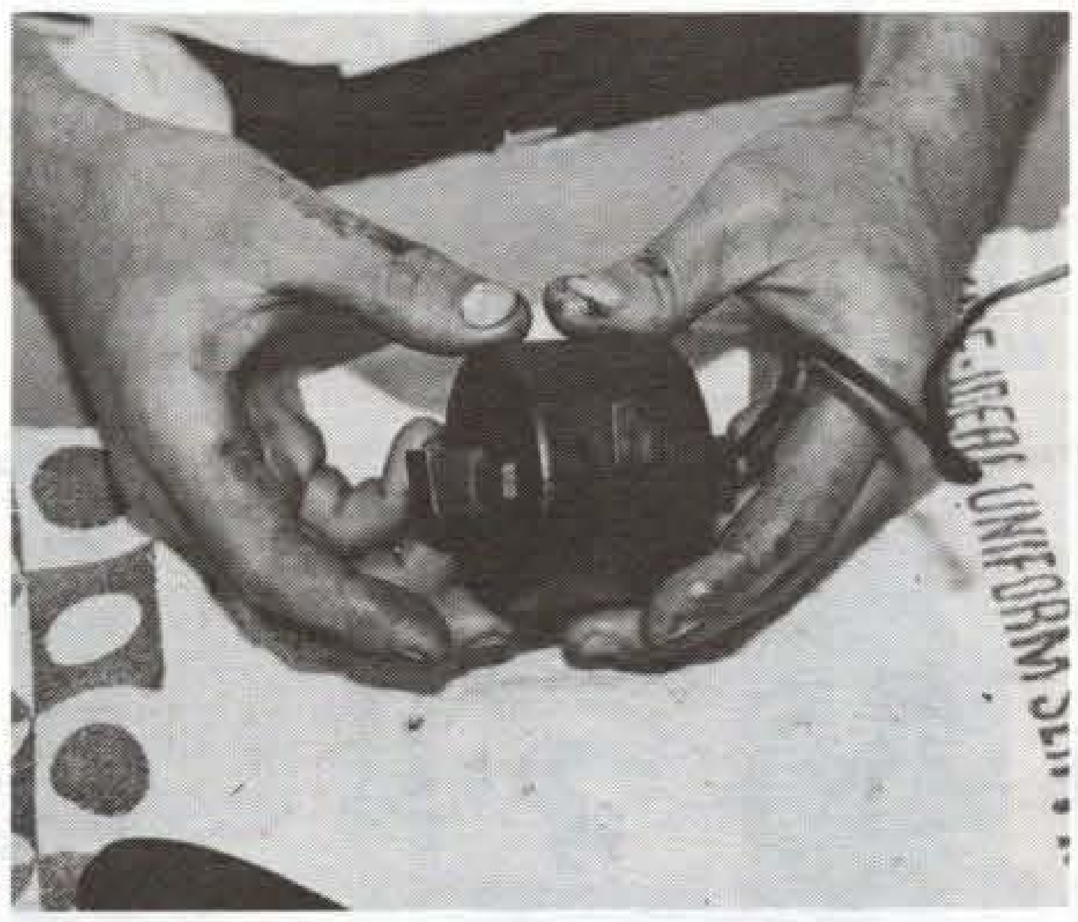
ing, in turn, can result in unpleasantness in the form of burnt pistons, bent con rods, blown jugs—things like that.

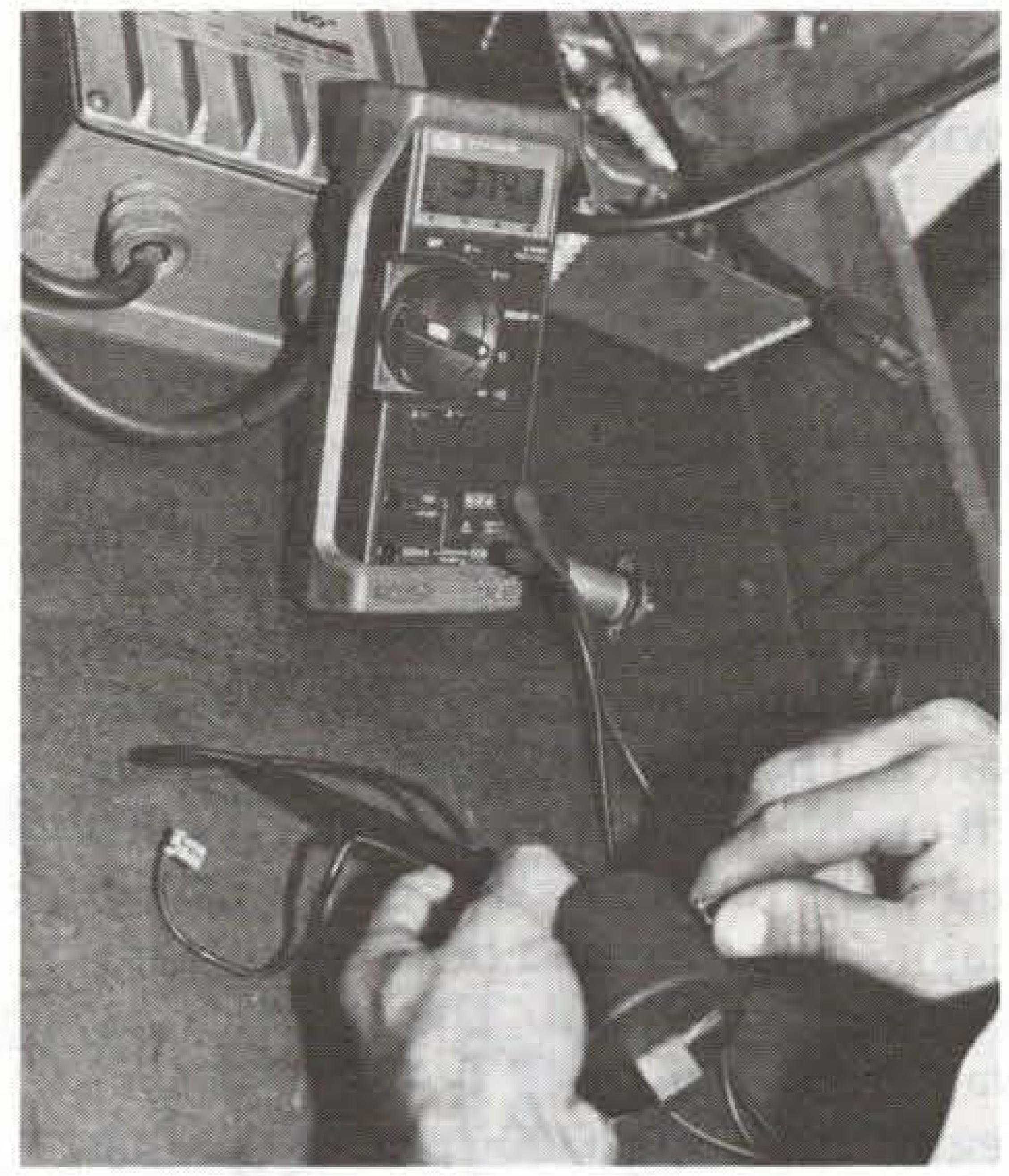
But wouldn't this be detectable during a mag check before takeoff, or when the engine is in climb or cruise? Not necessarily, says Terry Norris. In the case of a turbocharged plane, not at all. "At times," Norris explains, "on-the-ground mag checks won't reveal a problem that's waiting to show up at altitude—sometimes altitudes as low as 5,000 feet. You're climbing along, and then *pow*, it shows up." (On planes with constant-speed props, it's impossible to check the mags for an rpm drop in cruise, due to the governing action of the governor.)

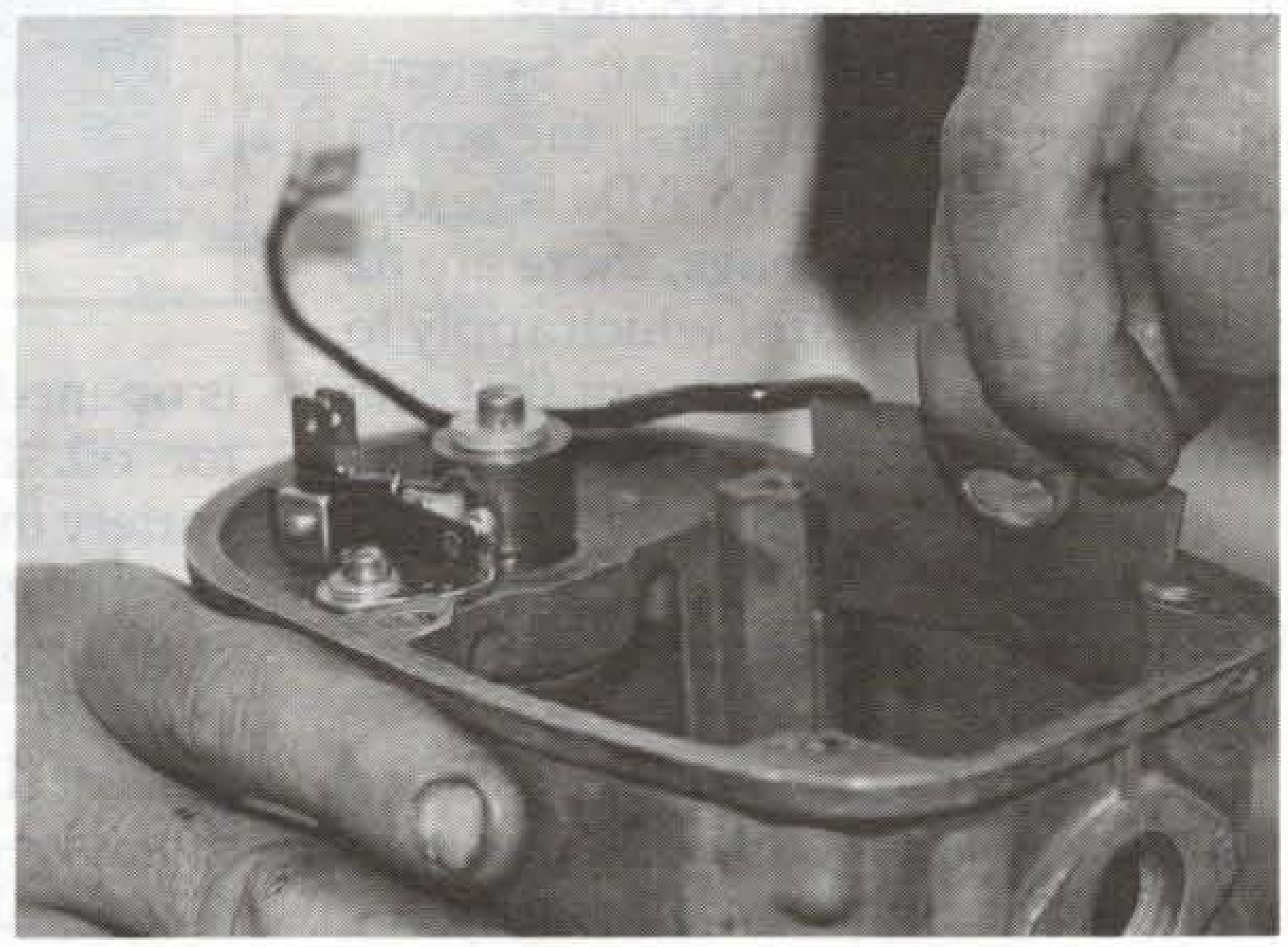
Unless the pilot is completely in tune with his or her airplane, some cases of out-and-out misfiring will go unnoticed even when it happens, even in high-speed cruise. "Engine mounts in today's aircraft tune out vibrations so well," Norris remarks, "misfiring that can lead to detonation is pretty much undetectable." Norris refers to this kind of misfiring as a subtle "thump-thump-thump." The end result can be a condition called (half-seriously) "holy pistons," which in the least will be a truly religious experi-



Clockwise from top left: Terry Norris subjects a distributor block to plastic-media blast-cleaning. Care must be taken not to damage the block (newer brown-colored blocks cannot be blast-cleaned). After cleaning, the block is checked carefully for cracks. Then one end is corked and the center cavity filled with special distributor-block lube, and the unit baked in an oven to get the oil to soak into the oilite bushing. Finally, the block gets a coat of special distrbutor sealant (which will insulate the block and cause moisture to bead up rather than wet the surface). If it needs it, the distributor gear timing marks are then repainted on.







Clockwise from top left: In the S-1200, the coil is held in place by wedges. To remove the coil without damaging it or the magnesium housing, heat (from a torch) is applied very judiciously to expand the housing so the coil can be popped out. Once out, the coil gets a careful visual inspection for damage to the wires and/or cracking of the potting compound. Then checks are made of the primary and secondary coil resistances. (The primary and secondary coils are potted as a unit. So even though we speak of "a coil," we're really talking about two coils.) Fish paper is used to keep coil wires from chafing; and a hammer and drift are used to wedge the coil back into place in its housing.

ence and at the worst will put you in direct communication with your Maker.

"Once a pilot has seen a piston with a big hole in the middle caused by detonation," says Norris, "he becomes an instant convert to 500-hour inspections."

In a turbocharged aircraft at high altitude, everything has to be up to snuff because of the fact that air (which is insulating) is only half as dense at 18,000 feet as at sea level. Depending on how badly a magneto is contaminated, the misfiring point can occur anywhere between 5,000 feet and the airplane's ceiling (or higher). Big mags like the Bendix S-1200 are less apt to misfire at altitude, simply because the distance between distributor towers is greater than in a smaller mag. The spark is thus more apt to go to the correct tower.

In some high-altitude aircraft, the tactic of pressurizing the mags is used (to make up for the lost dielectric of the thinner air), but these come with their own problems, says Norris—problems having to do with heat (it's the turbo compressor that supplies the air) and forced introduction of intake-system contaminants. Inline filters take care of most such contaminants, but heat is impossible to filter completely. Norris showed us a couple of examples of where some magneto components actually melted from heat. "A lot of mags used in high-altitude operations weren't designed for that kind of duty," says Norris. All the more reason to do a 500-hour inspection.

Repairs As Needed

One of my pet peeves is the "exchange" scam perpetrated by the aircraft industry. If a component gives trouble, the FBO—rather than simply fix it—will exchange the item out (for an overhauled unit) in kneejerk fashion, ensuring that the customer pays the most possible money for the job, since exchange prices are based on a "worst case" scenario. The overhauler expects to get a bad core in return, so he factors that in. Send him a unit that needs a complete rebuild, and he makes a fair margin. Send him a unit that needs little or nothing, and he makes a killing.

Aircraft Systems' Terry Norris doesn't work that way; he's from the "only fix what needs it" school of aviation mechanics. If a component needs reconditioning or repair, it gets it. If it doesn't, it doesn't. The customer, in turn, pays only for work that was necessary.

The four mags I brought with me to Aircraft Systems Inc. had varied histories. They weren't (properly speaking) good subjects for a typical 500-hour check, because they all had much more time on them than that. Three of the mags originally belonged to a Turbo Aztec that went off the end of a runway at Buffalo; I bought the en-

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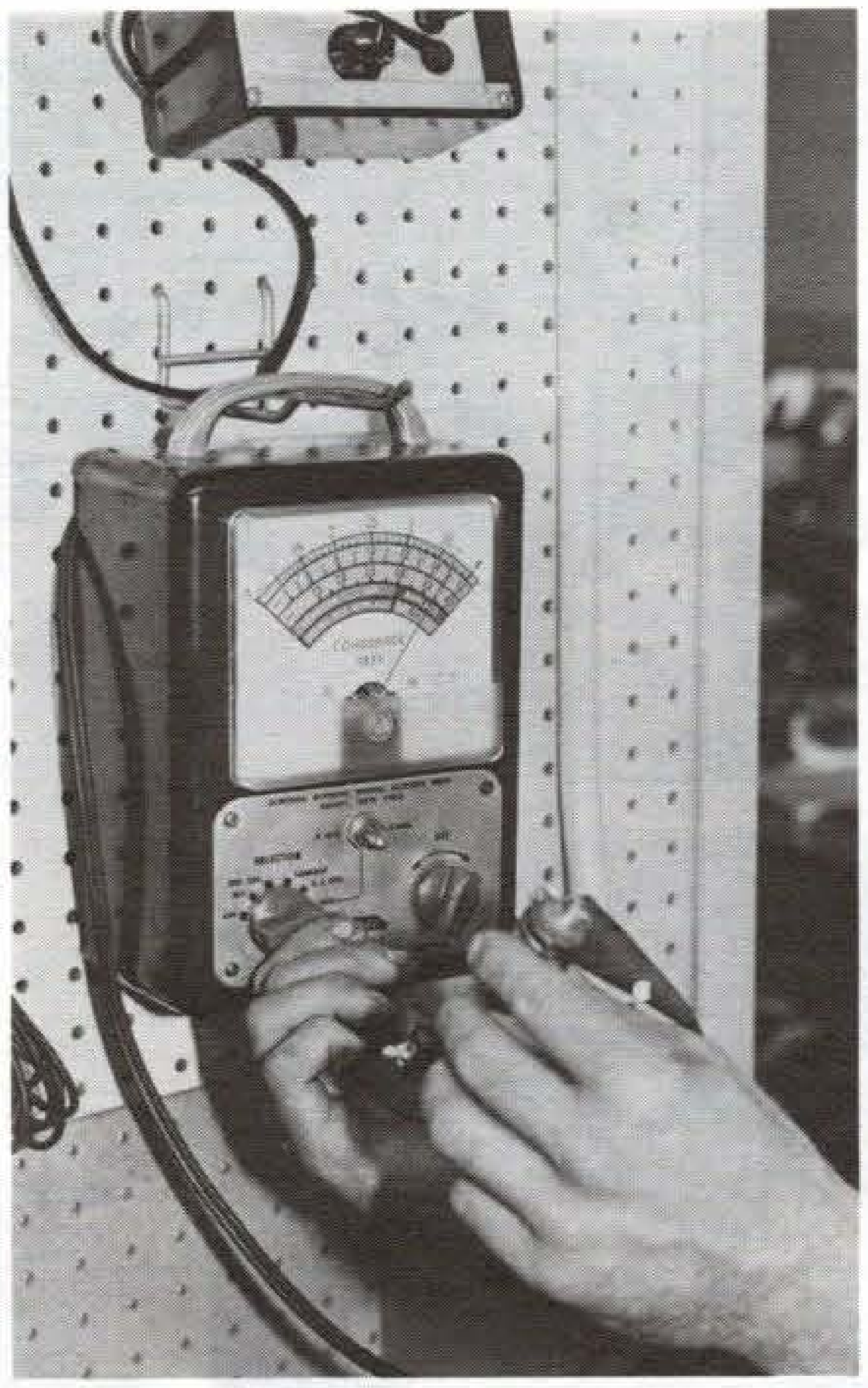
gines off this plane as spares for my own Turbo Aztec, which is now reaching 1,400 hours on the second go-around of its Lycoming TIO-540-C1A powerplants. Two of the mags I brought to ASI were off the right engine of the Buffalo plane, which had 1,780 first-run hours. The log on this engine indicated that no particular attention was paid to the magnetos beyond routine on-condition maintenance. The third mag came from the left engine of the Buffalo Aztec, which had only 160 hours since Van Dusen major. This mag had been completely rebuilt at overhaul. The fourth mag was from my own T-Aztec. It had begun showing 300-rpm drops on runup after 1,300 hours SMOH.

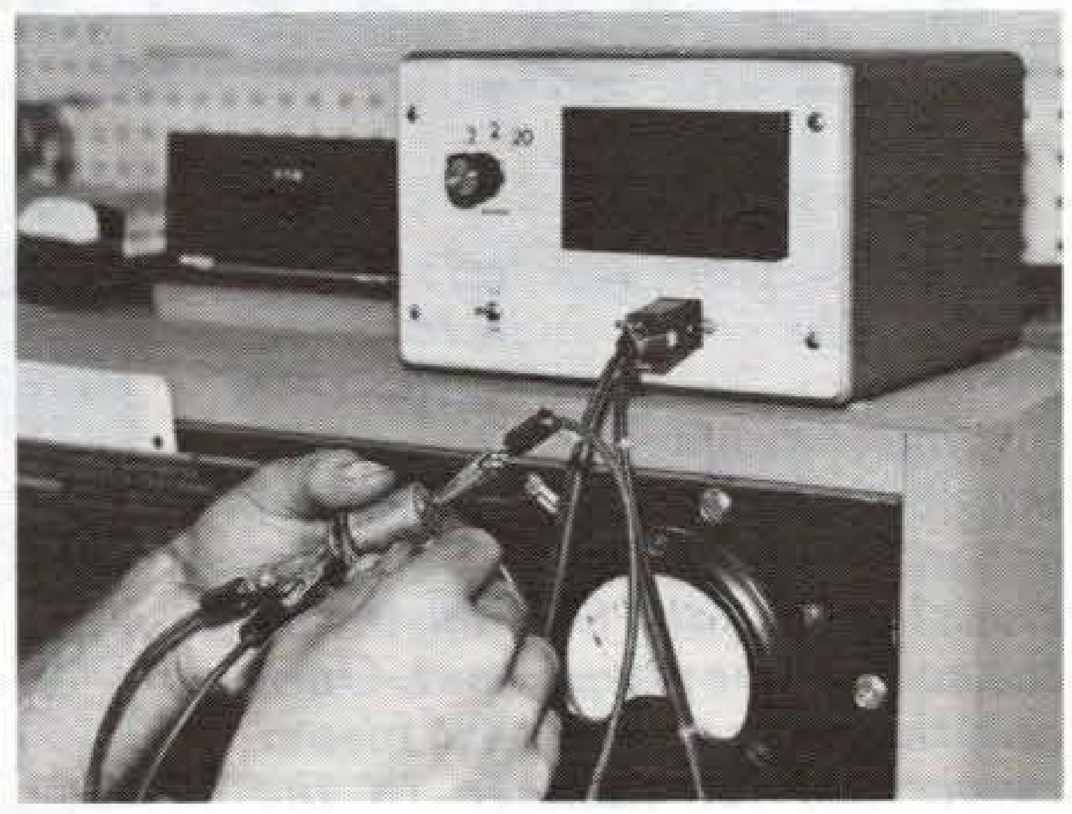
Here's how the Aircraft Systems mag inspection went: First, the applicability of bulletins and ADs is determined. For Bendix mags, there are 62 bulletins to check, 20 of which apply to the S-1200. Norris points out that one should never assume that just because the equipment is relatively new and the AD is relatively old. He tells of checking a brand-new mag and finding a five-year-old AD undone.

The next step is a quick check for major, obvious problems like cracks in the housings, which are a rarity for most magnetos. It turns out that the Bendix S-1200 series mags wind up with cracks in their magnesium housings 25% of the time, according to Norris. Luckily, all four housings I supplied were free of cracks. (Not all cracks mean junking the housing; Bendix Service Bulletin No. 533A, in fact, details with photos just which cracks are okay and which are not.)

If cracks are found, Norris stops the inspection right there, because at the price Teledyne charges for a new housing, the customer is better off sending the mag back to the manufacturer as a trade-in on a rebuilt unit. This is ASI's standard policy. If it ever becomes evident, at any stage of the inspection, that the cost of parts will exceed the price of a rebuilt ($371 in the S-1200's case), Aircraft Systems will button up the mag, charge the customr $20 for the inspection and handling, and suggest you buy a rebuilt. (If you buy one through them, the $20 is credited towards your purchase.)

When no cracks are found, the mag is opened up and the interior checked for oil. Excessive oil of the engine variety means that the seal on the front bearing isn't doing its job, and the mag at this point is in for a major overhaul because the bearings must be replaced. (If oil is of the residual variety, the inspection continues.)





Left: Condensors (or capacitors) can be reused if they meet electrical specs. Here, the condensor is checked for series resistance and leakage. Right: Here, it is checked for capacitance and feed-through.

It's really at this point that the decision is reached whether to overhaul or not. Aircraft Systems has two prices for labor: $57 for a routine 500-hour inspection, and $102 for an overhaul. That's it. If an overhaul *isn't* indicated (i.e., bearings don't need replacing) and no parts are needed, the entire job will cost you $57 for labor, and that's that. On average, an overhaul with parts will go $150 to $350 (tending toward the low side for most magnetos; the biggest Bendix models are the ones with the most expensive parts). A 500-hour inspection runs about $100, on average, with parts.

Internals

After turning the shaft by hand to check for binding, the breaker cam is visually checked for wear; then the points are removed and checked for condition. If they're fairly new, the technician will simply check them on an ohmmeter and reinstall them. Otherwise, if they've gone 500 hours or more, Norris recommends they be replaced 100%. (In the case of an overhaul, the rules say the points *must* be replaced.)

Terry Norris maintains that the felt lubricator on the breaker points is often the source of point contamination. That's why he washes all points (even new ones, fresh out of the bag) in MEK, then relubricates the felt with Bendix/TCM Breaker Felt Lubricant (P/N 10-86527) and blots it thoroughly until it takes ona frosty look. That leaves enough oil to lubricate the cam follower, but not so much as to contaminate the points.

Next, the distributor block and gears are removed, and the carbon brush at the bottom of the gear is checked for wear and replaced if necessary. Terry can pretty well tell how much time is on a magneto just by looking at how much of the carbon brush is worn away. Both the block and the gear are thoroughly cleaned in two types of solvent.

After solvent cleaning, the distributor block is blasted with plastic media, carefully controlling the pressure so as not to allow the block to be damaged. This is done to completely clean the block so as to reveal even the smallest crack. (Norris cautions others not to attempt to clean the new brown-colored blocks under pressure, as it will erode them.) After this, the block is washed again in solvent and carefully examined under a 10X magnifying glass, after which it gets placed in an oven (briefly) to evaporate off any solvents.

Since cleaning removes all lubricant from the oilite bushing in the center of the block, it's necessary to relube this portion. The bottom end of the block is simply sealed with a small cork while Bendix/TCM Distributor Block Lubricant (P/N 10-391200) is carefully poured into the top to fill the cavity; then the distributor block is placed back in the oven and baked at 190 to 210 degrees Fahrenheit for two hours (which helps the lubricant flow into the pores of the oilite bushing).

With the lubrication done, the block is then coated with a special Bendix/TCM Distributor Block Coating (P/N 10-391400) and allowed to air-dry. This shiny coating makes any water that contacts the surface "bead up" as on a freshly waxed car. It prevents the water from sheeting and the spark from following that continuous sheet of liquid to a point where it's not supposed to be. The key to lubing and coating the block is to make sure the oilite bushing oil doesn't get on the block, and the block coating doesn't get on the oilite bushing.

Electrical Checks

At this point, the shaft is spun and the magnet checked for strength. (Believe it or not, magnets are found with low field strength from time to time.) If needed, the rotor can be remagnetized with a P/N 11-1362 Magnet Charger (Bendix-Scintilla) or a Weidenhoff Model D-818.

Next, the coil is removed (see photos for explanation) and it and the capacitor are checked electrically—the coil for primary and secondary resistances (1.0 to 1.5 ohms for primary; 17-23,000 ohms for secondary), and the capacitor for series resistance, leakage, and capacitance (0.30 to 0.45 mfd).

If need be, the bearings are replaced at this point and then all components reassembled in the repainted housing. (Separate inspection procedures apply to impulse couplings; that's a whole article in itself.)

After the points are adjusted and internal timing is set at the proper E-gap (15 degrees plus or minus two, for 4- and 6-cylinder S-1200s), the mag is mounted on a test stand and its sparking performance checked. The test stand gap (in lieu of a spark plug) is set fairly wide to simulate operation at 25,000 feet. Spark output is checked at up to 5,000 rpm, but special attention is given to how the mag functions at 300-400 rpm also. According to Terry, "Low-speed operation is toughest on mags."

Post-Mortem

How did my mags work out? The one that gave up the ghost while on my Aztec was a basket case. It was in pieces. The post-mortem revealed that one tooth had broken off the distributor gear. Terry surmised that this must've happened when a mechanic attempted to hold the internal timing with a "mag lock" while installing the mag on the engine. (Norris advises against using mag locks.)

In addition to this, the drive end flange was worn from the bearing race spinning in it. The bottom line for this mag: $219.62 (including a used replacement flange), for both parts and labor.

The mag off the 160-hour Van Dusen engine was a surprise: We'd expected it to be in top condition, given its low time, but there was a lot of internal corrosion. Apparently, the mag had been in water at one time—perhaps from the ditch the Aztec went into at Buffalo. Both main and retard contact point assemblies had to be replaced (at $26.54 for one and $30.36 for the other) plus the bearings, and

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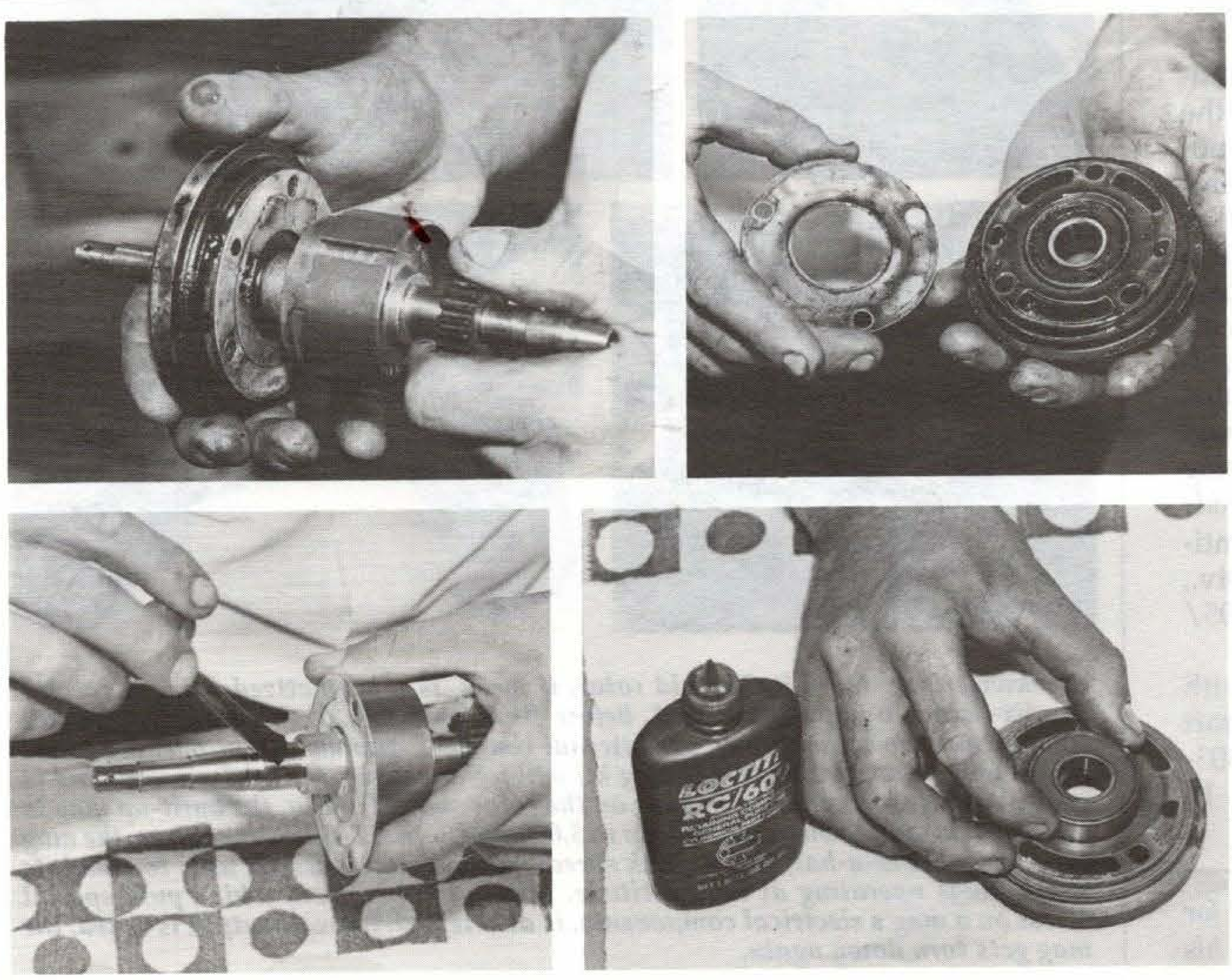

Clockwise from top left: The front bearing on this magneto was definitely passing oil. To get at the bearing, a spacer is removed, the old bearing is pressed out, and the new one is pressed in (using Loctite RC609 to keep the outer race from spinning). A little Loctite is also used on the rotor shaft, to keep the inner race of the new bearing from spinning.

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miscellaneous small parts. Overhaul cost: $182.26.

We didn't know what to expect when it came to the mags off the runout right engine of the Buffalo Aztec. We quickly found out. The first mag was in pretty bad shape; it had originally been set up improperly, the distributor gearing meshed one tooth off. This eroded the finger on the gear, but the resulting arcing also ate holes in the distributor block tower. Replacing the gear ($38.22), block ($61.94), main points ($26.54), retard points ($30.36), and miscellaneous small parts brought the overhaul cost to $278.22.

The second runout mag from the Buffalo plane's right engine was surprising for what it *didn't* require. Because of the number of hours on it, it was overhauled, but most of the components were serviceable, so the final bill was quite reasonable at $154.94.

My bottom line? I'm going to get these four mags on my Turbo Aztec as soon as possible and get the ones on there off. And I'm definitely going back to Aircraft Systems every 500 hours for a mag check.

For More Information

Obviously, the information in this article is for educational purposes only and shouldn't be considered the final authority on Bendix S-1200 (or any other) magnetos. Teledyne Continental (which now manufactures the Bendix line of ignition products) publishes an Installation/Operation/Maintenance manual for the S-1200 as well as an Overhaul Manual (and also a Parts Catalog); each is $5.00, and each is the FAA-accepted authority on maintenance of these mags. *[The Ignition Systems Master Service Manual containing all Bendix bulletins, overhaul manuals, etc., is $85. Add $10 shipping within the U.S. or $50 shipping outside the U.S.—Ed.]* Write: Teledyne Continental Motors' Aircraft Products Div., P.O. Box 90, Mobile, AL 36601 (205/438-3411).

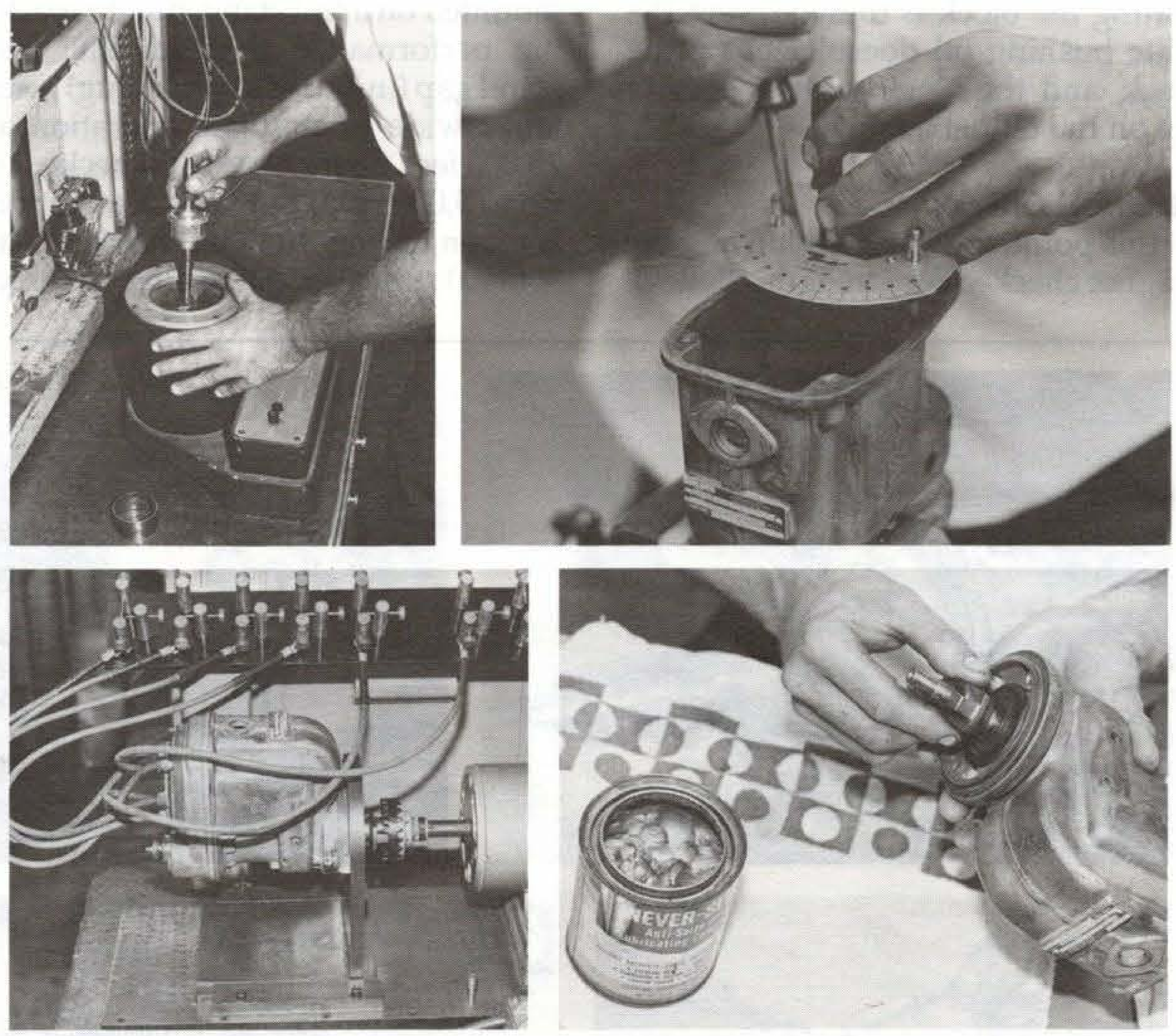
Anyone wishing to get in touch with Terry Norris should contact Aircraft Systems Inc. (FAA Repair Station 303-17) at 5187 Falcon Rd., Rockford, IL 61109 (phone 815/399-0225).

Fred Mackerodt writes on aviation for POPULAR MECHANICS. This is his first article for LPM.

What's in a Name?

Magnetos for aircraft come in two brands: Bendix (*nee* Scintilla) and Slick (formerly J.I. Case Tractor Company Magneto Division). Bendix's product line is the oldest (Scintilla mags were used on the Wright Cyclone, circa 1930) and some would say the best-trusted. (Slick Electro's aircraft mags didn't come on the scene until the late 1950s, and many mechanics still see Slick as "the new kid on the block.") Bendix's magneto business was bought out by Teledyne Continental approximately 18 months ago. Slick is now owned by Unison Industries.

Bendix mags in current production include S-20, S-200, S-1200, D-2000, and D-3000 series models. The S-20 and S-200 series are compact, lightweight units which differ in that the S-20 mags utilize impulse coupling drives, while the S-200 mags employ "shower of sparks" circuitry for starting. The heavy-duty S-1200 (notable for its large, bulbous coil housing) is physically larger than the S-20/200 and is found mostly on higher-performance aircraft. The D-2000/3000 is the so-called "dual mag," wherein two coils, two sets of breaker points, and two distributors are operated by one cam and one four-pole magnet driven by one shaft. Some D-2000/3000 mags are pressurized (and painted dark blue); others are unpressurized (light blue). Only Lycoming engines that have a 'D' in the last digit of the model designator use the "dual mag": e.g., O-320-H2AD, IO-360-A3B6D, TIO-540-J2BD, etc. (No Continental uses this type of mag.)



Clockwise from top left: The old rotor, if weak, is remagnetized using a special Bendix-Scintilla apparatus. Next, before final assembly of the mag, the breaker compartment is set up for proper internal timing (E-gap and point opening tolerances) using a special Bendix timing kit and feeler gauges. Anti-seize compound is used when installing the drive gear on the rotor shaft. Finally, the built-up mag is put on a test stand, where it is run up to 5,000 rpm. (On six-cylinder engines, the mag turns at one-and-a-half times crank speed.) Special electrodes are used to simulate spark plugs operating at high altitude. Low-rpm operation, which puts special stress on a mag's electrical components, is also tested. If weak output is noted, the mag gets torn down again.

I own a 1975 Lycoming O-320-E2D in a Cessna 172M with 1,992 hours TTAE. My last annual showed the cylinders with 72/80 or better compression all the way around. Oil consumption has been one quart burned every six to eight hours, and the engine starts better than (and runs almost as smooth as) my BMW. The only unscheduled maintenance in my four and a half years and 250 hours of ownership has been an alternator rebuild and some brake work. I am aware of the 2,000-hr oil-pump A.D. and possible upcoming A.D. notes on valves and/or guides. Your opinion, please: Should I rebuild the oil pump and wait a year or two to see what new A.D. requirements might affect the engine, or should I do a top or major overhaul now? I do not want to have an unsafe airplane, but I hate to tear down a perfectly good engine.—R.M., TN

It's a shame to have to stop what you're doing at 2,000 hours TT to comply with A.D. 81-18-08 (on sintered iron oil pump impellers; applicable to many Lycomings), but if the logbooks leave any doubt as to the type of pump gears in your engine, you definitely should stop and comply with the A.D. at this time. As we've said many times before, the sintered iron pumps are a definitely hazard and should be replaced no later than 2,000 hours; we fully agree with the A.D. Unfortunately, there is often no easy way to tell what kind of pump is in the engine. (A call to Lycoming might be in order: 717/323-6181.)

We wouldn't automatically overhaul the engine while it is down for the pump A.D. As a Part 91 operator (and sole owner-operator of the plane), you are within your rights to go beyond TBO, and your engine appears to be a good candidate for TBO-busting. (Of course, if you have an accident and somebody sues you, it won't look good in court when the engine manufacturer's representatives testify that you knowingly disregarded their explicit recommendations regarding overhauls; but that's a risk you'll knowingly have to take.) Even if the FAA goes ahead with its proposed valve A.D. (*LPM*, June '88, p. 24) and requires you to replace your P/N 74541 valves at 2,000 hours, it *still* may be worthwhile to postpone a major. (A lot will depend on what else you find while the jugs are off for the valve job.)

With all the above caveats in mind, we feel a reasonable course of action is to comply with the oil pump A.D. immediately (no later than 2,000 TT) and fly for one to two years, before stopping to top or major the engine.

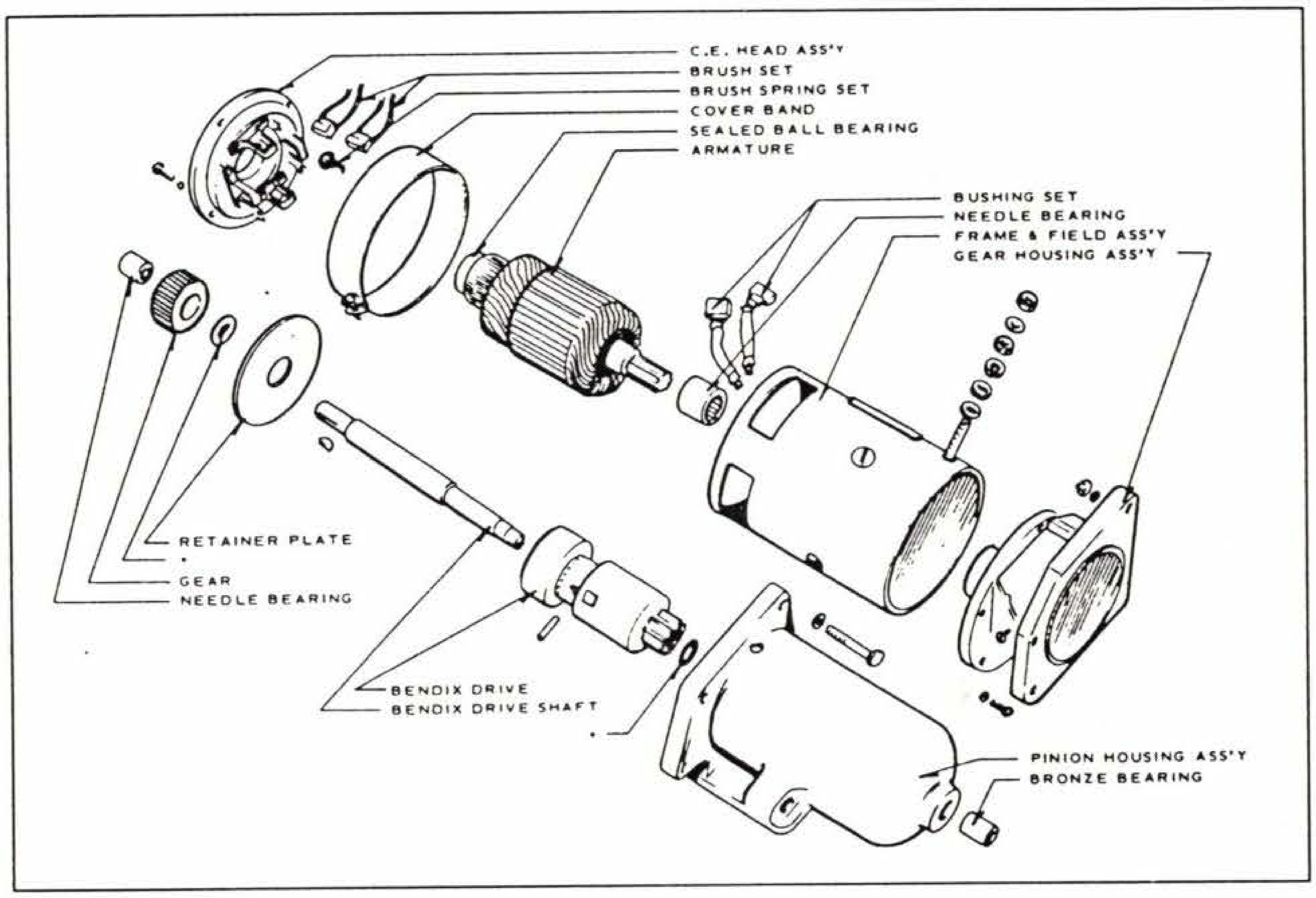
Slow Cranking: Causes and Cures

Slow cranking has been a persistent complaint of pilots from time immemorial, no doubt partly because aircraft batteries are so small, and partly because engine displacements are so large. And also partly because aviation oils (until recently) have tended to be molasseslike in consistency. Multivis oils have abated the latter problem somewhat, but the problem of slow cranking remains.

Easy answers are few. Wherever possible, aluminum battery cables should be replaced with copper ones (for less 'IR' drop), and it would no doubt help if tail-located batteries (as in the 182) could be relocated to the engine compartment, although weight-and-balance considerations preclude this for most operators.

Then too, some owners just need to up and face the fact that airplane batteries generally aren't good for more than two winters of (ab)use. A new battery will go a long way toward fixing many owners' complaints about slow cranking.

Unfortunately, some owners will find that even a new battery doesn't improve the FWF turnover rate. When the battery has been replaced and connections cleaned, and the engine *still* won't turn more than 30 or 40 rpm on startup, it's time to look at the starter motor (and *its* connections).



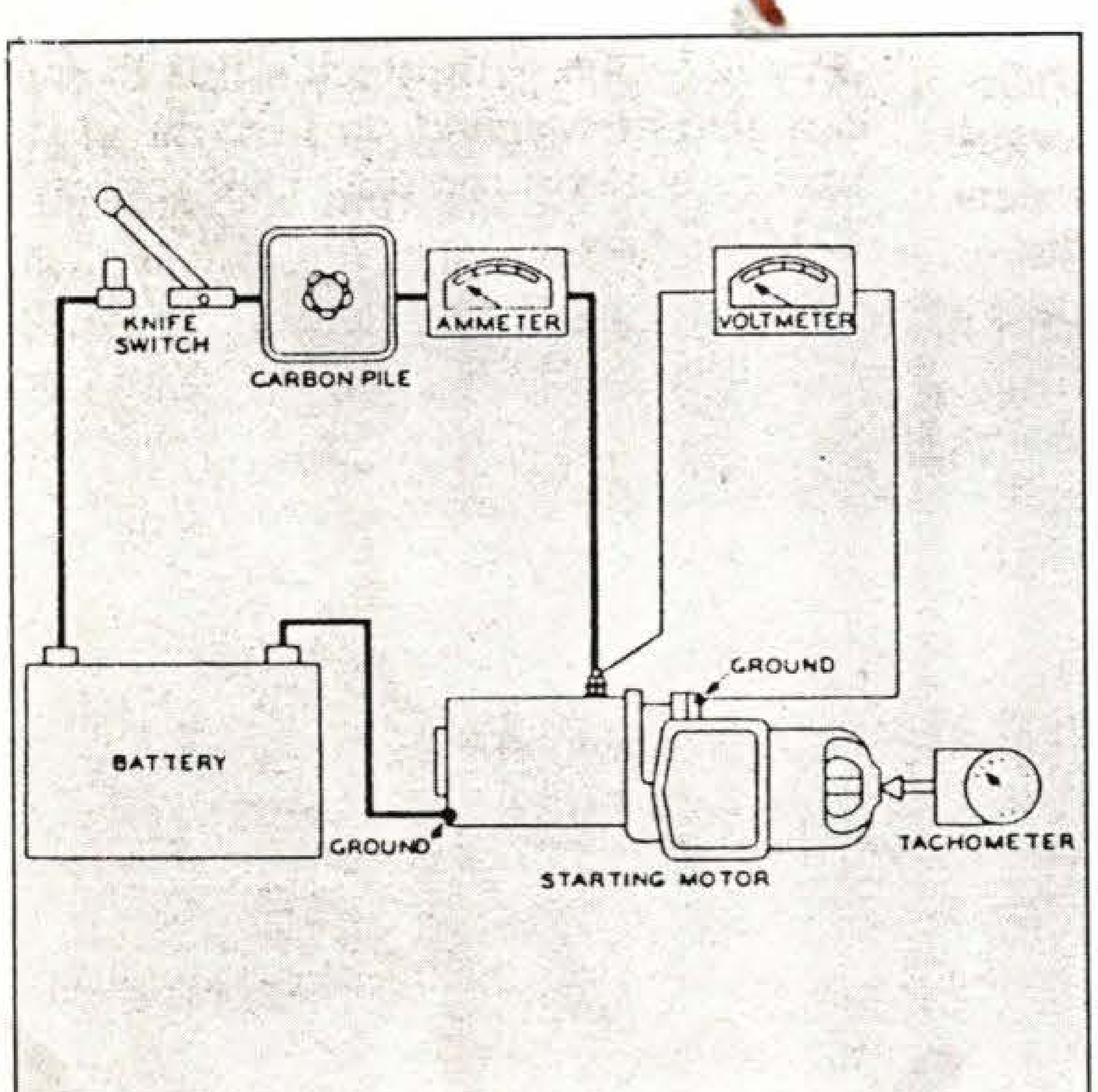
Exploded view of typical Prestolite starter motor with Bendix drive.

Starter TBOs

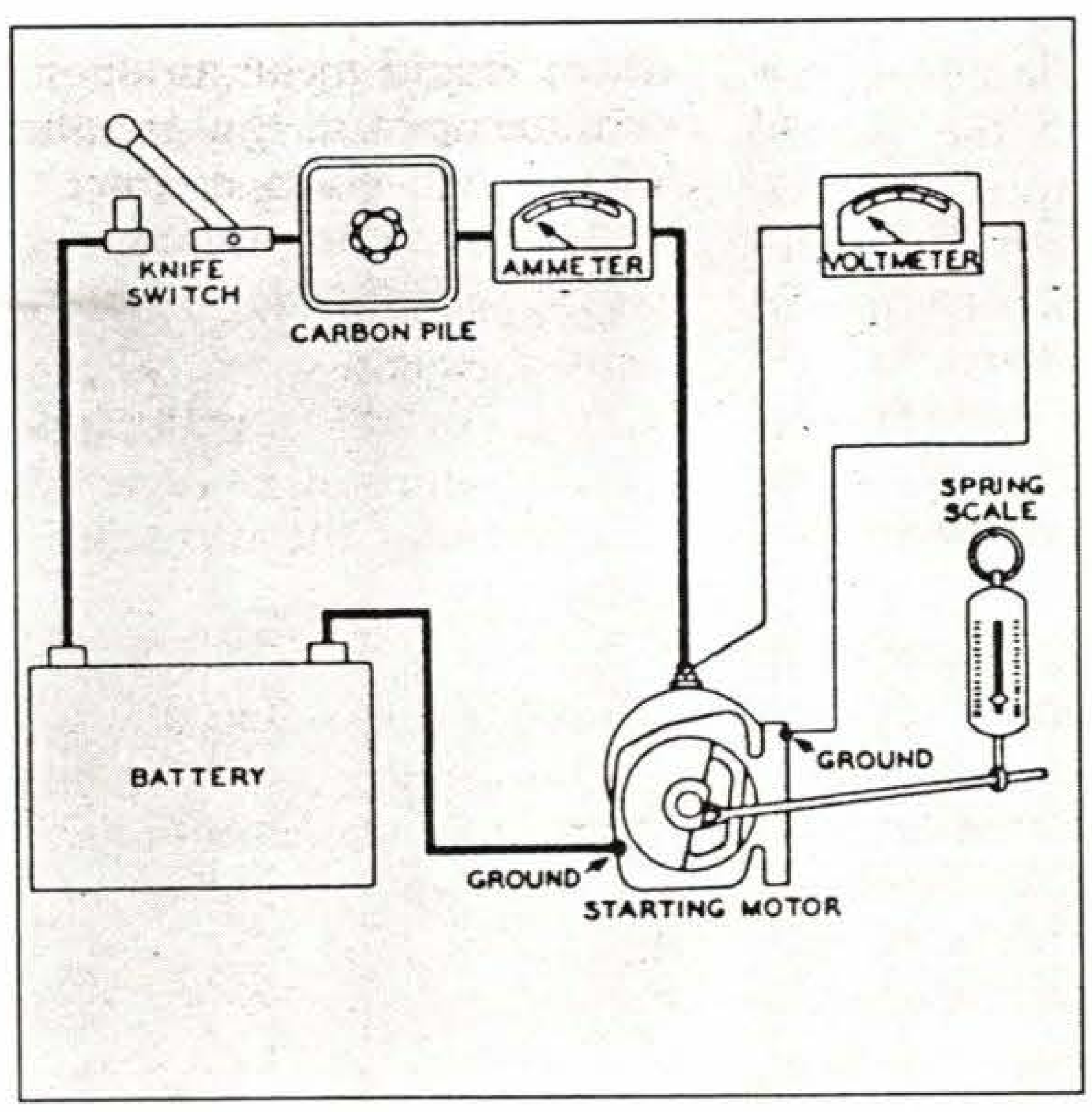
Pilots are often surprised to learn that there is no carved-in-stone TBO on starter motors. According to Prestolite and Delco (makers of the majority of units in current use), starter motors are—like alternators and generators—an 'IRAN' item (inspect and replace as necessary). This is because the frequency of use, the conditions under which the motor is operated, etc. vary so much from plane to plane.

As a rule, starter motors get overhauled on one of two occasions: (1) When the starter begins to show signs of disrepair; and (2) at the time of engine major overhaul. (The "major overhaul" price quoted to you by an engine shop should include a rebuilt starter motor.)

Before assuming your starter motor is the actual culprit in a slow-cranking episode, you should make a few precautionary checks. (We have known many owners who've paid for costly starter overhauls only to find out later that their slow cranking



No-load test components.



Static torque test components.

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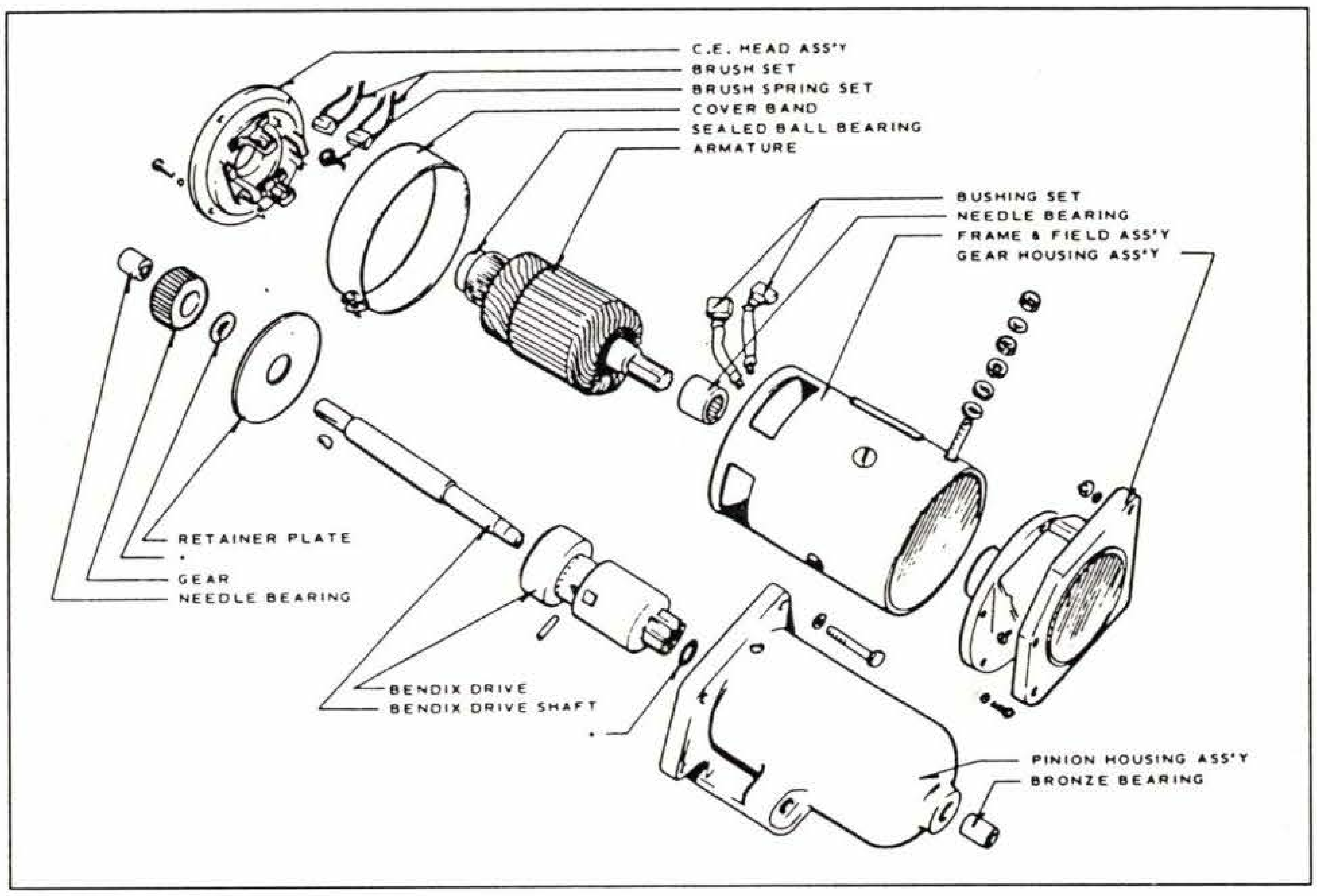

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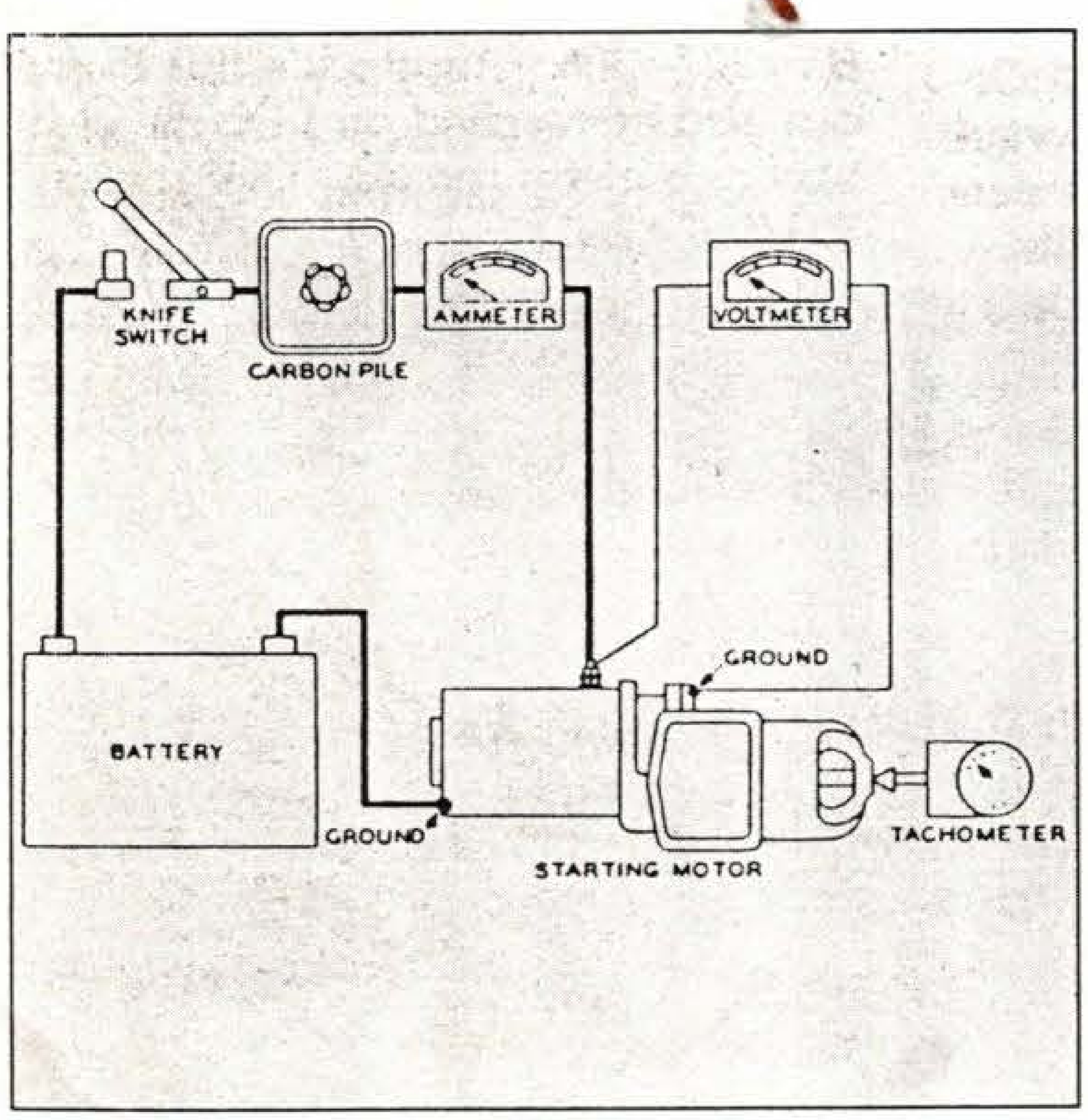
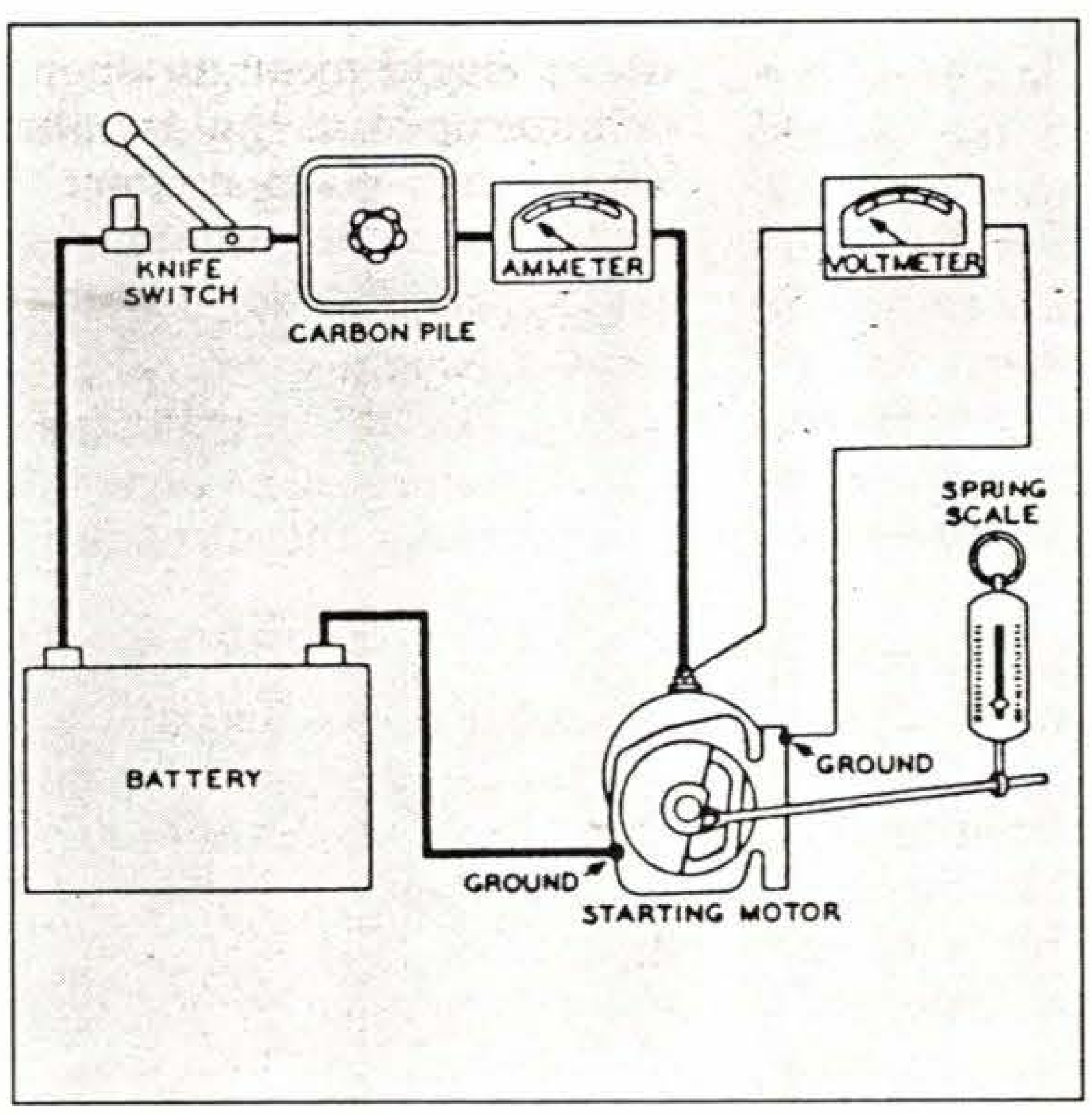


No-load test components.



Static torque test components.

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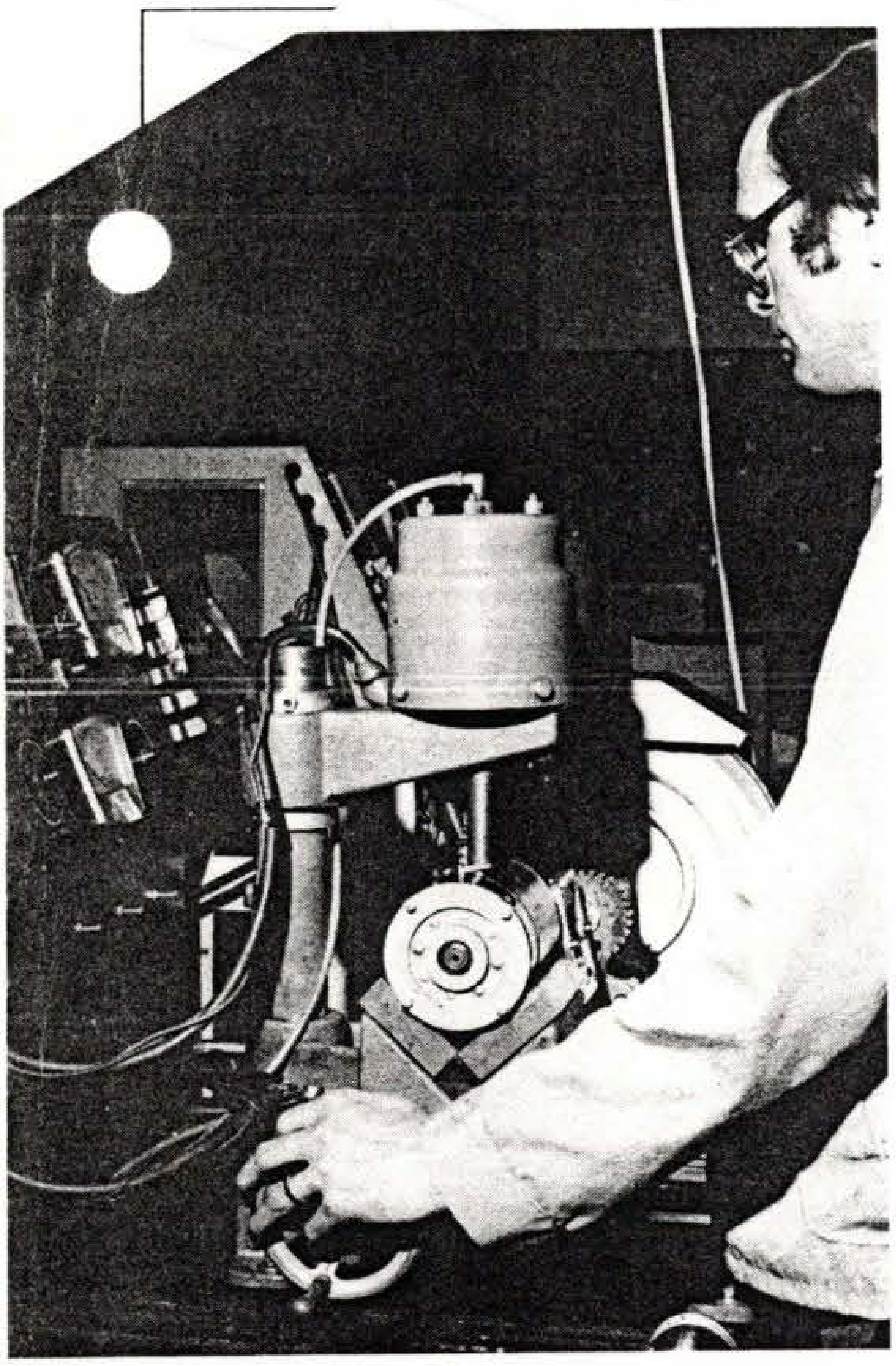

Proper testing of a starter motor includes a bench check of stall torque, stall amperage, and no-load rpm.

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episode was due to a bad contactor or poor connection.) Prestolite recommends checking the voltage loss from the battery to the starter motor during cranking (observing due caution with respect to whirling propellers); the drop should be no more than 0.2 volts per 100 amperes of current draw. (The voltage loss from the battery ground post to the starter frame should be no more than 0.1 volt per 100 amps.) Better yet, connect a jumper around any switch or solenoid (contactor) suspected of being defective, and see if the engine cranks faster with the jumper in place. If it does, you know where the problem is.

Note that a properly working starter motor (motivated by a properly charged and functioning battery) will draw substantial current in normal operation—a couple hundred amperes isn't unusual for a 12-volt system. (The exact amount depends on many things, including the viscosity of the oil in the crankcase.) In addition, voltage may fall well below 12 volts (or 24, on a 24-volt aircraft). In a total "lockup" condition—where the starter won't turn at all—a typical 12-volt Prestolite motor will draw 500 amps or more, producing 40 ft-lbs of torque.

No-Load Test

Some idea of how healthy a starter motor is can be gotten by removing it from the plane and running it with no load. (Note: If you can, hook a tachometer up to the shaft.) Ideally, you should also put a carbon pile or other variable-resistance "voltage controller" in the circuit in series with the motor, so that you can control the voltage seen by the starter. When you do this, your Delco-Remy starter should spin 3,000 rpm at 10.6 volts, and it should draw 60 amps in the process. (That's for a 12-volter. A 24-volt unit should make 2,800 rpm at 23.5 volts, with 55 amps' draw.) A Prestolite 12-volter should achieve at least 2,000 rpm at 10 volts, drawing 75 amps. A 24-volt Prestolite motor should run 1,800 rpm (minimum) and draw 35 amps at 28 volts or so.

What if you don't get these numbers? Low speed and high current draw means tight bearings, a dragging (possibly bent) armature, etc.—i.e., high friction in the motor somewhere. It could also mean a shorted armature. Low speed and *low* current draw would indicate a high internal resistance due to poor connections, dirty commutator, or possibly worn brushes.

Failure to operate, with *no* current draw, would mean an open field circuit, an open in the armature somewhere, or poor contact between brushes and commutator segments.

Failure to operate with *high* current draw means a direct ground in the terminal or fields, or frozen bearings (which you could have determined by hand-turning the armature to begin with).

Miscellaneous Checks

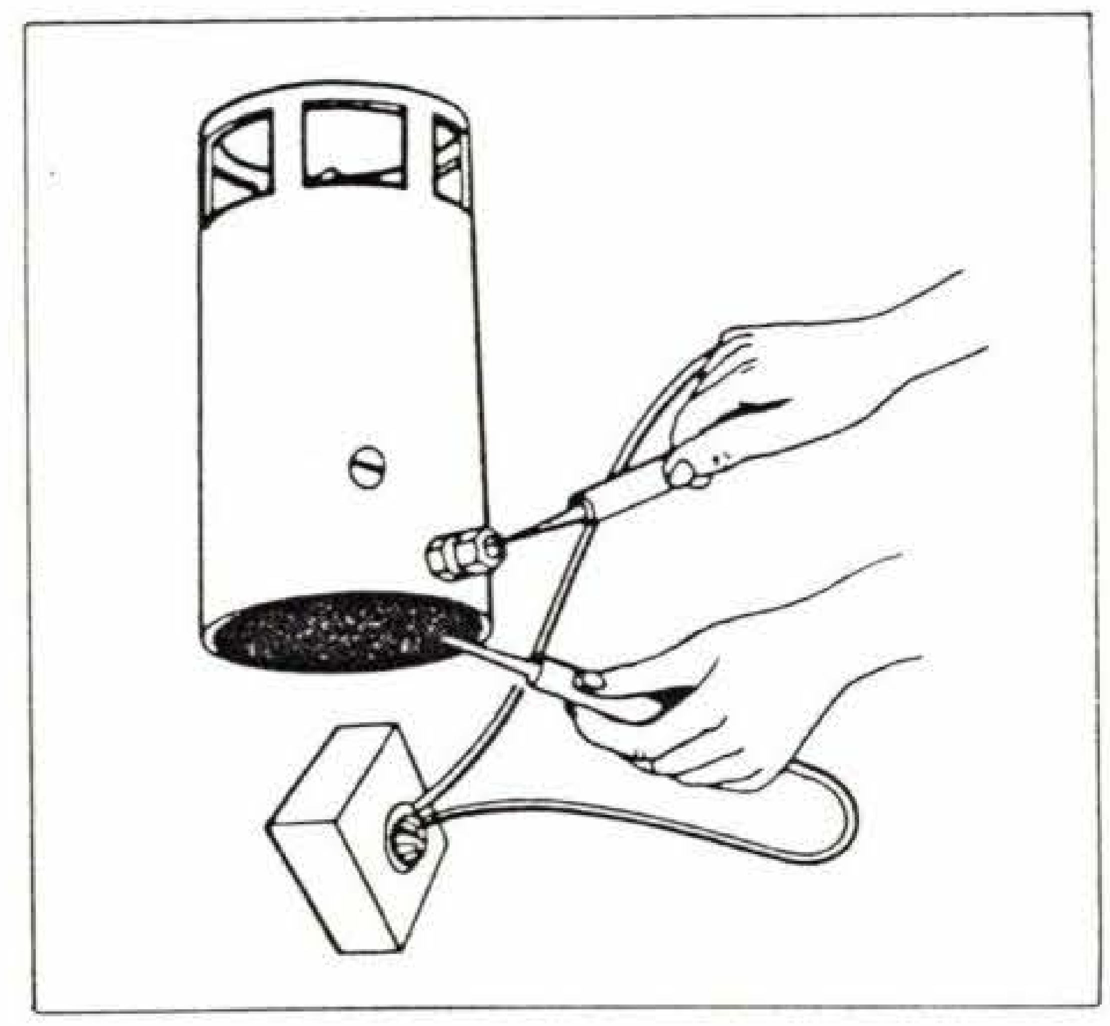
The no-load test isn't the only test of a starter motor's condition. A repair shop will also check the unit's torque in a static lock test (by hooking a brake arm and spring-type fish scale to the shaft, for example). As indicated above, the stall torque (and amperage draw) can be quite high. The applicable specs vary from motor to motor; a complete listing of specs is not possible here. For further information, write directly to Prestolite, P.O. Box 931, Toledo, OH 43694 or Delco-Remy, 2401 Columbus Ave., Anderson, IN 46018.

Still, there are other checks an owner can perform. One is simply to check brush condition. Brushes that have worn down beyond half their original length (compare with new parts) should be replaced. Brushes should also be making firm contact with the commutator. Brush tension should be somewhere between 1.5 and 2.5 lbs.

Field coils should also be checked for grounds. With coil ground connections disconnected, you should be able to touch one probe of a hot light to the motor's frame and the other to the starter terminal without getting continuity (be sure brushes aren't touching the frame). If the hot light lights, the fields are grounded and should be repaired or replaced as necessary.

If the motor checks out good (and is getting juice) but the engine doesn't want to crank, or there is noise coming from the Bendix drive, check the Bendix per the article in *LPM* in April '87 (p. 8).

Should your starter need rebuilding, try Aerotech (FAA Certified Repair Station 713-13), 815 Huntington Rd., Louisville, KY 40207 (502/895-5262) or Electrosystems, Inc., P.O. Box 273, Ft. Deposit, AL 36032 (phone 205/227-8306. (Aerotech's Bill Evans can also be reached on LIX, the electronic bulletin board. Dial online: 203/967-8260.)



Testing fields for grounds.

Spark Plug Basics

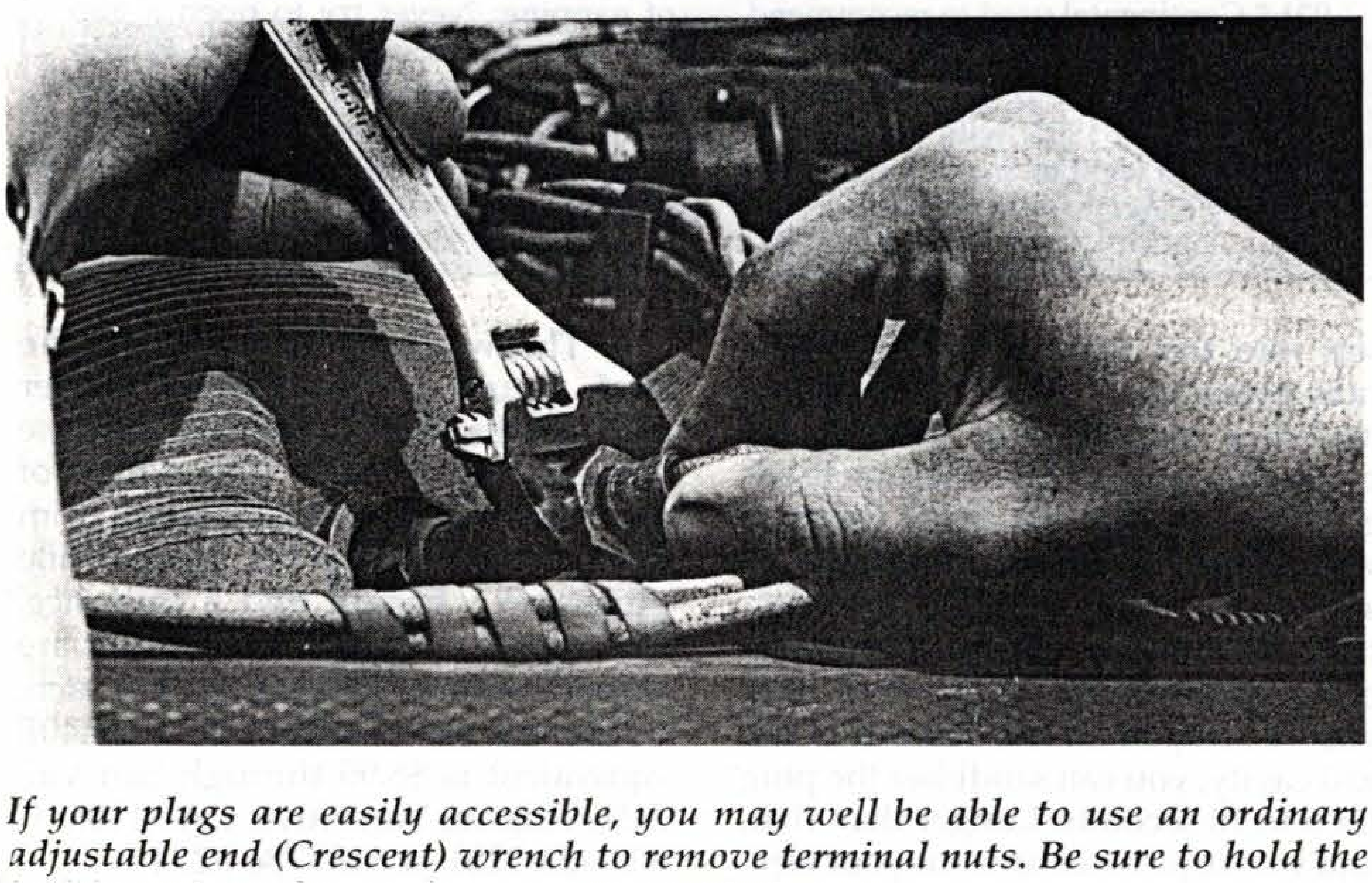
Even if you flinch at the thought of getting your fingers dirty, you can (and should) know how to remove and install plugs

by Kas Thomas

Spark plug R&I (removal and installation) is one of the simplest—and most important—techniques in the pilot's preventive-maintenance repertoire. Knowing how to get plugs in and out is basic to diagnosing cylinder problems, troubleshooting a bad runup, monitoring the effectiveness of one's leaning regimen, and, of course, replacing old plugs with new. You can't even do a compression test—or a check of ignition timing—without removing plugs. It really is fundamental.

But many pilots shy away from spark plug maintenance, reasoning that because plugs *are* so fundamental to engine operation, there's no sense taking a chance on messing anything up. Which is nonsense. The pitfalls of spark-plug handling are few, and once you know what they are, the chance of bungling anything is miniscule. Even if you don't routinely change the plugs on your automobile, you can safely do your plane's spark plug maintenance if you simply remember the following:

1. Choose the right tools. This is a prerequisite to *all* successful maintenance, of course. For purposes of plug maintenance, you want to be sure to have on hand at least a 7/8-in. deep socket, a 12-in. or longer wrench handle (for plug removal), a torque wrench (for installation), Crescent or other open-end wrenches for undoing terminal connections, and U-joints, extensions, and/or adapters as necessary to reach hard-to-get-at plugs. Special spark plug terminal wrenches, spark plug sockets with magnetic collets, and other custom



If your plugs are easily accessible, you may well be able to use an ordinary adjustable end (Crescent) wrench to remove terminal nuts. Be sure to hold the ignition wire to keep it from rotating with the nut.

Ratchet-type torque wrench should be set to 30 ft-lbs and used for installation only—not removal.

doodads can be purchased through aviation catalogs (at substantial cost), but the only thing you really need to invest big bucks in is the torque wrench. Everything else can be bought locally at reasonable cost.

The most important item aside from the torque wrench is the plug socket. Be sure the one you buy is deep enough to hold an aircraft spark plug, and be sure it fits the plug snugly. (Aircraft Tool Supply sells a good one for $9.95. ATS, Box 370, Oscoda, MI 48750; 1-800-248-0638.) Whether the drive end is a half-inch or quarter-inch square drive is immaterial, as is the issue of hex versus 12-point openings. The hex type socket is (in theory) less prone to slippage. But the 12-point (box wrench) type socket is better in tight spaces, since only 30 degrees of throw are needed to operate the wrench. With a ratchet, the throw requirement is further reduced (SK's Tuff 1 series ratchets have 72 teeth and thus need only 5 degrees of stroke per bite). But you shouldn't plan on using a ratchet handle for removing plugs. (Ever hear of a ratchet rebuild kit?) A stuck plug—and that includes just about half of all plugs in this world—will make mincemeat out of your expensive ratchet: i.e., you'll strip the ratchet teeth in no time. (Obviously, you won't want to use your $80 torque wrench for plug removal.) I say again: Go ye to Sears and buy a 12- or 15-inch *non-ratcheting* wrench handle.

Ten-inchers are too short to allow enough leverage to deal with balky plugs, unless you're Lou Ferrigno; 12 inches is a workable minimum. Longer is better.

2. Don't cock your socket. Proper technique is to plant one hand on the spark plug socket (where it joins the wrench) and the other hand on the wrench handle, then use your first hand to steady the socket while you push—or bump—with the other hand. The force needed to start a high-friction object in motion is always more than that needed to keep it in motion, so *bumping* is the technique of choice when a plug balks. When the little devil finally breaks loose, you can resume pushing. Uncouple the wrench handle when you've got the plug going easily, and hand-twirl it the rest of the way—then take the plug *and* socket out *as a unit*. The main thing to remember, though, is: Don't let that socket cock over while you're bumping, pushing, pulling, or cursing. Any sideways force applied to the plug can end up cracking the ceramic internally.

3. Don't drop a plug on the ground. And if you do, throw it away immediately (even if it looks and/or tests good). A dropped plug may be cracked internally, and if a piece of ceramic falls out later, it could score a cylinder wall or induce preignition. (See The Engine Clinic, March '88.)

4. Don't get the plugs mixed up. Presumably one reason you're removing the plugs is so you can judge the condition(s) of the cylinders from whence they came. Also, you want to rotate the plugs when they go back in (see accompanying box). If you don't have a plug tray, identify each plug with masking tape and a word or two in ball-point about the cylinder number and top/bottom orientation. A plug tray will cut time spent labelling, make plugs easy to tote around, and tend to prevent droppage. Buy one while they're still only $13.95. (Chief Aircraft Parts, 345 Whispering Pines, Grants Pass, OR 97527; 1-800-447-3408.)

5. Keep blast-cleaning to a minimum. Sandblasting is a final-cleaning procedure. Your primary line of defense against lead and carbon buildup is a vibrating-prong cleaner or (just as good, but more work) a finely pointed object that you can insert into the firing cavity to physically break loose those crusty deposits twixt ceramic and shell. Spark plugs with a high heat rating are hardest to clean, since the firing cavity is very deep. It's almost impossible to see into the cavity (to judge the effectiveness of the cleaning process) without a strong light, so get one. *After* you've scraped all the BBs out of the end cavity, you can sandblast the plug for 5 to 10 seconds. Longer than that, and you're just wearing out your electrodes needlessly.

6. Throw worn-out plugs in the trash. Reusing a plug whose center electrode looks like a football is a false economy. When more than a third of the metal has been eroded away from any electrode, scrap the plug. Senile plugs are a hazard and a nuisance. Don't push your luck. New plugs are cheap insurance at less than $10 each. (Auburn's new 2-electrode REM40E equivalent is $8.95 through San-Val, 7456 Valjean, Van Nuys, CA 91406; 1-800-423-3281 or 818/786-8274.)

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How Important Is Gap?

The voltage needed to fire a spark plug is related in a fairly direct way to electrode gap: Obviously, the greater the gap, the more jolt is required to make the juice flow. But if you understand how a magneto works, you know that—in theory, at least—a mag can deliver any voltage asked of it (because of the near-instantaneous collapse of the field when the points open), which means it really shouldn't matter what gap your plugs are set to. They should fire regardless.

Still, there are limits. Extremely narrow gaps admit very little fuel-air mist between the electrodes, and (in massive-electrode plugs especially) the weak spark may ignite nothing more than the few droplets of fuel sequestered between the electrodes. I.e., combustion fails. Cold-weather starting thus suffers dramatically, and lean misfire occurs prematurely in cruise.

Too large a gap makes the mag work hard and puts extra stress on the harness. The plugs fire energetically and reliably, but they (and the rest of the ignition system) wear out fast. And at high altitude, the slightest carbon or oil residue in the distributor will invite crossfire, as electrons look for a path of lower resistance.

To avoid high-altitude misfire, and to keep ignition-system wear-and-tear low, gaps greater than .022-in. should be avoided. But to ensure reliable cold starts and misfire-free operation in cruise, gaps should be set wider than .015-in.

Lycoming, in S.I. 1042R, says flatly: "Spark plug gaps shall be set at .016 to .021." Continental used to recommend .019-.022 as a standard gap, with .015-.018 optional (see S.B. M77-10, now inactive). But in 1985, with S.B. M85-7, Continental went to an elaborate, five-category Gap Chart, with various gap ranges for various plug/engine combinations. (The gaps run from .015 to .022.) To obtain a copy of the bulletin, write TCM, P.O. Box 90, Mobile, AL 36601.

In the end, gap choice becomes a matter of personal preference. Most operators will find .018-in., +/- .002, to be satisfactory; and after you've gap-checked a couple hundred electrodes, you'll find you don't really need a gap gauge or feeler to spot a too-wide or too-narrow gap. Trained eyes can distinguish .018 from .021 quite readily. (If this weren't true, Bic wouldn't sell Ball Liners in Fine and Ultra-Fine widths.)

Just remember the one cardinal rule of gapping: Never try to open a gap back up after closing it too far. Wedging anything between inner and outer spark plug electrodes is a sure invitation to cracked ceramic and (possibly) inflight loss of juicy-juice.

Spark Plug Rotation Revisited

What possible difference could it make whether you rotate your plugs every 50 hours? Is plug rotation really of any practical value? Or is it tantamount to rotating your socks?

Glad you asked. As luck would have it, I've seen countless examples of spark plugs with center electrodes worn to the shape of a (flat) football, but with like-new outer electrodes—and the converse (plugs with severely worn outers, with a like-new inner). This sort of lopsided wear can, I'm convinced, be prevented (and plug lives lengthened) by periodic rotation of spark plugs.

The reason? The magnet in a magneto can be in either of two orientations when the points open—N/S or S/N—and the orientation governs the polarity of spark plug firing. In one magnet orientation, the plug's center electrode is at high *positive* potential when the points open; in the other orientation, the center electrode is at high *negative* potential. In one case, the electrons jump from the outer electrodes to the center electrode. In the other case, the electrons jump from the center electrode to the *outer* ones.

The reason any of this is important is that over a long period of time, constant-polarity arcing will cause preferential erosion of one or the other electrode. When the center electrode never changes polarity, it can wear out before the outer electrodes (or the outers can wear out before the center, if the polarity is in the other direction).

This effect wasn't important in radial-engine days, because radial engines had an odd number of cylinders (although their magnetos still had even numbers of poles)—which meant spark plugs fired with alternating polarity. But in flat engines with 2, 4, 6, or 8 cylinders, magneto output reverses polarity *an even number of times during each revolution of the distributor finger*. Hence, the even-numbered-cylinder plugs always fire with one polarity and the odd-numbered plugs always fire with the other polarity. A plug that might be declared unairworthy in 200 hours because of a football-like center electrode (or paper-thin outer electrodes) could, if rotated every 50 hours, go a couple hundred hours more before *all* electrodes wore out.

You knew all that, of course. But did you know there's a right way and a wrong way to rotate plugs? Not only that, the procedure to follow differs for 4- and 6-cylinder engines. (Listen up now. This gets interesting.) The firing order for a six-cylinder engine is odd-even, odd-even, odd-even (typically 1, 6, 3, 2, 5, 4). On a flat four, the firing order is odd-odd, even-even (for an O-320, it's 1, 3, 2, 4). What this means is, on a *six*, you have to rotate plugs up for down, *and even for odd* (i.e., bank to bank), to achieve polarity change. (The "up for down" part is to keep the plugs on the same magneto harness. Recall that each mag fires the top plugs on one bank of jugs and the bottom plugs on the opposite bank.)

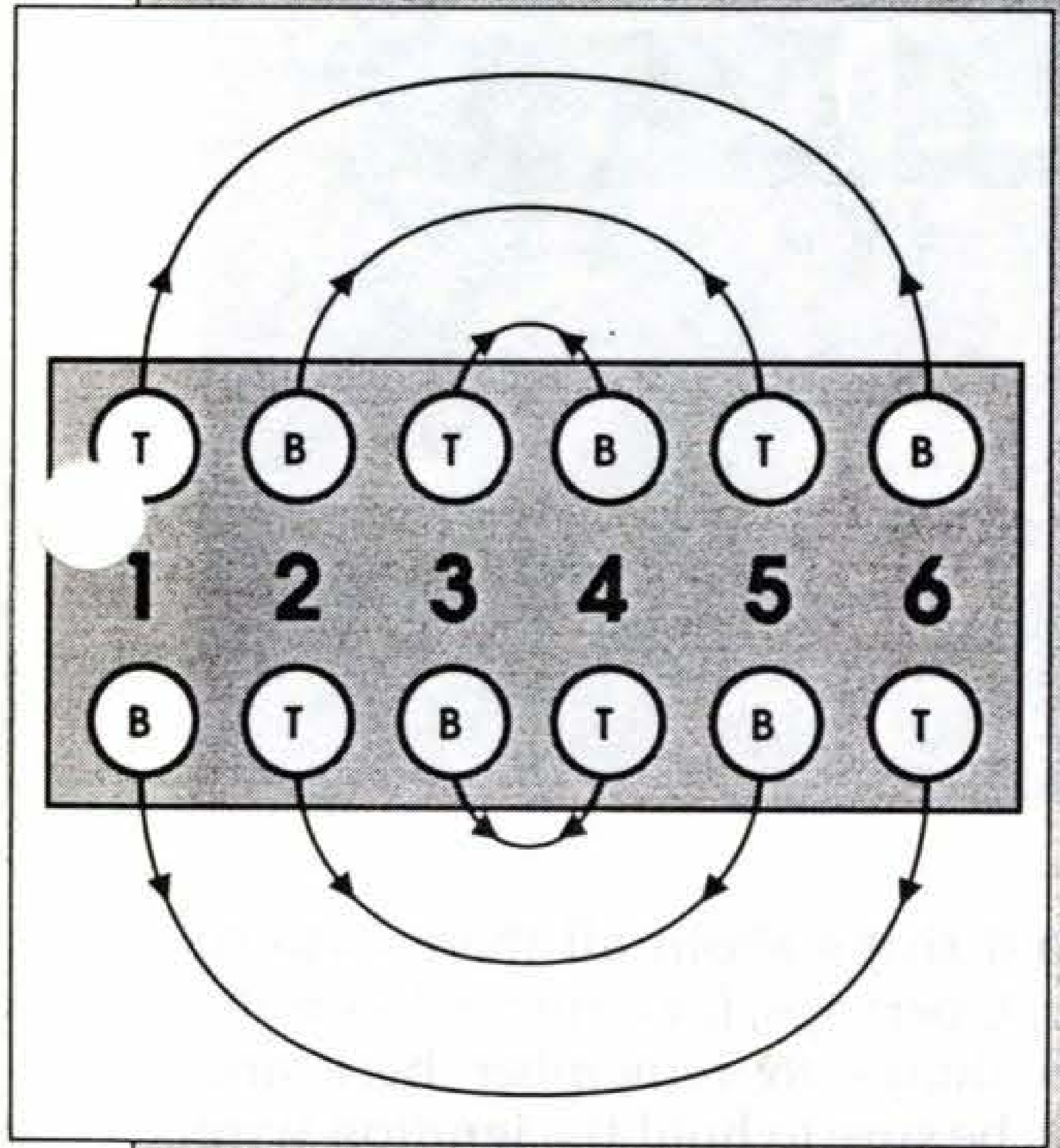
On a *four*, swapping plugs top for bottom and side for side will *not* result in proper rotation. If the firing order is 1, 3, 2, 4, then it's obvious that if 1 fires +, the magneto output will be 1+, 3-, 2+, 4-. Hence, you *don't* want to swap 1 for 2 or 3 for 4, because the polarity is the same. Instead, you want to swap plugs *fore to aft* (No. 1 to No. 3, No. 2 to No. 4), staying on the same bank.

In short: For a six, remember to rotate plugs "about all axes" (up for down, odd for even). In a four-banger, swap plugs with their *nearest neighbors* (top No. 1 to top No. 3, for example, or bottom No. 2 to bottom No. 4).

The mnemonic concept for fours, you might say, is "sameness": odd for odd, even for even, top for top, bottom for bottom. The mnemonic concept for sixes would then be "scrambled-upness": odd for even, top for bottom.

Whatever. Just remember, the idea is to rotate plugs on the harness *in firing order*. If you don't—if you just put plugs back in the same holes, or you rotate them incorrectly—plug life will be cut roughly in half.

—*Kas Thomas*



Owners of six-cylinder engines should rotate plugs as shown here, but first they should be arranged in the top and bottom orientation depicted. (Note the Ts & Bs in the little circles.) This scheme assures polarity alternation.

(*Continued from previous page*)

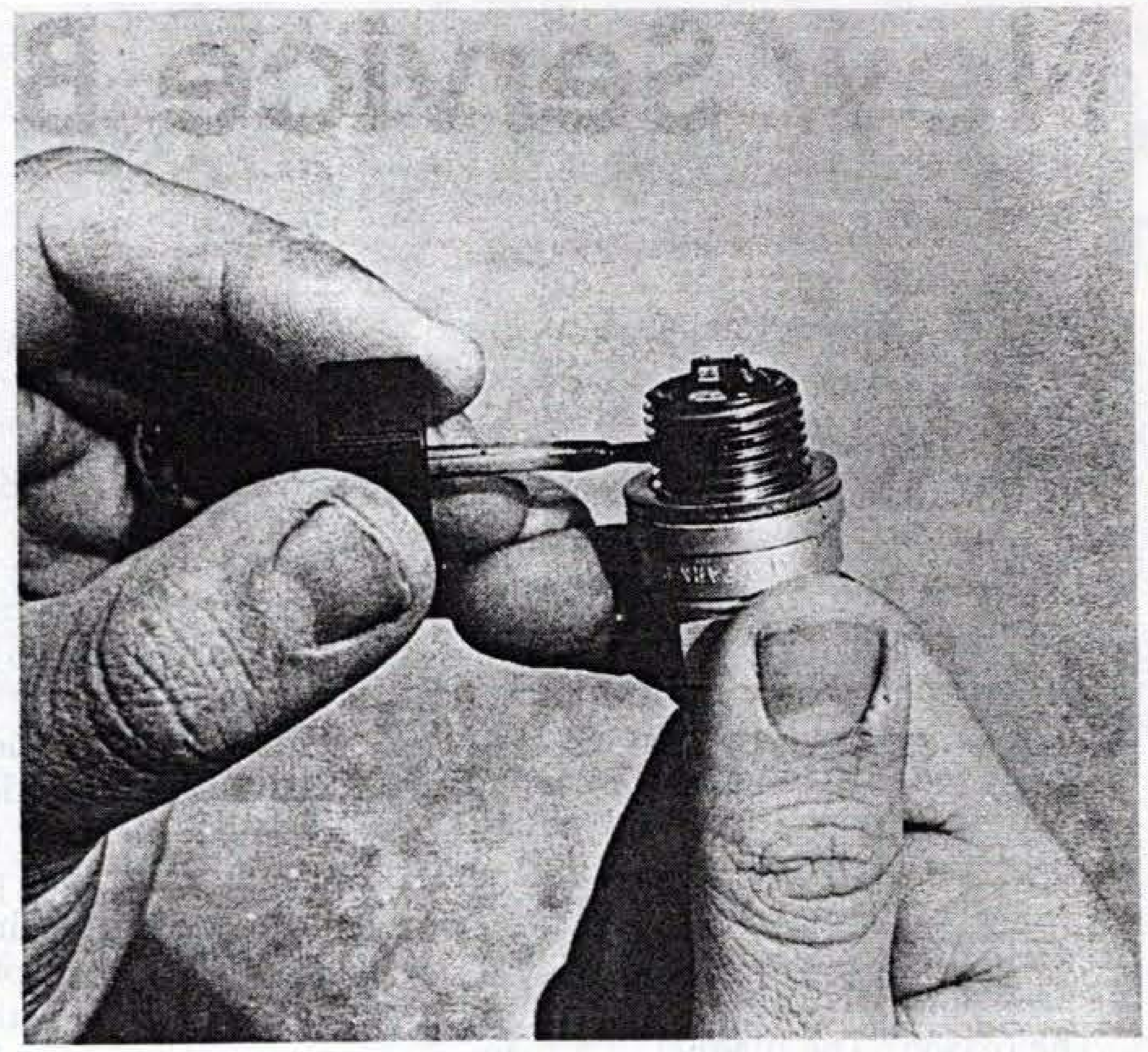
7. Use new gaskets. Or at least, anneal your old ones before reusing them. You know the trick: Torch the old copper washers until they're cherry hot, then dunk 'em in a Maxwell House can (or other FAA approved container) full of water. The water quench will give the copper extra softness over air-cooling (see FAA AC 65-9A, page 99, column 1). With iron, the effect is just the opposite. But this is copper, not iron. Quench the damn gaskets.

Old gaskets are brittle and take a cone-shaped "set" due to the 3-degree bevel of the spark plug seat. If you install a coned-out, work-hardened (non-annealed) gasket upside down, your torque wrench will be working against the deformation of the gasket as well as against normal friction drag, and you're apt to reach final torque prematurely. Not only that, but the gasket may flatten and harden even more in service, again relieving more of the torque. Why take a chance on a loose plug? Either anneal your old gaskets, or throw them away. Saving them is a false economy.

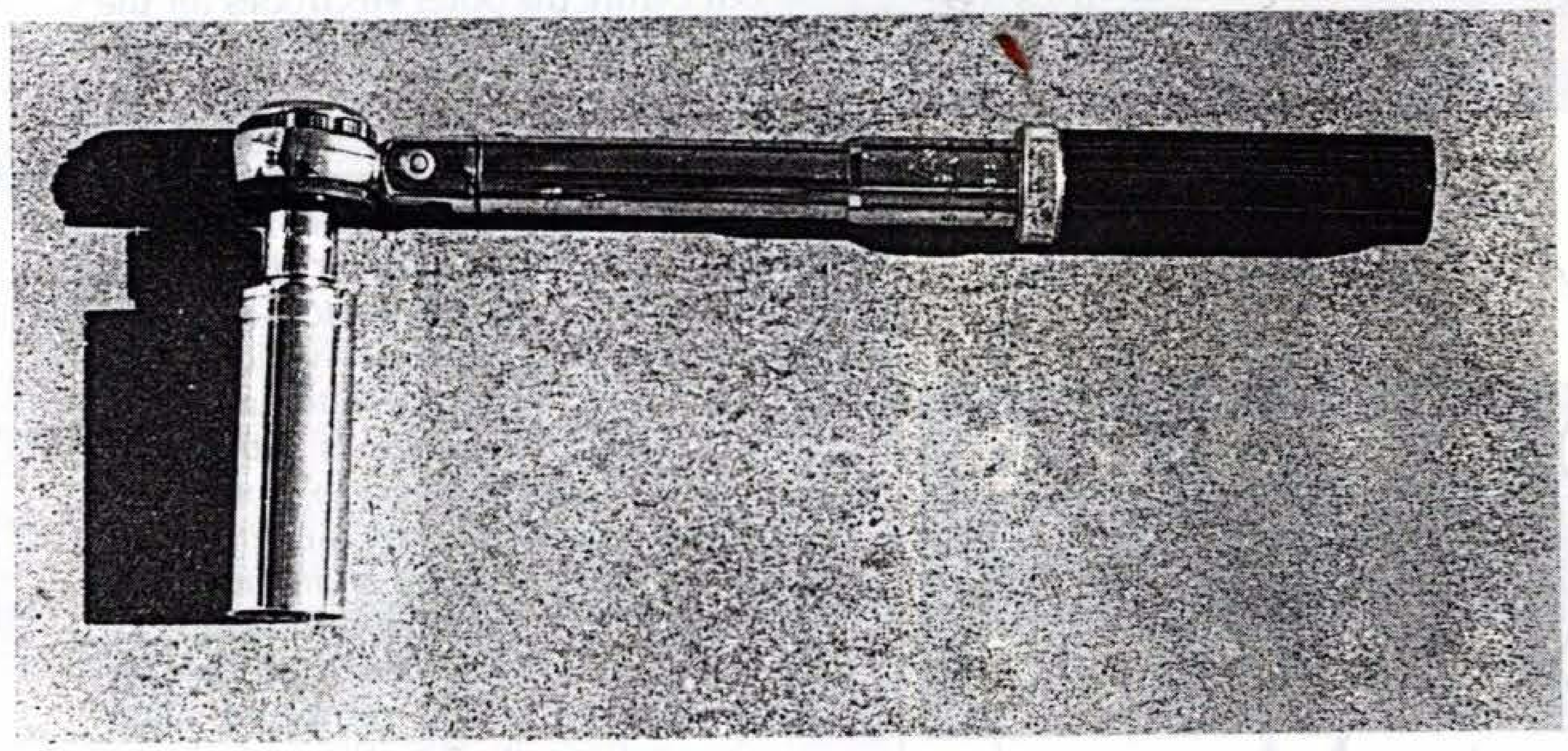
8. Don't accept dirty threads. To ensure proper torque on installation, 23CP13

you should start with clean threads (in the hole and on the plug itself), and *use a thread lube*—either Champion No. 2612 ($2.25 from Chief, above), or engine oil, preferably Mobil synthetic. If you don't clean the grit out of all threads, your installation friction drag will be artificially high and you'll reach "proper torque" prematurely. (Also, you may dislodge gritty particles into the combustion chamber.) The thing to do is to go over all threads with a bristle brush and/or terry cloth (not a thread chaser, which might back out Helicoils). Then apply thread lube sparingly to each plug, starting a full thread away from the end. (You don't want excess to run off onto the electrodes, shorting out the plug.) We like Champion No. 2612, but if you don't use this product, at least use a dab of engine oil on the threads. (Synthetic oil will resist thermal breakdown.) Use *some sort* of lube. Otherwise the plug won't want to come out next time.

9. Thread plugs into place by hand. Save the socket and torque wrench for the last minute. Putting plugs in by hand avoids any possibility of crossthreading, and gives you a valuable doublecheck of thread condition. If you can't turn a plug almost all the way down by hand, then there's something wrong: threads are damaged or dirty, the plug isn't in right, etc. (You did remember to put a gasket on each plug, right?) Apply the socket and torque wrench only after you're sure everything is hunky. And dory.



Application of Champion 2612 thread lube should begin a minimum of one full thread away from the firing end. Some people use Dow DC-4 or DC-10. Engine oil will tend to turn to coke, cementing the plug in place; if you use engine oil, be sure it's synthetic. Your torque wrench (below) can be 3/8-in. or 1/2-in. square drive. The important thing is that it is accurate in the 25-35 ft-lb range.



10. Don't overtorque. Lycoming (in S.I. 1042R) says to torque to 35 ft-lbs. (Period). Continental (in its overhaul manuals) says 25 to 30 ft-lbs. If your threads are clean and your gaskets are fresh, 30 ft-lbs should be plenty. Beyond 30 ft-lbs, plugs get very difficult to remove later. Lycoming's 35 ft-lb spec is apparently designed to provide more margin against error (dirty threads, coned-out gaskets) for sloppy mechanics, on the theory that it's a sloppy, sloppy, sloppy, sloppy world. We've always had good luck with 30 ft-lbs. Maybe because we know how to do the job right to begin with.

And that's about all there is to it, except, perhaps, for terminal hex nuts. Two things to remember here are: First, be sure to hold the ignition wire still as you install (or remove) each nut. Ignition leads get a lot of wear and tear where they go into the plug, and it's because careless types let the wire twist as the terminal hex is done/undone. Second, don't overtorque the nut. (They're hard enough to get off as it is. Plus, the nuts are thin and will split if you overtorque them.) You don't use a torque wrench for this. The standard rule is: Tighten finger-tight, then turn a maximum of one flat (60 degrees) more.

For additional guidance on plugs and plug maintenance, go straight to the source: Champion Spark Plug Co., Toledo, OH 43661 (419/535-2461); or SL Auburn, 89 York St., Auburn, NY 13021 (315/252-9501).

Proper technique is shown here. Object is to avoid side force on the plug.

Understanding the Aircraft Magneto

by Kas Thomas

In a world of software-driven electronic ignition, it's something of an anomaly that small airplanes—85 years after the Wright brothers—still rely on whirling magnets and tungsten breaker points to achieve controlled combustion. Even *motorcycles* (for crying out loud) no longer use magnetos. What are we, nuts?

Frankly, we probably *are* nuts for accepting magnetos. Mags (once touted for their light weight) are heavy compared to solid-state ignition, and—much more important—they contain moving parts (some even touching each other). Which means reliability isn't what it should be.

More amazing still, though, is the fact that most pilots don't have the slightest clue as to how a magneto does what it does, or why mags were once considered (and perhaps still are, in certain circles) *the* high-tech solution for aircraft ignition.

Fun with Magnets

If you ever played with magnets, batteries, or wires coiled around nails when you were a youngster, you're way ahead of the game when it comes to understanding magnetos. The ancient Chinese could have invented the magneto (and probably would have, if they'd had a need for one); it's that simple.

Start with the fact that if you wrap a wire around a nail and send DC (direct current) through the wire, you get a magnetic field in and around the nail, with a north pole and a south pole and every characteristic of a magnet.

The converse is also true: If you start with an ordinary nail and a coil of wire, and suddenly magnetize the nail, current will be produced in the coil (for the brief time period in which the magnetization takes place).

Suppose you could alternately magnetize the nail in one direction (N-S), then the other (S-N), then the other (N-S), etc., very rapidly. Attach the two ends of the wire to a voltmeter, and you'll find that an alternating current (AC) is being generated in the wire.

Perhaps as a child you played with horseshoe magnets. And maybe you noticed that a nail placed across the ends of the horseshoe would act as a small magnet. (Iron filings sprinkled around the nail will fall into the familiar pattern made by the field of a bar magnet.) You've "induced" magnetism in the nail.

Again, the converse is true: Take a nonmagnetic horseshoe-shaped piece of metal and lay a bar magnet across the ends, and you'll set up a magnetic field in and around the horseshoe.

Now. Imagine that you have a horseshoe-shaped piece of metal and a small bar magnet mounted on a stick so you can spin it with the ends just passing the tips of the horseshoe. Obviously the field in and around the horseshoe will alternate in polarity (N-S, S-N, N-S) as the ends of the bar magnet swap positions.

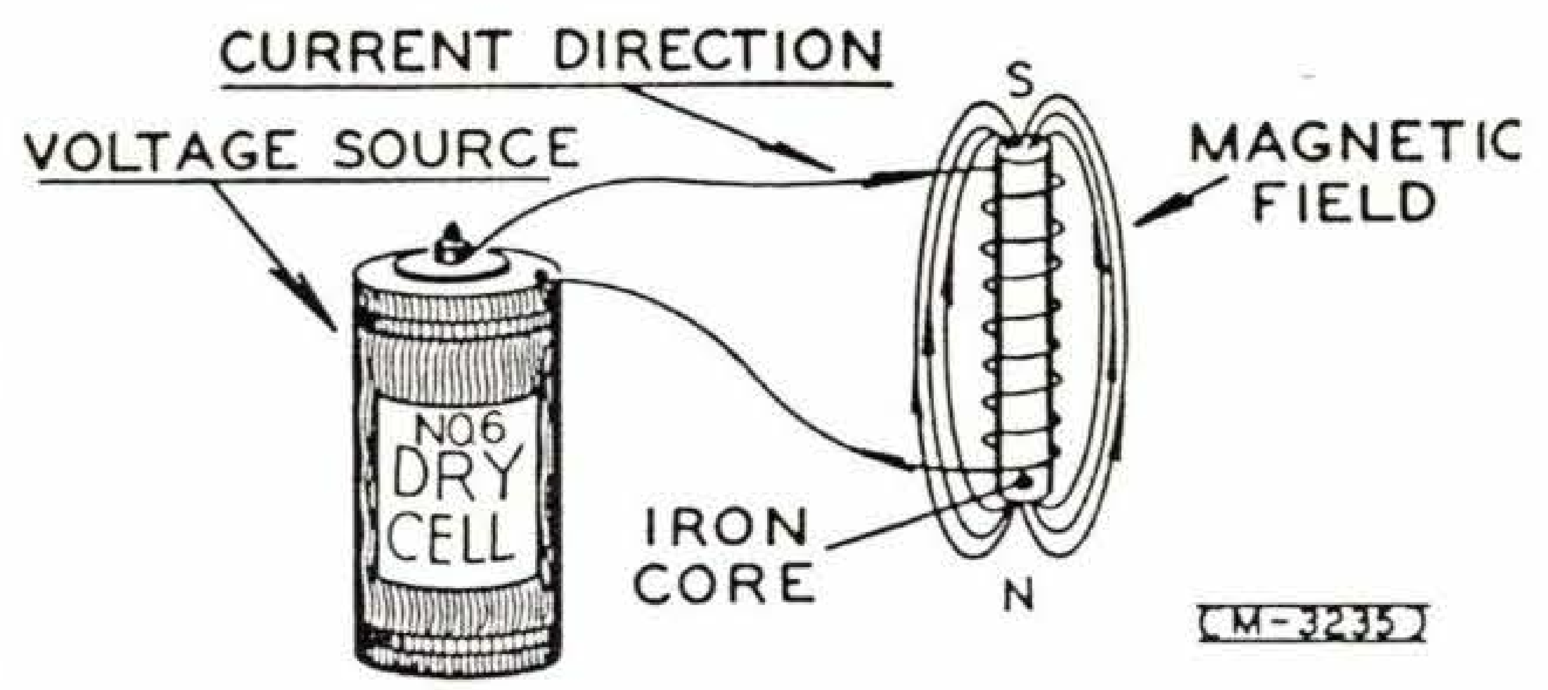


FIG. 1

Current in a wire coiled around an iron bar creates a magnetic field around the bar.

Next, wind a piece of wire around the curved portion of the horseshoe. Spin the bar magnet, and voila! You've created an alternating current in the wire.

In a magneto, the ends of the horseshoe are called *pole shoes* and the rotating magnet is called a *rotor*. The windings around the horseshoe comprise the *primary coil*. (Starting to sound familiar?) If you can figure a way to harness the AC produced by this little contraption so as to fire spark plugs in an engine, you call the contraption a magneto.

Harnessing the AC

An important fact about the spinning-magnet contraption we just built is that the voltage produced in the coil increases with increasing rotor (magnet) rpm. If you were to grab the loose ends of the coil wire and hold them very close to each other (but not touching), then spin your magnet to higher and higher rpms, you'd observe sparking across the wire ends at some rpm. (Or you'd shock yourself silly, if you touched the bare wire!)

Unfortunately, the coming-in speed of our prototype magneto would be rather high (many thousands of rpms), unless we were to wrap 100,000 or 200,000 turns of wire around our coil core. Obviously that's out of the question. We don't have all the wire in the world, and we don't want to spin our magnet at relativistic speeds.

There's a fairly easy way out, though, and that's to get a spool of very fine wire and wrap a *second* coil around the first coil. The alternating current in our original (primary) coil will induce an AC flow in the secondary coil, and the voltage in the secondary will be proportional to the ratio of turns of wire in the two coils. If we use 100 times as many turns in the second coil as in the first, the AC voltage produced in the secondary will be 100 times the AC voltage in the primary. We won't have to turn our magnet so fast to get a spark, because we've *transformed* the low voltage of the primary into a high voltage in the secondary.

It makes little difference whether we actually transform the magneto's voltage at the magneto, or at the spark plugs. If we want, we can run the primary voltage all the way out to the cylinders and put dedicated transformers at each spark plug. Exactly this scheme was used in the ignition systems for many high-flying piston aircraft of the 1940s and 50s. It's called a *low-tension* magneto system, because the magneto itself puts out very mild AC voltages. Internal arcing is unlikely with such mags (which is what makes them so well suited to high-altitude work).

When the secondary and primary windings coexist inside the magneto itself, the result is a *high-tension* ignition system—so called because the output of the mag is (potentially, at least) very-high-voltage indeed.

Spark Timing

Transformer action can give us the voltages we need for firing our spark plugs. But unfortunately, the magneto device we've been describing has a serious drawback in that it doesn't allow us to hold a constant relationship of spark timing to crankshaft (and piston) position. We noted earlier that the AC voltage output of the magneto goes up or down with magnet rpm. Say it takes 5,000 volts to cause gap arcing in our spark plugs (a not untypical value for a spark plug in cruise conditions). The problem is this: magneto output reaches 5,000 volts *quicker* at high rpm than at low rpm. If you set the mag so it'll fire your plugs at, say, 20 degrees before top center (BTC) of piston travel at 2,000 rpm, you may find that your plugs are firing at 30 degrees BTC at 2,500 rpm.

That's not all. Suppose some of your plugs are worn out, dirty, or gapped wrong (and maybe you have a leaky ignition lead or crusty terminal here or there, too). Some of your plugs are going to require 5,000 volts to fire, others will require 6,000, others 7,000, maybe 10,000. Each of these voltages falls on a different portion of the magneto's AC output curve. What it means is that your spark plugs are going to fire at different times in the Otto cycle!

This is clearly unacceptable. Reciprocating engines demand precise timing of the ignition event for proper operation. Some way must be found to allow precise adjustment of ignition timing.

The thing to do is suddenly, within a split second, step up the voltage output of the mag at *exactly* the moment you want ignition to occur (rather than simply wait for voltage to build to the required threshold level). We can do this by interrupting the current flow in the primary coil (in a precisely timed way), causing a sudden—near-instantaneous, in fact—collapse of the magnetic field associated with the primary coil. The secondary coil, sensing this enormously fast *flux change*, will respond by momentarily experiencing an astronomic voltage level. This voltage spike will, of course, spark the plug without hesitation.

The mechanics of this setup are shown in the accompanying simplified drawing of a magneto (Fig. 2). In this case, the magnet is actually a double magnet (four poles on one rotor); modern magnetos contain just a two-pole rotor. Notice that on the same shaft as the magnet is a cam with lobes (or ramps) that rub against a breaker finger. The contact breaker contains two *points* which in turn serve the same function as the contacts on a switch. The breaker assembly is little more than a glorified switch.

The primary, as we've seen, doesn't develop much voltage (compared to the secondary). But there is certainly a possibility of arcing across the breaker points when they open. To prevent this, a capacitor (or condenser) is wired across the points, providing a different "path of least resistance" than the air gap between the contacts.

The Lenz Effect

What about this flux-change business, anyway? How does it work? And what's this about "astronomic voltage levels"?

First let's back up a step or two and recall that it's the *change* of a magnetic field's strength that induces a voltage in a coil. (This is why voltage is proportional to

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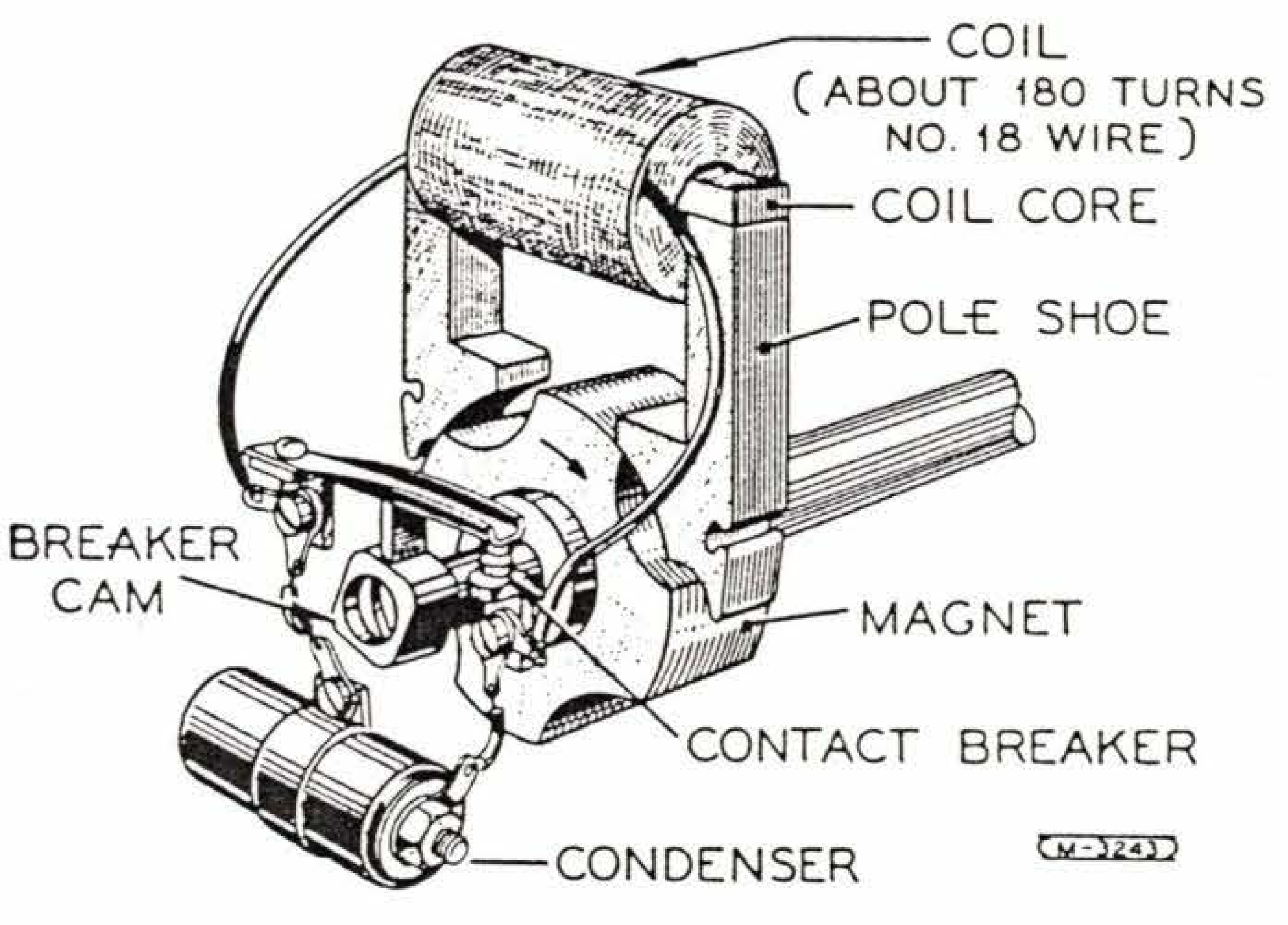
FIG. 2



The components of a crude magneto would include a coil of wire wrapped around an iron core, a rotating magnet, and a breaker assembly to interrupt the flow of current in the primary coil circuit. (A four-pole magnet forms the rotor in this diagram. In real life, two-pole rotors are used.) Note that a capacitor (or "condenser") has been wired across the breaker to prevent contact arcing.

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magnet rpm.) But when we talk about the primary coil in a magneto, we've got more than one magnetic field to concern ourselves with. On the one hand, there's the field produced by the rotor magnet, which alternately changes strength and direction in the coil core as the rotor spins. This is what induces current in the primary coil. The field strength of the magnet in the core is plotted at the top of the accompanying graph (Fig. 3) as the "static flux curve."

Magnet rotation induces a current in the primary coil. This current, in turn, gives rise to *another* magnetic field, since a magnetic field always accompanies current flow. It turns out that the direction of this induced-current field is such as to *oppose or resist* the original flux change that gave rise to the current in the first place. What it means is that the *net* field strength in the vicinity of the primary coil is nothing like what the static flux curve of Fig. 3 would suggest. Instead, the resultant or net flux wants to stay high for a while when the originating flux is decreasing, and it wants to stay low when the original flux is on the way up. (See the "resultant flux" curve, Fig. 3.)

The flux interactions just described are summed up by *Lenz's law* (which says that an induced current is always in such a direction that its magnetic field opposes the flux-change that induced the current). The reason this is important is that it has the effect (in a magneto) of keeping the *total* flux of the coil-and-core *high* until well after the magnet has swapped ends. (Note: "Flux" here refers to imaginary magnetic lines of force. It does *not* imply a dynamic change of anything. In other usages, the word "flux" implies flow or dynamic change, but in magnetism it merely implies static lines of force.)

The effect of this flux-change lag is to make point-opening a very dramatic event, electromagnetically speaking. Thanks to Lenz, a coil (or core) can in effect *store up* magnetic-field energy while the rotor of the magneto is undergoing a reversal of direction. Then, *bang!* The breaker points open and the stored energy has to be dissipated.

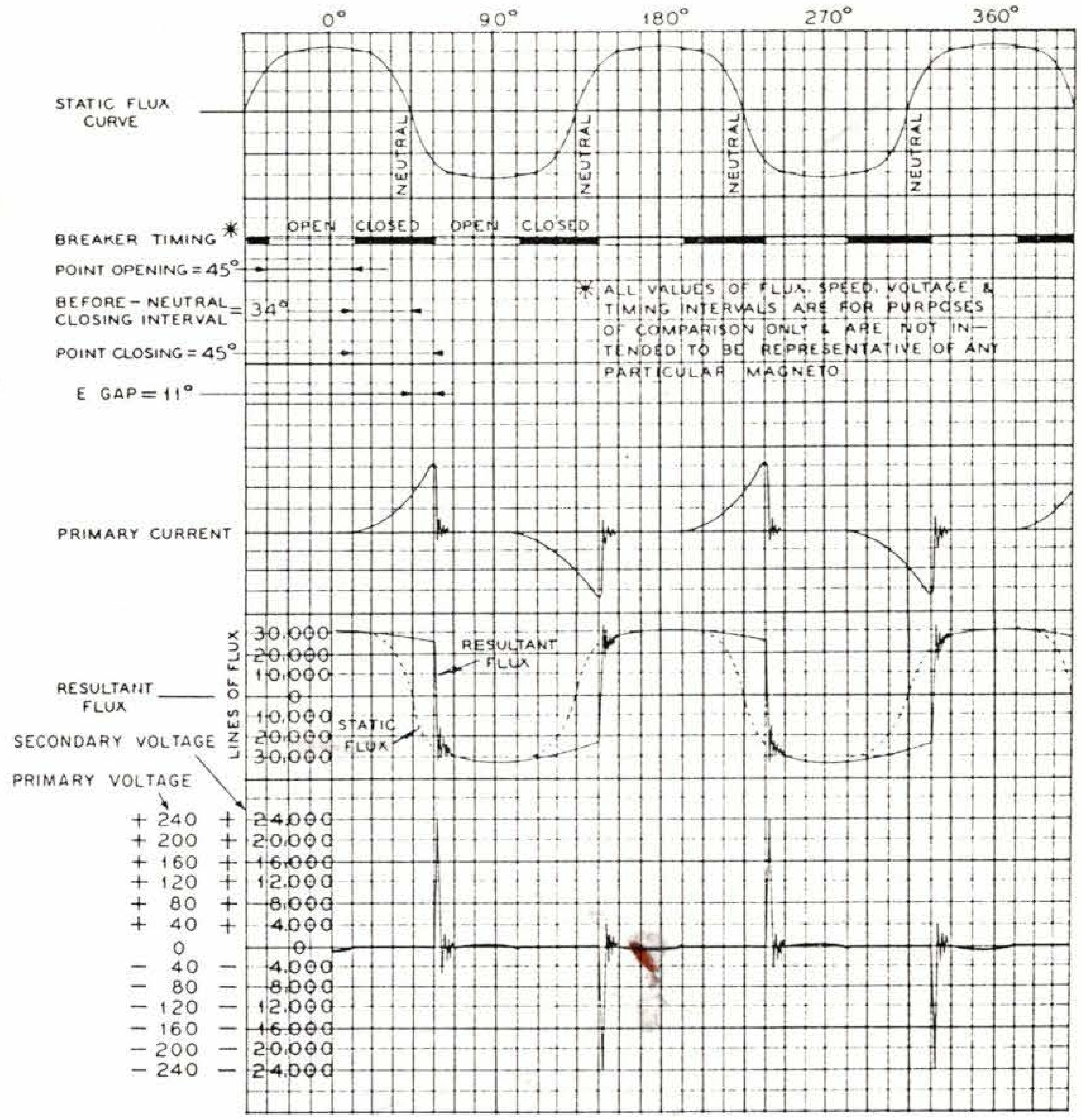


FIG. 3

The flux and current relationships for a magneto with an open-circuited secondary. (In an engine, spark plugs would dissipate the energy in the secondary, preventing the voltage spike from taking the form shown in the bottom plot.) Note the relationship of point opening to magnet neutral position. Also note the lag in resultant flux caused by the Lenz effect. Resultant flux stays high even as static flux is going from positive to negative. The sudden change of flux that results when points open is what causes the voltage spike in the primary and secondary. With a quick enough flux change, the voltage spike could (in theory) go to infinity.

Flyback Action

Where does that stored electromagnetic energy go? Well, again, recall what happens when a coil of wire is exposed to a *change* of a magnetic field's strength. A voltage is induced in the coil proportional to the rate of change of the magnetic field, right? In this case, when the points open, the current is going to stop flowing (instantly) in the coil, and the associated magnetic field is going to collapse.

What happens then is, the collapsing field "cuts" the turns of the primary winding. As some people like to say, the coil *self-induces*—a voltage spike appears in the primary.

This is like a gift from God (or from Lenz, at least) for magneto designers, since a voltage spike in the primary automatically means one heck of a voltage spike in the secondary (which, remember, has 100 times as many turns of wire in it).

The rapidity of the field collapse means that the voltages induced can be very, very high indeed. In fact, an instantaneous collapse of the field would mean an infinite voltage in the coil(s). This is the so-called *flyback effect*.

In a real engine, of course, magneto output doesn't go infinite, because sparking will occur across the plug electrodes at anywhere from a few thousand to 10,000 or 20,000 volts, depending on cylinder pressure and gap dimensions. If the plug is defective, presenting an infinite resistance to the mag, arcing will occur somewhere else along the circuit, possibly inside the mag itself.

Right away we can see why it's so important to keep plugs clean and correctly gapped in a high-altitude ignition system (e.g., Turbo Arrow, Turbo Saratoga, Mooney 231, P210, Seneca II/III, Skymaster, or other aircraft flying above 10,000 or 12,000 feet). Air acts as a dielectric inside the mag. That is to say, air is insulating. But air is only half as dense at FL 180 as it is at sea level. In a turbocharged plane, manifold pressure continues to increase at high altitudes (thus continuing to insulate the spark plug electrodes), but magneto air thins out (unless you have pressurized mags). Arcing is therefore increasingly likely to occur inside the mag—rather than at the plug(s)—in a high-flying aircraft.

Points Are Optional

The keen reader will note that breaker points aren't strictly necessary in a magneto turning at high speed. In fact, the crude magneto device we constructed very early on in this article operated satisfactorily, without breaker points, when spun at sufficiently high rpm. There are even occasions on record where aircraft magnetos have continued to operate without breaker action. We know of one case in which both sets of points (from both mags) fused in a six-cylinder helicopter engine, yet the pilot continued to fly under full power. It was only when he landed and performed a low-rpm mag check that the engine quit altogether!

This is a good time, perhaps, to digress for a moment and take note of the fact that two-pole magnetos turn at one-and-a-half times crankshaft speed in six-cylinder engines (and at exactly crank speed in four-cylinder engines). In a six-cylinder, four-stroke-cycle (Otto-type) engine, there are three power events for every 360 degrees of crank travel. Accordingly there has to be three flux reversals (or point-opening events) in every turn of the crank. Since a two-pole mag gives one flux reversal every 180 degrees, it follows that the mag rotor must turn one-and-a-half revs per single crankshaft revolution.

In a four-cylinder engine, two cylinders fire with every complete crankshaft revolution. That means two flux reversals in the mag, and (at 180 degrees per reversal) one full turn of the rotor per crank revolution.

Helicopter engines, incidentally, normally operate at very high rpms (by fixed-wing standards)—usually on the order of 3,000 to 3,400 crankshaft rpm. This means a magneto rotor rpm of 4,500 to 5,100 rpm for a six-cylinder engine. At such rpms, breaker action isn't strictly necessary. Flux reversal is rapid enough to give sparkworthy voltages without precisely timed flyback action.

E-Gap

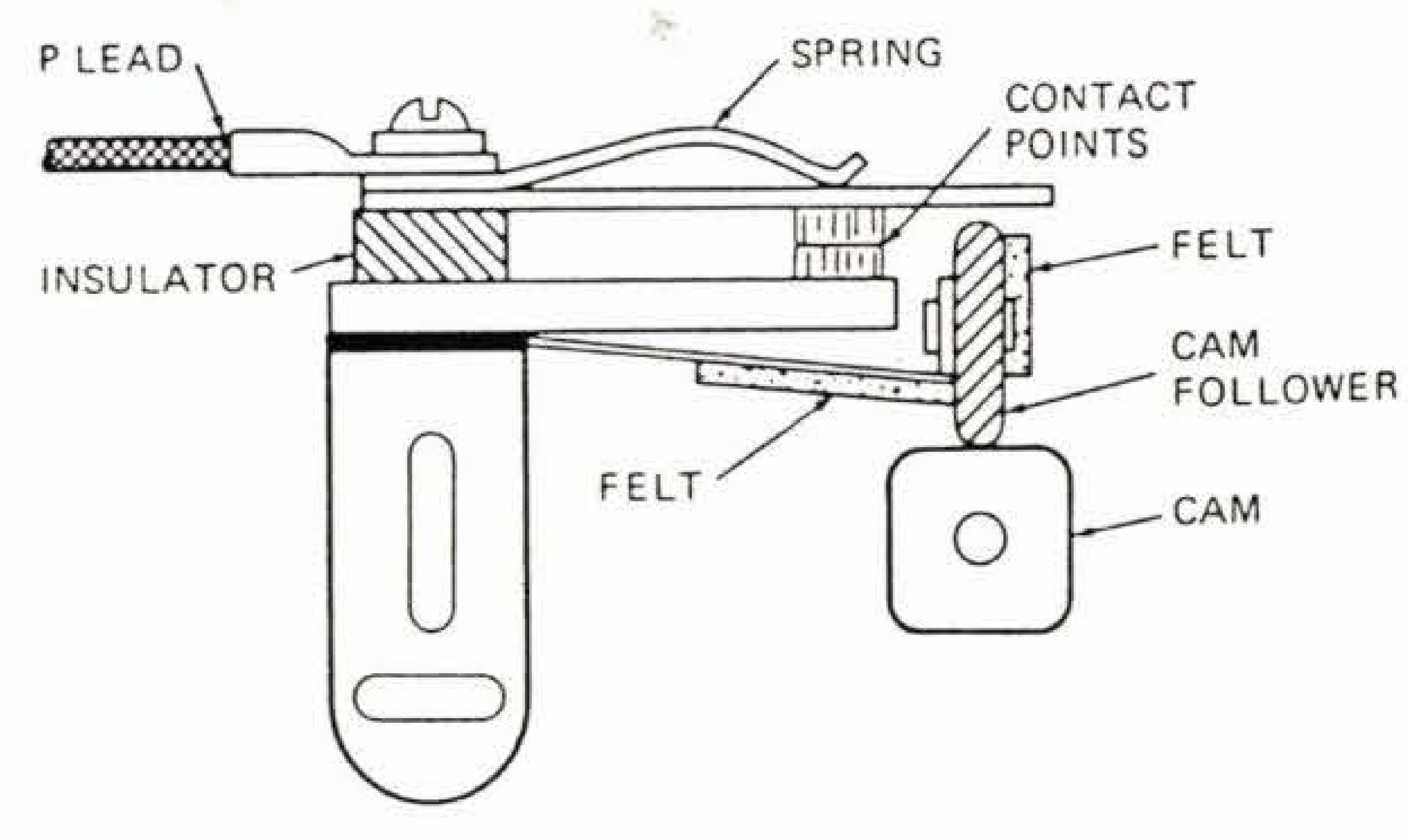
If you're going to use points to control ignition timing, you might as well set things up so that point-opening occurs precisely when the electromagnetic stress in the mag is maximal. This is easy enough to do. We know that current in the primary peaks when static flux (from magnet rotation) is undergoing reversal. That is, when the magnet goes through its neutral point (where the poles are aligned neither in one direction along the coil axis nor the other direction), we know that the magnetic field in the coil core is about to reverse—going from N-S to S-N (or vice versa).

Offhand you'd think that this would be the time to open the points—right at the moment of max-flux-change, where the magnet is reversing itself. But we're forgetting something. Our old buddy Lenz says that the induced current in the primary is going to set up a magnetic field that will cause a lag in the net flux change. What it means is that we'll get a far more dramatic zap if we wait until the magnet has actually turned an extra few degrees beyond neutral, *then* break the circuit.

It's a simple matter—if you're a scope-head—to hook an oscilloscope up to a mag and determine the optimum moment of breaker-point opening empirically. When you do this, it turns out that the *most efficient* angular gap (E-gap) for point opening is 10 to 15 degrees past neutral, for a two-pole mag. (Some actual published specs are: 10 degrees plus-or-minus 4, for the Bendix S-20/200 series; 15 plus-or-minus 2 for the 1200-series; 8 degrees for the D-2000/3000 series.)

Setting the E-gap angle is also called setting the mag's *internal timing*, as distinct from external, mag-to-engine timing. The former is concerned with the relationship of breaker opening to magnet position. The latter is concerned with the relationship of breaker opening to piston position.

FIG. 4



A typical breaker assembly. Points are tungsten-alloy. (In radial-engine mags, platinum was sometimes used.)

E-gap specs are fairly narrow, not because a magneto won't function if the internal timing drifts (it will), but because the distributor finger lines up with the output towers of the harness cap over very tiny angular travel ranges. If points open too early or too late, the distributor finger may not be lined up with the output tower. When distributor finger coverage is poor, the spark may well find an easier path to ground than via the towers, in which case distributor arcing occurs and you land with an uneasy stomach.

Note: This concludes the "theory" portion of our tour of aircraft magnetos. Next month we'll go inside an actual magneto and look at the mechanics of magneto assembly, inspection, and operation.—Ed.

How to Fabricate an Ignition Lead

by Mark Howards

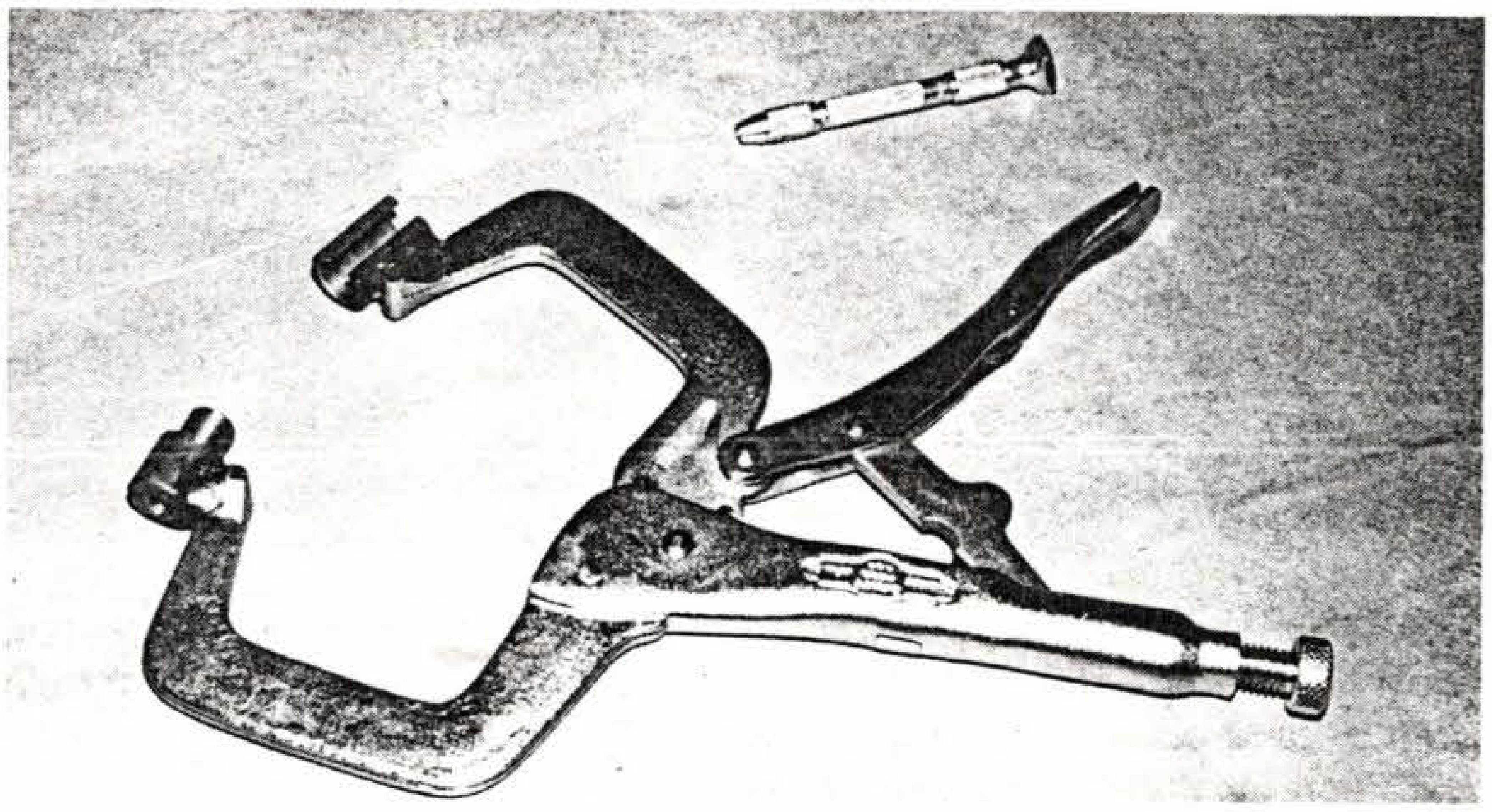
Radios giving you static? Rpm drop excessive during pre-takeoff runup? Spark plug terminal wells dirty? When was the last time you took a close look at your ignition cables?

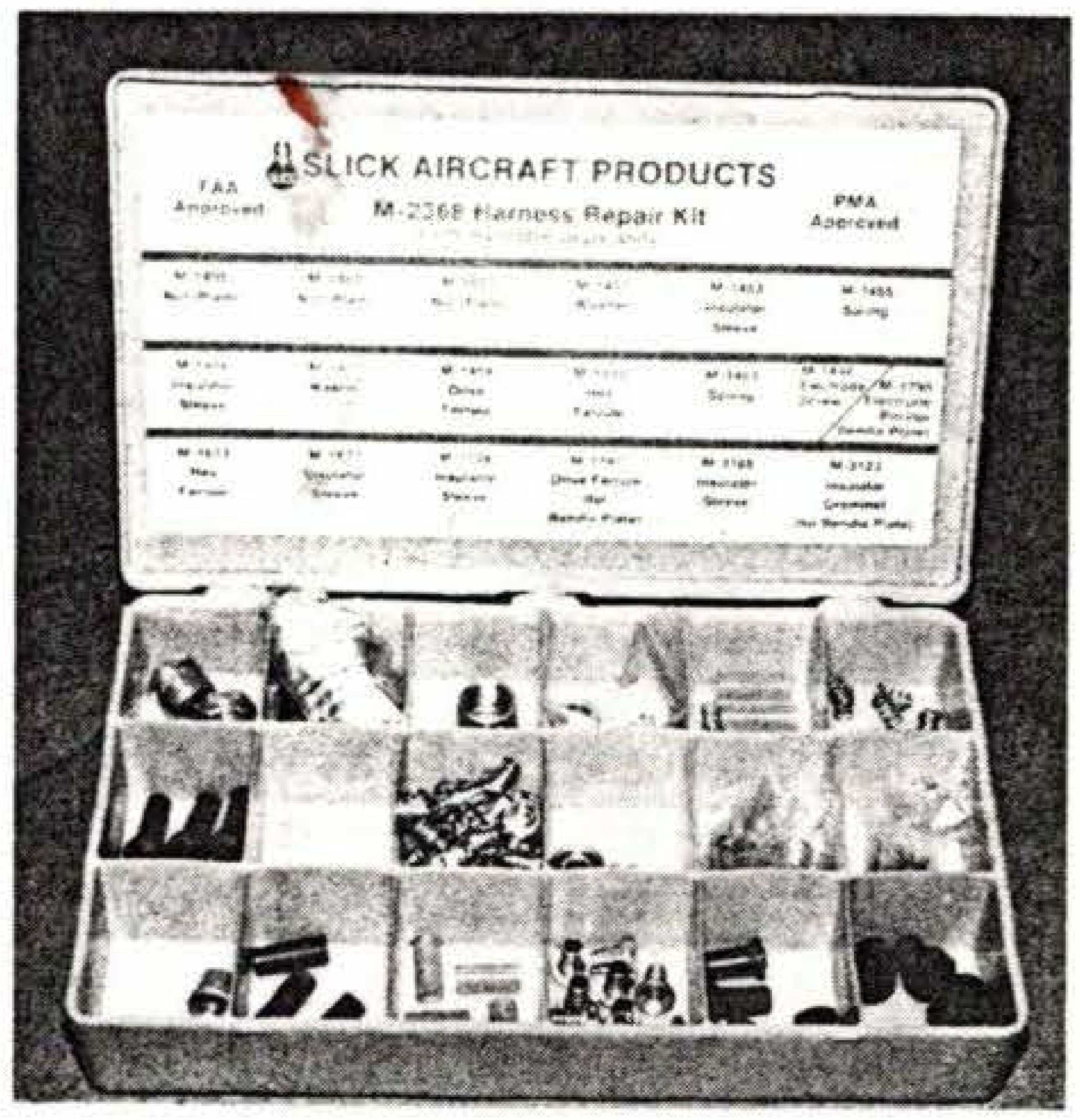
A variety of ills can beset ignition leads, of course. The most common problem is damage to the shielding (or even the cable itself) where it exits the plug, at the cigaret. Over the course of many plug removals, you (and others) may not always have held the ignition lead motionless while unscrewing the terminal hex from the top of each plug. The wire twists and flexes and eventually frays through the shielding. Cables also get damaged through vibration (inadequate clamping), placement too close to hot exhaust manifolds, or routing over sharp edges without proper protection.

There are several ways of dealing with damaged ignition leads. Probably the most expensive way is to replace the affected magneto's ignition harness *in toto*. For a four-cylinder engine this will run you anywhere from $90 to $180, depending on whether you want a half-harness or a full harness. The other solutions are to make up individual replacement leads as necessary, or—if the damage is localized, at one end—using replacement parts to build up a new end for the existing lead. Naturally, this is a good bit less expensive. But you have to know the ins and outs of ignition-wire fabrication (and you may well have to borrow some specialized tools—more of which in a minute).

Supplies

Unison, Electrosystems, and others supply ignition leads either as custom kits or as universal kits, the difference being that in the latter case you have to custom-trim your cable to final length. (Obviously, parts suppliers prefer to carry just the universal-type kits, since it cuts down on stocking requirements.) The single-cable kits come in various lengths—15-in., 18-in., 21-in., etc.—and, at least in the





The Slick M-2368 repair kit contains a wide assortment of ferrules, screws, and hardware items, all of which are available separately. Special tools (above) include T-109 pressing pliers and T-111 vise pin. If your FBO won't let you borrow these, they can be bought for under $50.

case of Electrosystems (formerly Airborne) kits, may already have the spark-plug end made up, in which case you'll need to specify 3/4-20 all-weather ends or the old-style 5/8-24 ends. To make matters even more confusing, the spark plug end may incorporate a 90- or 120-degree elbow, or it may be perfectly straight. It's perfectly legal (so far as we know) to install a 3/4-20 all-weather-ended plug lead on a harness whose other wires end in 5/8-24 terminals (as long as you use the right spark plug—one end takes REM-type plugs and the other takes RHM), but people generally upgrade to all-weather leads all at once, at harness-replacement time. Intermixing styles on a piecemeal basis is likely to make your A&P look at you as if you've got a screw loose.

For this article, I had Chris Wray and Lance Drew of Wiggins Airways (Norwood, MA) show me how to make up both ends of a lead. We used a Slick M-2368 harness repair kit, which includes a variety of hardware (grommets, ferrules, etc.), 50 feet of ignition cable, and all necessary tools. This particular kit is intended for FBO use and is rather expensive, at $261 Linda Lou Inc., Box 30340, Memphis, TN 38130; phone 1-800-824-9912 or 901/365-6611); you will not need everything that's in it. The tools and hardware that you'll need are all available separately (ask your local Slick Aircraft Products dealer to quote your needs), and if you've been nice to your A&P, he may let you borrow the special-purpose tools at no charge. Or nominal charge, anyway.

For this story, we repaired both ends of a cable from an O-320 with Slick magnetos. Keep in mind that the exact engine and magneto model numbers will determine the particular type of hardware you'll need. Bendix, Slick, and Eisemann all differ.

The Spark Plug End

This portion of the job, you should be able to do without much problem on the aircraft (no need to remove the

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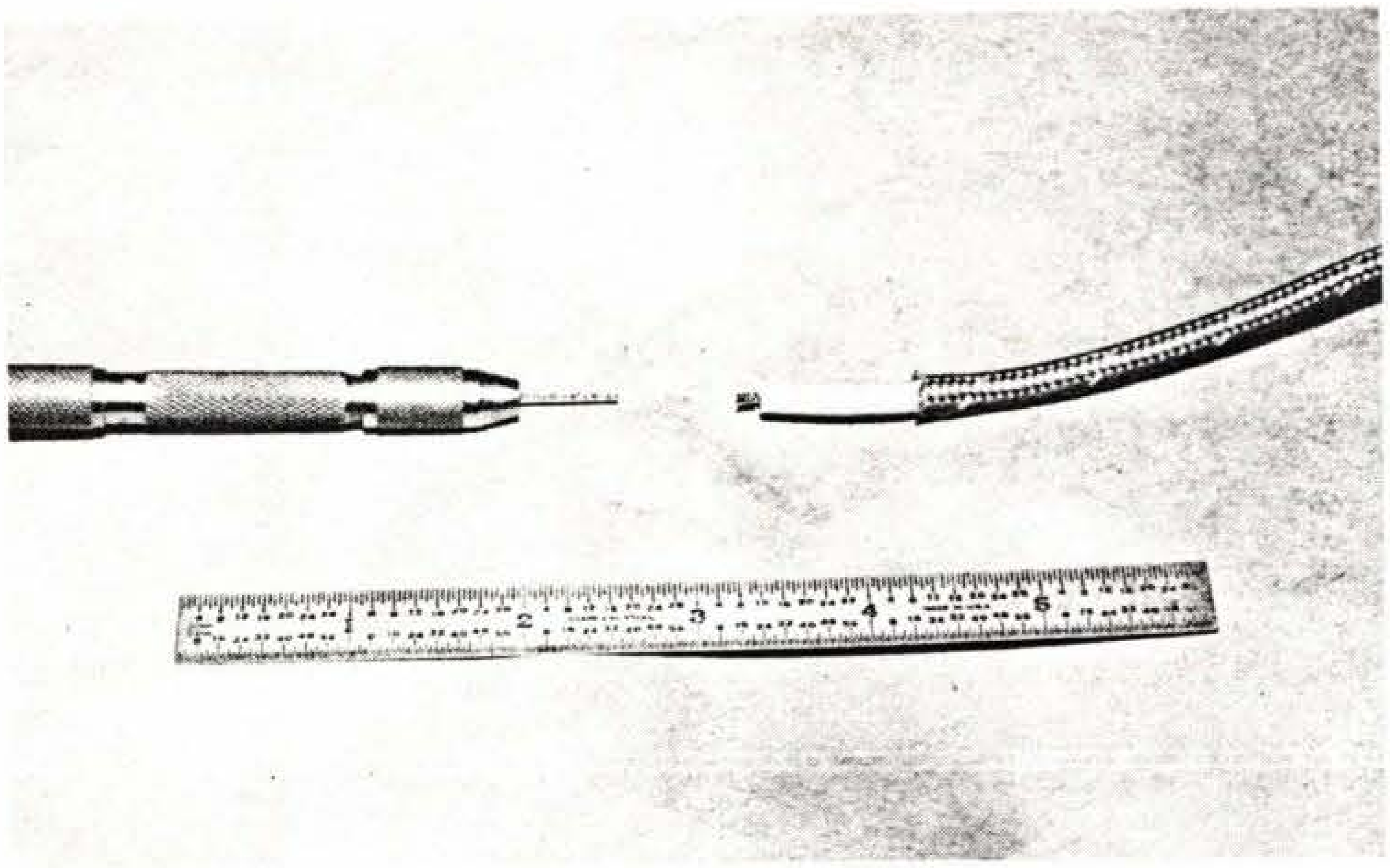
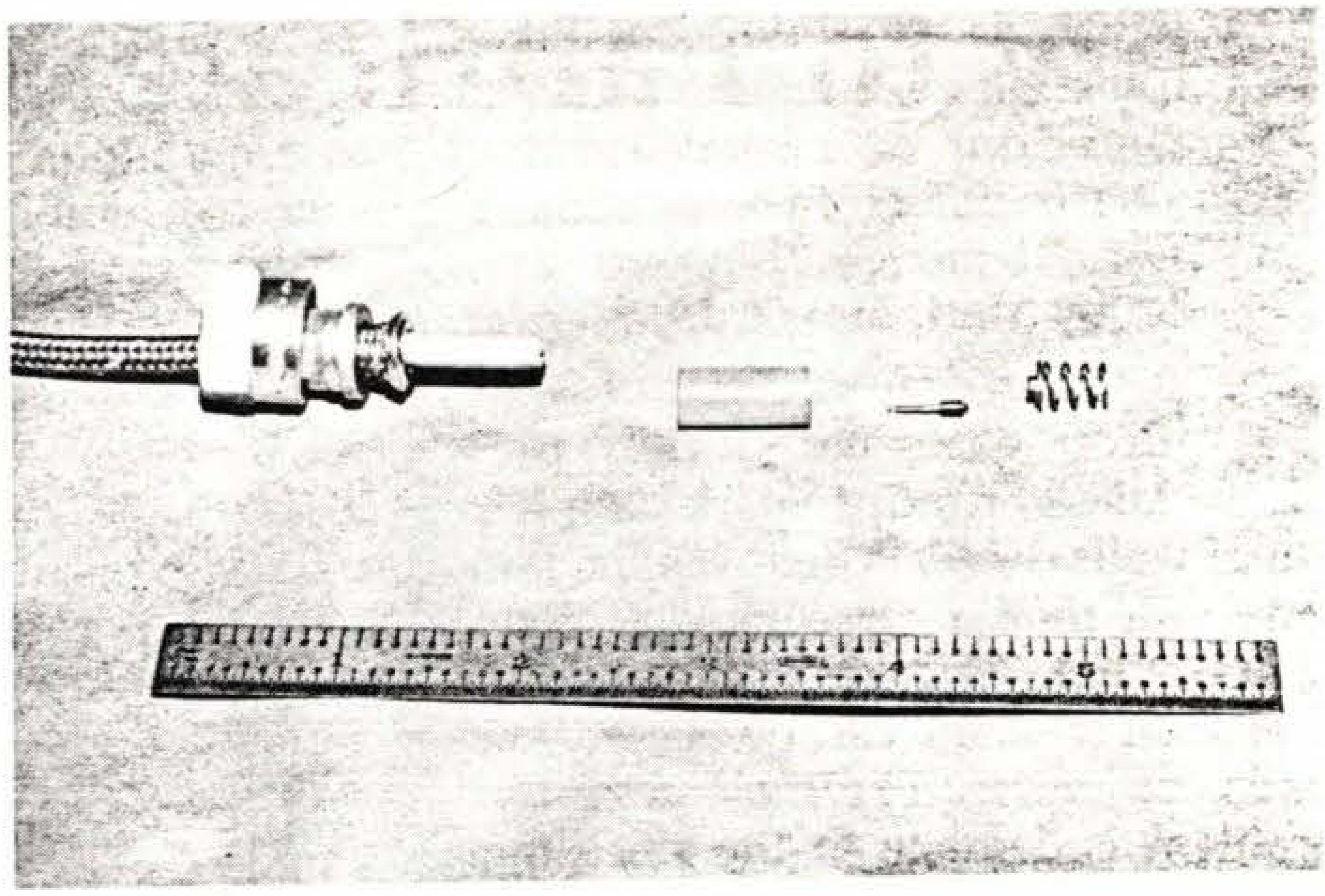


Here, the properly stripped wire is ready to accept an electrode screw (M-1498). Pin vise and No. 72 bit are shown on left.



The spark-plug end ready for pressing. From left: an M-1673 5/8-in. hex nut, an M-1671 hex ferrule, the M-1458 drive ferrule (inserted under shielding, but with lip exposed), M-1677 insulator, M-1498 electrode screw, and M-1455 contact spring.

(Continued from previous page)

harness or cable). The main requirement is a little slack in the cable—you want enough excess so that after trimming a couple inches of cable and fabricating a new end, there's still enough lead to reach the plug (without radical bending). Oftentimes, extra cable will be bundled with wire-ties near the magneto end, or the cable run will be long enough at the cylinder that you can shorten it slightly without creating a problem. Obviously you'll want to check this out carefully. (You'll also want to keep in mind how useful this slack is the next time you replace a cable and cut new material to length.)

Remember that sharp bends and strained routing are no good. If shortening the cable will cause this, invest in a new run of cable.

Step One: Cut the damaged portion of cable off at a point where the shielding is in good shape. Don't just clip it with a pair of dikes, however, because the shielding will get smashed and deformed. Instead, first cut the shielding with a Slick T-126 shield stripper (or with a sharp knife) using a rolling motion. Then use dikes to cut through the silicone insulation and inner conductor. We marked the shielding back 15/16-in. for the 5/8-24 standard cable end. This length of shielding will now be cut off, but this time using great care not to damage the silicone insulation. The T-112 stripping tool is designed to prevent insulation damage; you just slip it between the shielding and insulation up to a point about 1/4-in. past where you marked the shielding. (This is easier if you pull the shielding back a little along the length of the cable. Be careful, though, not to allow the shielding to fold under, and don't insert the stripping tool any further than is necessary to protect the insulation.) Cut the shielding with a sharp knife, again using a rolling motion. Pull the piece of shielding off.

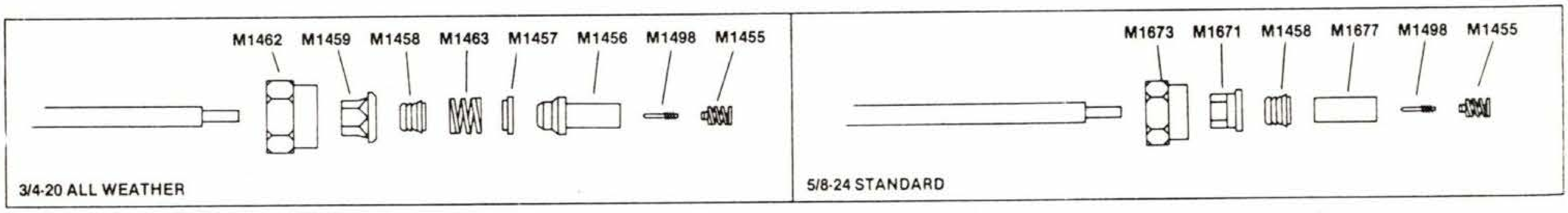
Next, use your sharp knife to cut 1/8-in. of silicone insulation off the end of the wire. *Don't cut the inner conductor,* and be careful not to pull on the insulation as you're trying to cut it. Remove the insulation by *gently* pulling it and turning it clockwise. There should now be three conductor coils showing. Clean away any insulation that may remain in the center of the coil using a knife and #72 drill in a Slick T-111 pin vise.

The next step is to put an M-1498 electrode (actually called an *electrode screw* in Slick parlance) in the end of the conductor. The easiest way to do this is to clamp the threaded end of the electrode screw into a T-111 pin vise and turn the electrode CCW (counter-clockwise) on the conductor end until the threaded portion is flush with the insulation. Pull the pin vise tool off clockwise so the electrode screw doesn't back out.

Murphy will get you now if you don't remember to *slip the spark plug nut (M-1673 for 5/8-24 ends) and a hex ferrule (M-1671) onto the cable* so that the smallest diameter of the nut and the largest diameter of the ferrule are closest to the end of the cable. (If you're making up a 3/4-20 all-weather lead, you'll use an M-1462 nut and an M-1459 ferrule.)

Now bend and rotate the silicone insulation so as to flare the edge of the shielding. (If you have the stripping tool, a nice trick here is to use it to help flare the shielding.) Don't let the sharp shielding cut into the insulation, however. Slip an M-1458 drive ferrule between the shielding and insulation so that the shielding rides up to within 1/16-in. of the ferrule's lip (the M-1458's flange or lip). Then

Below: Ignition harness hardware (for the spark plug end).



slip the hex ferrule (M-1671) down over the shielding so as to sandwich the shielding between the two ferrules. Push the two ferrules together tightly, being sure that the shielding doesn't ride up under the flange or double over. Press the two ferrules together using a Slick T-109 pressing tool or equivalent. (This is a plier-like device that is specially designed to mash the two ferrules together when you grip the handles.)

Next, clean the exposed insulator with solvent and avoid touching it any more at this point. (One longtime A&P that I know uses choke and carb cleaner for this.) Slide the insulation sleeve (M-1677, otherwise known as a cigaret) over the silicone insulation, and—using the T-115 spring assembly tool—screw the M-1455 spring (otherwise known as a contact spring) clockwise onto the electrode screw until the end of the screw is flush with the first big coil on the spring. If you back the spring off at this point, you may inadvertently unscrew the electrode screw (in which case, just reassemble it as before). I mention this because this may happen if you ever have to replace a burned or corroded spring (*LPM*, November '87). Use some solvent to clean off the fresh cigaret assembly.

You now have a complete, new spark plug end—at a cost of $7.96 in ferrules, insulators, and springs. (Every item mentioned above is available separately from Slick, including the special tools, the most expensive of which is the T-109 presser at $31.) You've saved yourself the cost of a whole new lead, and maybe a whole new harness. (Remember, if an A&P sees a frayed lead, he may order a new half-harness for that mag, rather than take the time to make up a new end.)

The Magneto End

Rather than repeating each step again, let's just look at the differences. Most of the steps in fabricating a magneto-contact end are identical to

Above: The T-115 spring assembly tool can be used to punch the old drive ferrule out of the harness cap.

those for the spark plug end, except part numbers. All you're doing is installing an electrode screw (M-1498, same as before) and some ferrules on the end of the properly stripped cable.

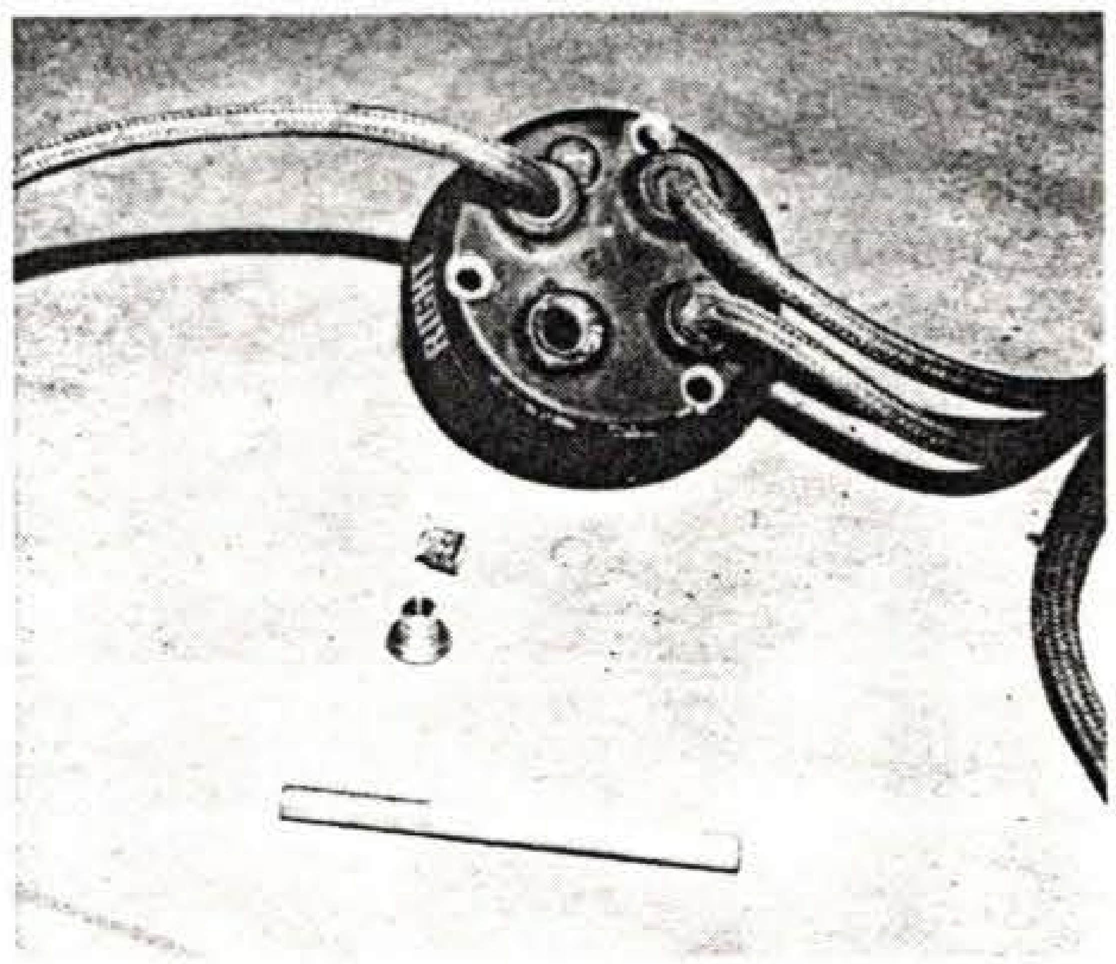
In order to gain access to the magneto end and get enough free cable to work with, you may need to clip a few wire-ties (and you'll need to pull the distributor cap off the mag). Once again we'll talk about how to make up a new end on an old wire. Obviously, the same techniques apply if you're making up an entirely new lead from fresh wire.

Start by cutting the bad cable as close to the distributor cap as possible, using the two-step cutting procedure described earlier to prevent damage to the shielding. *[If you're going to fix more than one lead, work with one lead at a time, or else carefully label the wires as to location so you don't end up accidentally changing the firing order of your plugs.—Ed.]* On the cap, fold the shielding in towards the center of the cable and use the spring assembly tool or a punch and hammer to knock the slug of cable out from the cap. (See photo.)

Mark the shielding for stripping as follows: For Slick 400 and 600 series mags, mark the wire one inch from

Below: Ignition harness hardware (for the magneto end).

Below: The ferrule, punched free and ready to be reused. (The small bit of shielding can be discarded.)



the end; for 4200 and 6200 series mags, make the mark 3/4-in. from the end; and for Bendix mags, mark it 9/16-in. from the end. Once more, removal of the short section of shielding will be easier if you insert a T-112 stripping tool under the shielding before cutting with a sharp knife (being careful to avoid pricking the silicone insulation). The 3/4-in. or 1-in. piece of shielding will then pull off cleanly with the T-112 tool.

Next, cut 1/8-in. of insulation off the tip of the cable as before, being careful not to pull on (or deform) the coiled conductor when removing the silicone. The coiled conductor should protrude approximately three coils, and the interior of the coils should be clear of debris.

The terminal for a 400 or 600 series Slick harness cap is different from that of a more modern 4200 or 6200 lead in that the older 400 and 600 series Slicks have threaded output towers, which means it's necessary to slip an M-1406 nut onto the wire (with the threaded portion facing the end of the wire, obviously) along with an M-1451 washer. (The beveled side of the washer faces the end of the wire.) If you have a 4200 or 6200 mag, you'll skip the nut and washer.

Pull the cable's free end through

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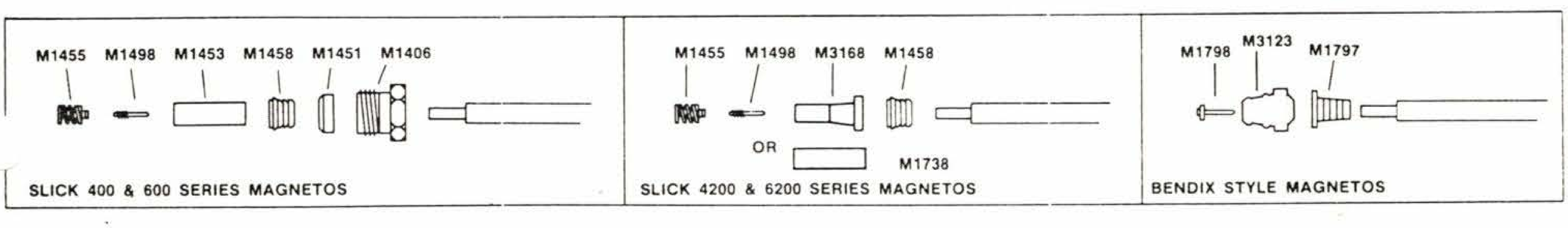
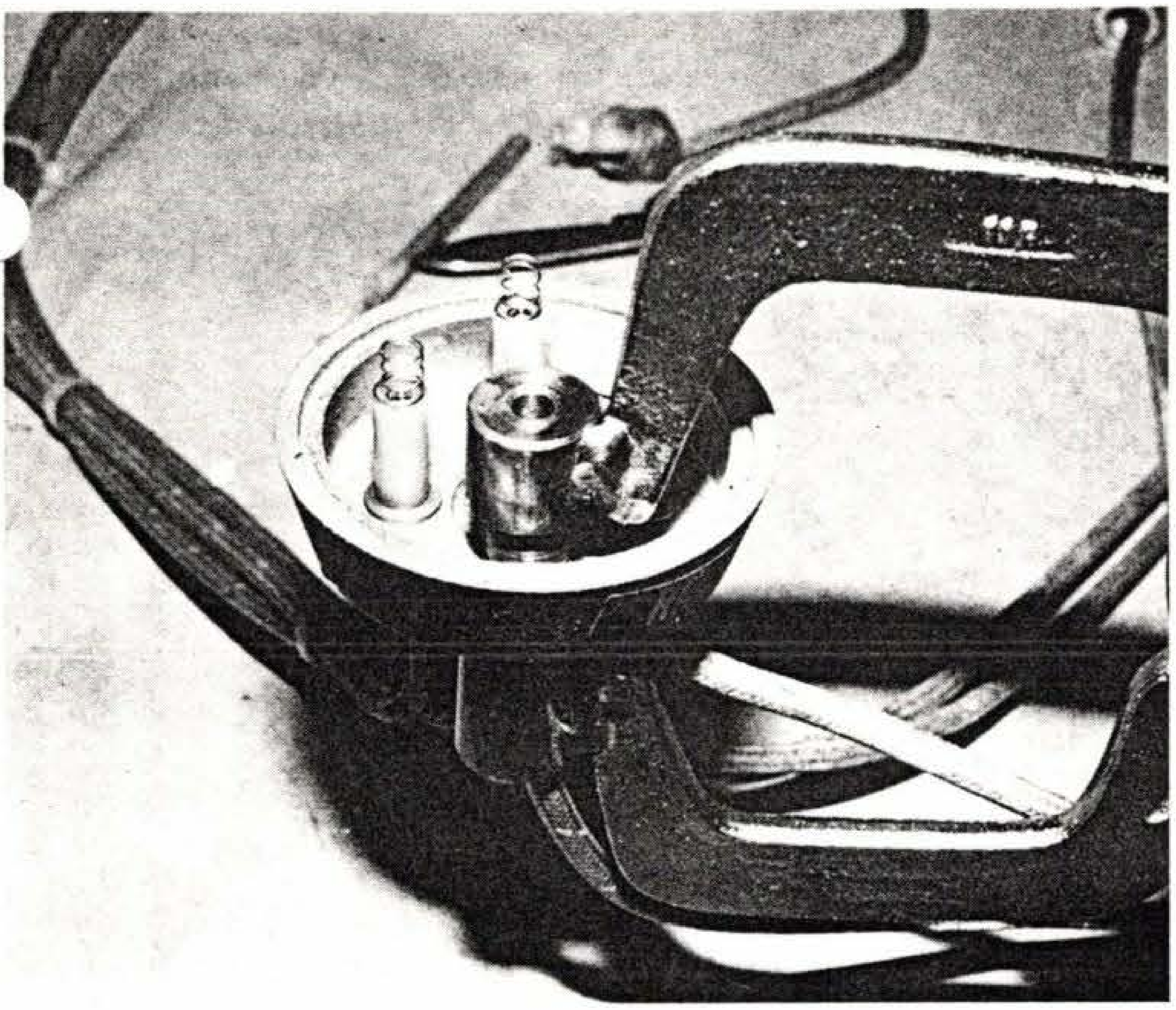
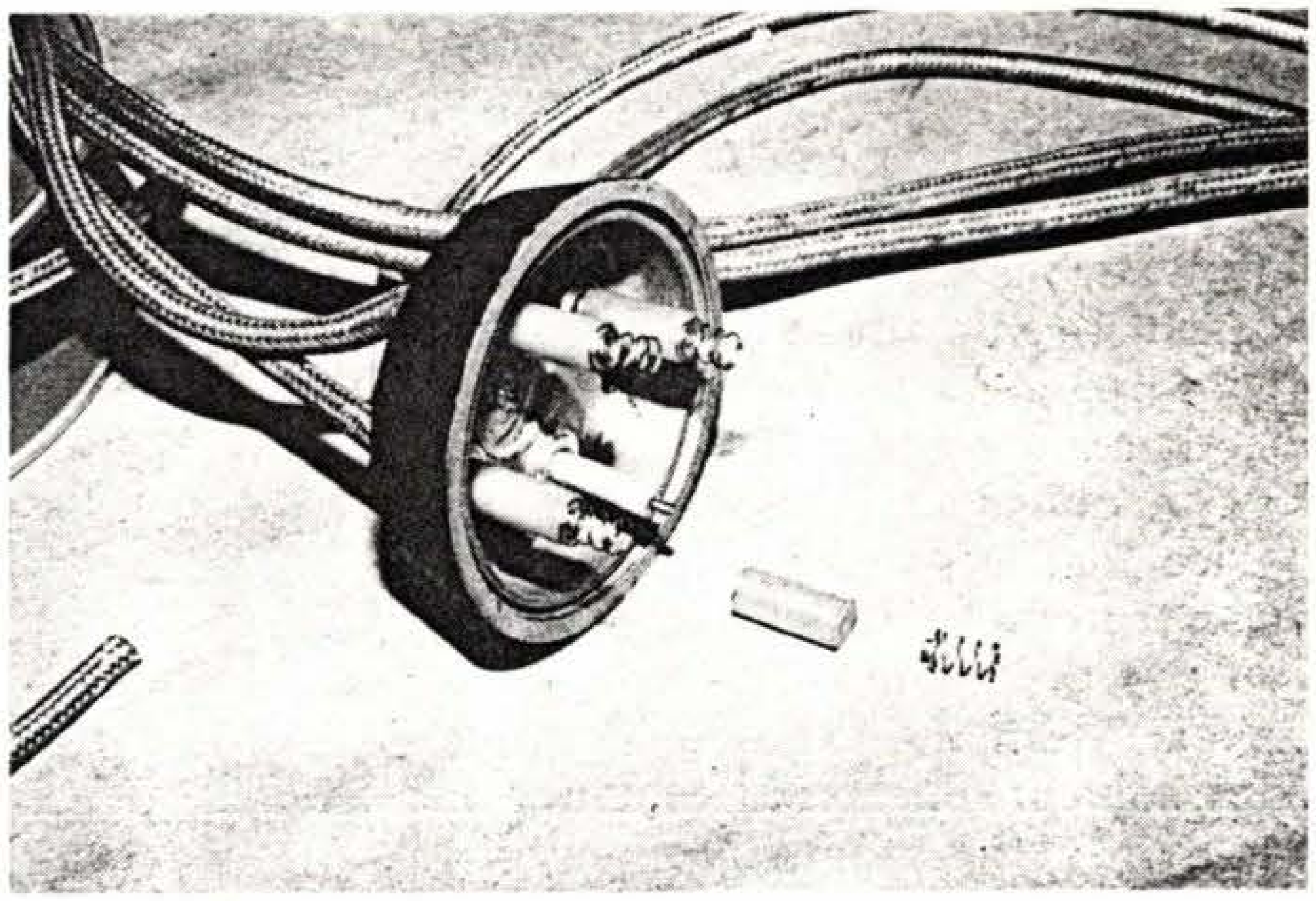




The T-109 pressing pliers are used not only at the spark plug end but also (as here) at the magneto cap end. Its purpose is to ensure good contact of the shielding to the M-1458 drive ferrule and an electrical ground (such as the mag end cap).



After pressing the cap and ferrule together, the proper insulator and contact spring can then be installed.

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ne harness cap a few inches. Flare the shielding (by flexing and rotating the end of the wire), being careful not to let the metal braid cuit into the soft silicone insulation. Then slide an M-1458 drive ferrule onto the end of the wire, with the lipped end of the ferrule facing the magneto end of the wire. Push the ferrule into the flared portion of shielding, stopping 1/16-in. short of the shielding touching the ferrule lip. (This was described further above, in the section on making a new cigaret end.) Don't let the shielding actually overlap the lip. Press the ferrule into the magneto harness cap using the T-109 pressing tool. (Bendix mags only: You want an M-1797 ferrule instead of the M-1458, and you want a T-109C pressing tool.)

For Slick applications, screw an M-1498 electrode (or "electrode screw") into the three coils at the end of the conductor wire as described in the previous section. For Bendix mags, push an M-1798 electrode pin into the wire instead. (In either case, use a T-11 pin vise and turn CCW while inserting.)

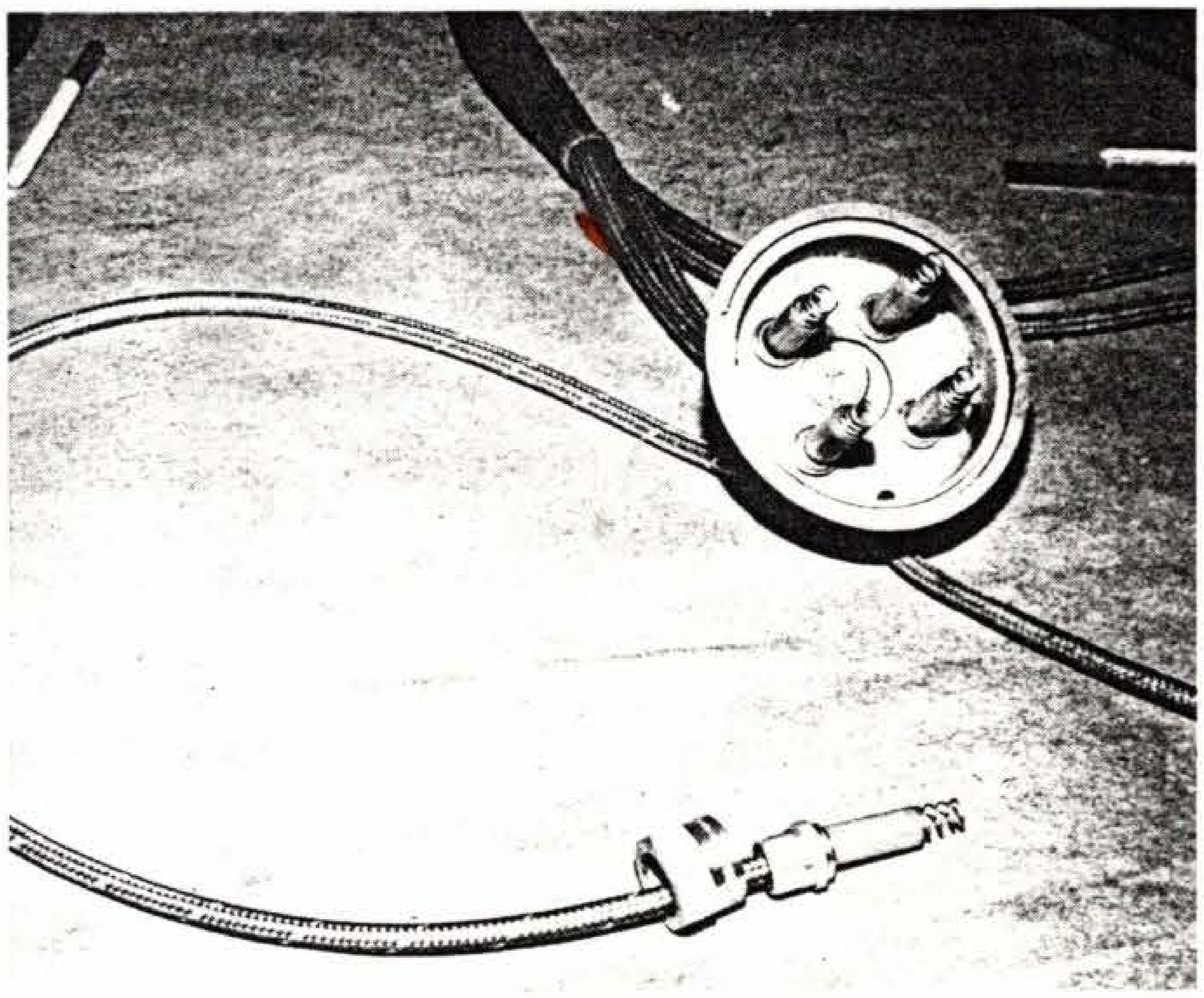
Next comes the insulator (analogous to the cigaret at the other end of the wire). For 400 and 600 series Slicks, use a white M-1453 insulator sleeve (one inch long); for 4200 series mags, use an M-1738 (white, 3/4-in.); for 6200 Slicks, use a brown M-3168 (3/4-in.); and for Bendix mags, use a brown M-3123 insulator. Regardless of P/N, clean the insulator with solvent and avoid touching it afterwards.

Bendix mag wires need no further work at this point, since Bendix spring contacts are integral to the magneto. With Slicks, however, the spring contacts are integral to the wires in the harness cap. So to finish the job, get an M-1455 cigaret spring and (using the T-115 spring assembly tool) turn the spring clockwise onto the electrode screw threads in the end of the wire assembly. (Turn three full turns or until the end of the screw is flush with the first large coil of the spring.)

At this point, you're done.

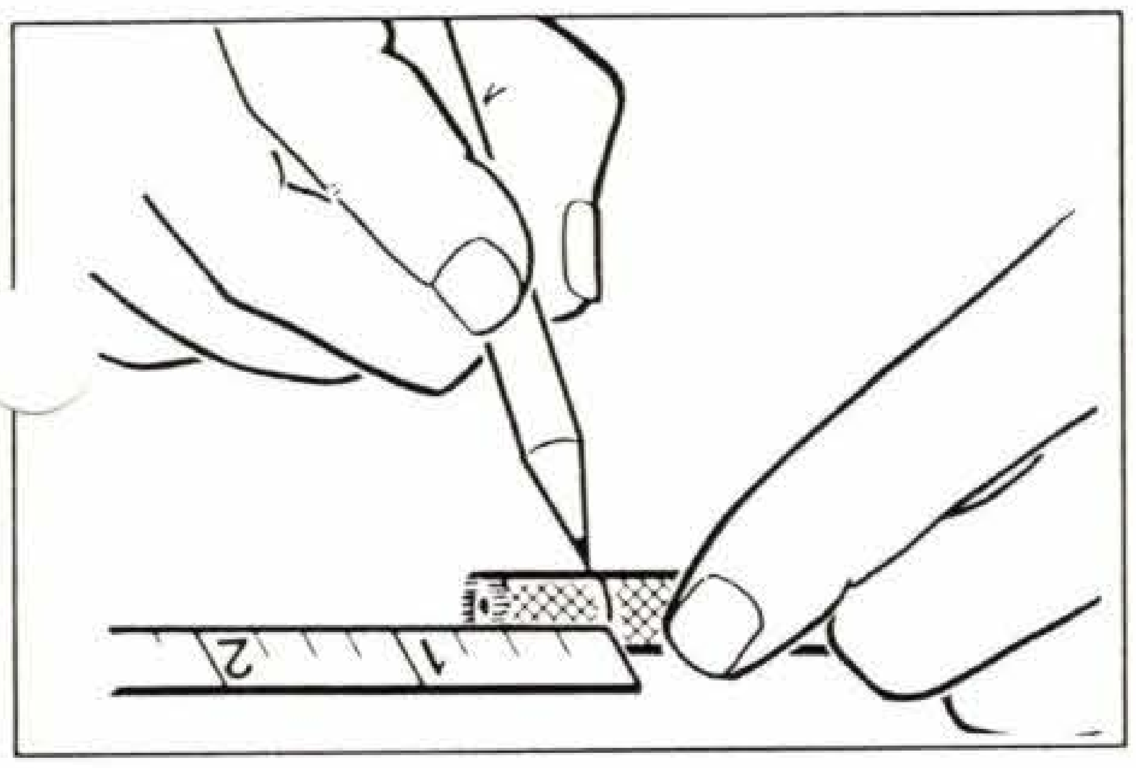
Parting Comments

Virtually everything described in this article requires a signoff by an A&P mechanic, so don't just dig in and expect that somebody will sign it all off after you're done. Contact your A&P *before* you start. And don't hesitate to call on him at any point if you're unsure about something. An A&P is going to want to be absolutely sure that you know what you're doing, because he really can't (for example) inspect a drive-ferrule/harness-cap connection after it's been press-fit together to see that you've joined the parts together with the shielding properly positioned.

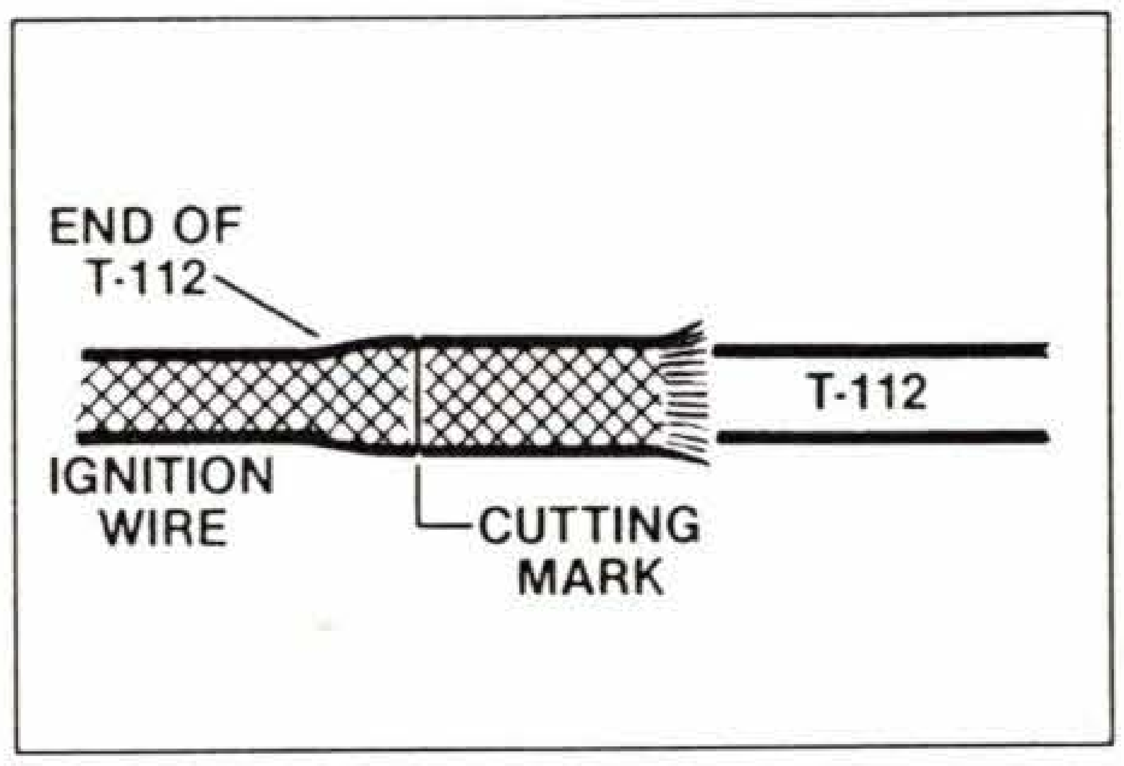


The finished lead, with new spark plug termination and magneto cap end.

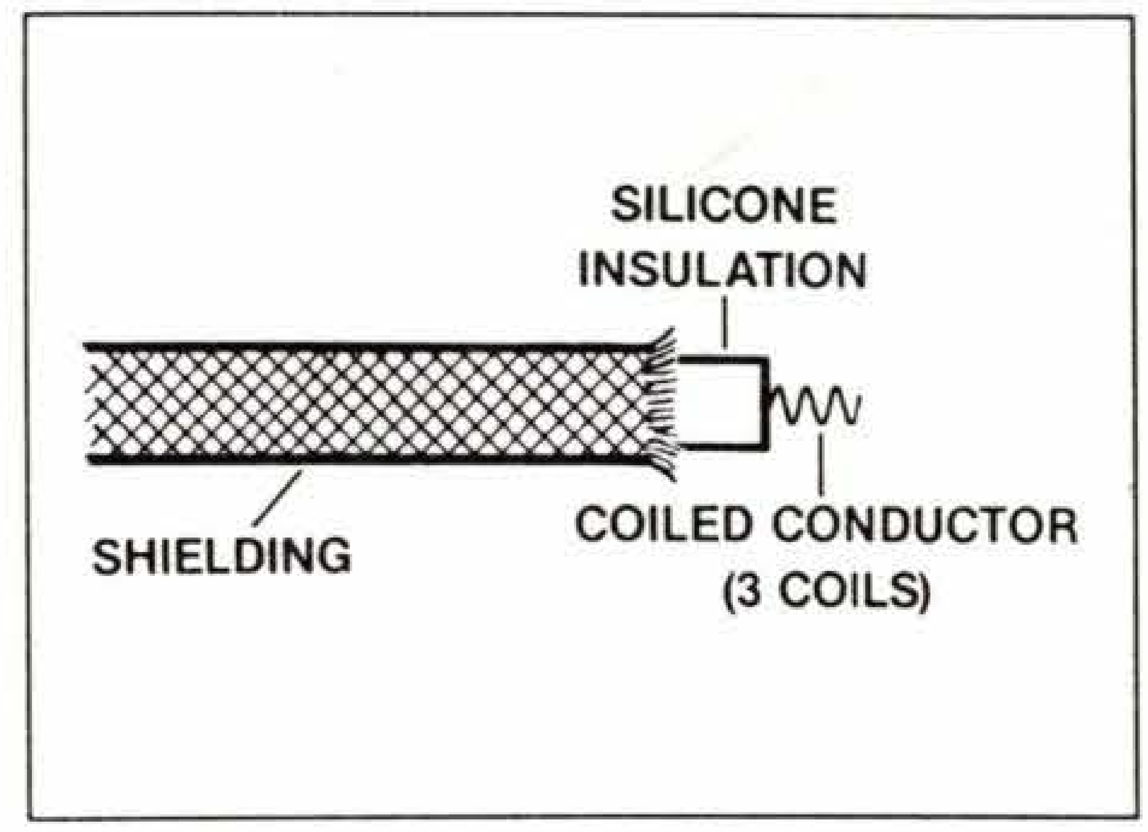
The astute reader has probably noticed that most of the special-purpose tools listed above are of the "nice, but not essential" variety and can be dispensed with, with the possible exception of the T-109 pressing tool (which is actually nothing more than a set of Vise-Grips with special ends that fit the ferrules). I have been told by knowledgeable sources that if you



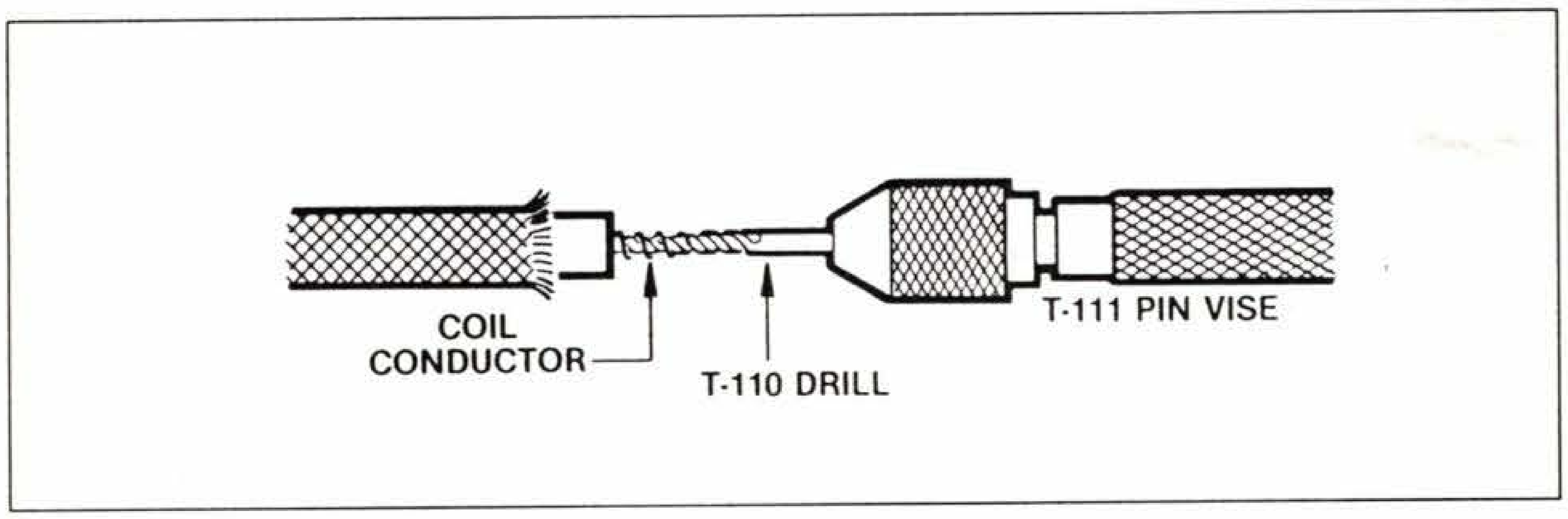
Mark the shielding 15/16-in. from the end (to make a 5/8-24 standard spark plug termination).



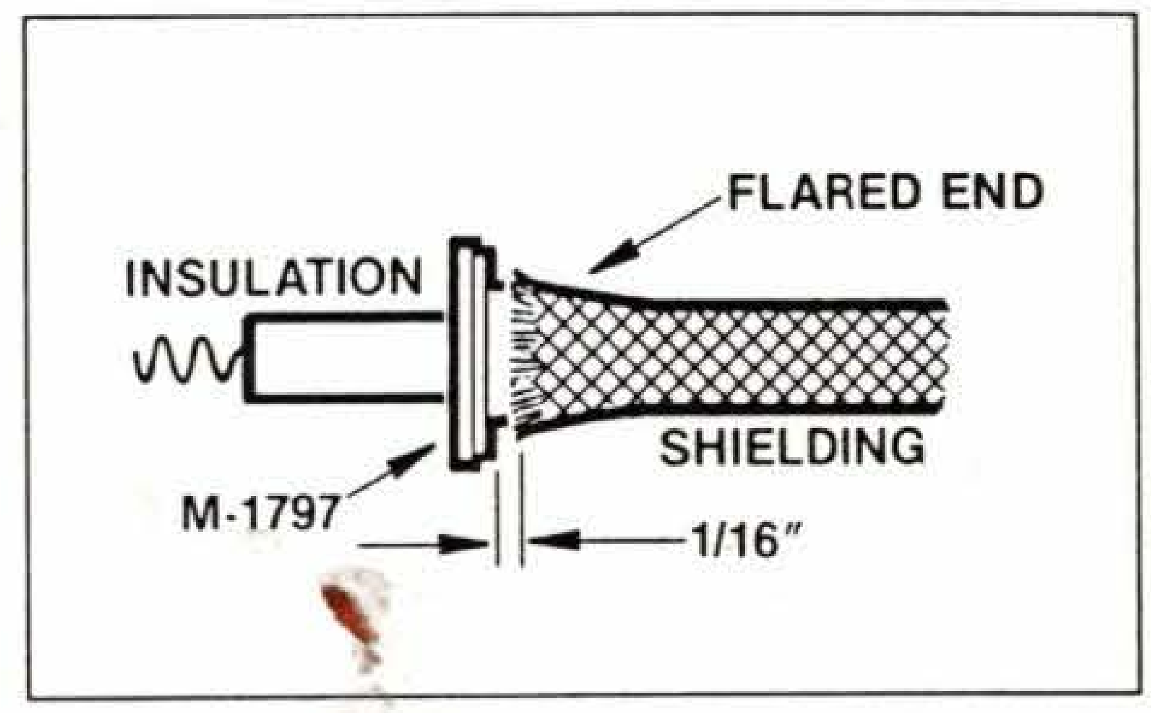
Insert the T-112 stripping tool under the shielding to beyond the mark. Then cut along the mark with a sharp knife.



Carefully remove insulation to expose three coils of wire. Do not stretch the coils.



Using a No. 72 drill and the T-111 pin vise, remove silicone insulation from the center of the coiled conductor to a depth of 1/2-inch. (Turn the drill CCW when withdrawing.)



When inserting the flared end of the M-1458 or M-1797 drive ferrule into the shielding, stop 1/16-in. short of the ferrule's lip as shown here.

find yourself stuck in the Mongolian outback, two sets of channel-lock pliers will work just as well. You'd be well-advised to have a steady hand, however, when trying this; and it'd be a good idea to protect the ferrules and cap from the bite of the channel locks (by applying duct or masking tape to the jaws of the pliers, for example).

Slick has some excellent publications that deal with the operations described here. In particular, I recommend the *Ignition Lead Assembly & Installation Manual* (L-1178-A) and the *Harness Maintenance Manual* (L-1177-A). Both are available together for $5.00 from Slick Aircraft Products, Unison Industries, Inc., 530 Blackhawk Park Ave., Rockford, IL 61108 (phone 815/965-7704). While you're at it, request Forms L-1039-A (mag end) and L-1040 (plug end); these brochures describe all of the foregoing steps in somewhat abbreviated fashion. If you have a Bendix dual mag (D-2000 or D-3000 series), Slick offers Form L-1042-A telling how to do all the above for a dual harness cap.

For information on Electrosystems harness kits, write P.O. Box 273, Ft. Deposit, AL 36032 (or phone 205/227-8306).

Mark Howards is a CAD/CAM specialist and Warrior owner based in the Boston area. We told him to do this story.

Crusty Contact Commentary

A couple years ago, I was preparing to depart Columbia County Airport (Hudson, New York) in the 310 when, on pre-takeoff runup, I fell victim to a bad rpm drop that just wouldn't go away. No amount of mixture leaning or static running would clear the problem up, so I taxied back in, leaving the right engine running on the bad mag. It was rough as a cob. After shutting down, finding the cold jug was a simple matter of touching a plastic pen to each exhaust riser. The offender, it turned out, was cylinder number six.

Richmor Aviation's Sal Alessi and I spent the next 20 minutes removing, cleaning, and bomb-testing (i.e., pressure-testing) both spark plugs from the No. 6 jug and safety-wiring the cowl doors for a brief open-cowl ground run. But alas, even with clean plugs, the 200 to 300-rpm mag drop was still there.

We were all set to remove the No. 6 injector nozzle when Sal got the idea to pull the harness cap off the right mag (a Bendix 200-series) to see what evil might lurk therein. When the cap came off, the problem became evident: One wire's contact pin was burned and black. "Look here," Sal said, holding the cap in my face. "See the way the pin is cocked over?" It had been driven into the wire at a 30-degree angle. "Somebody didn't put the pin in straight."

I never did find out who installed the pin wrong (it wasn't me, I swear). No matter. In seconds, Sal was back out on the ramp with a fresh M-1798 contact pin in one hand and T-111 pin vise in the other. After ensuring that we had enough good wire to work with, Sal cored the old pin out and had a new one pressed in faster than you can say "shower of sparks."

Minutes later, I started the right engine again and happily gave Sal the thumbs-up on selecting single-mag operation. We had indeed found the problem.

For 90 cents in parts, I was on my way.—*Kas Thomas*

Engine & Prop Dynamic Balancing

by John Loughmiller

In 1961, my father bought me a 1954 four-door Chevrolet with power-glide transmission as a graduation gift. It took all his savings, and I, being a dumbass teenager, didn't appreciate it and wondered why he didn't buy me a Corvette instead.

The car had an annoying vibration that was present only at certain speeds, and I remember taking it down to the neighborhood gas station for a wheel-balancing episode. The local petrol-pumper (who was a bit unbalanced himself, incidentally) straightaway decided that a session with the static balancer would cure all the ills present in the fire-breathing six-banger. Out came the proverbial bubble-type tire balancer, and quick as a flash the appropriate lead weights were affixed to each wheel, the tires reinstalled, and the fee collected.

One mile down the road it became apparent that the problem was still there—maybe even worse. Back to the station, and—this time—out came the "spin the tire on the vehicle" dynamic balancer. Different weights installed at different places thereupon cured the problem as if by magic.

The Chadwick Solution

The foregoing object lesson was forgotten until recently, when I decided (after much procrastination) to do something about the foot massage I was getting from the rudder pedals on my Piper Lance at various (make that almost all) rpm ranges.

Enter the Chadwick vibration analysis machine and its keeper, Mike Jones of Aircraft Specialists, Inc., of Louisville, Kentucky (phone 502/241-0971). Now, if you haven't met Mike, let me say he's not your average wrench. Along with being an IA-rated A&P, Mike's a pilot and honest-to-goodness graduate aeronautical engineer (Purdue, 1976). He holds court along with partner Eric Taylor and the two of them can usually beat a problem into submission with generous applications of both practical and theoretical knowledge. Killing the vibrations present in my Lance presents a good case history for purposes of looking at how the Chadwick machine works and how it is used. Suffice to say, if the Chadwick were a violin and Mike were playing it at the Kennedy Center, both would get rave reviews.

We all know that anything that moves generates numerous byproducts to its movement: heat (from friction), turbulence in the medium through which it passes (wake turbulence), and so on. If a device has a rotational component, vibration is sure to be present as the mass rotates, since no mass is ever truly, perfectly balanced. The vibration occurs as the mass deflects (by Newton's third law) the object away from its rest position. The object, in the case of an airplane, may be a prop, crankshaft, etc.

Now imagine for a moment that the propeller on your airplane is a solid disk. And since we're just imagining, create in your mind a lump of extra material on the disk out near the edge. If we were to spin the disk, whatever the disk was attached to would try to follow the point of unbalance as it went along its path. The result would be vibration.

In a direct-drive aircraft engine, the prop, prop spinner, and crankshaft can be considered to be one unit as far as vibrations are concerned. Any unbalances present in the crankshaft will affect the prop, and vice-versa. If you were to instrument the engine with a device (call it a transducer) capable of measuring relative movement of the crankcase with respect to a fixed surface (the Earth), you could measure and observe the degree of vibration intensity. Further, if you knew where the prop blades should be at any given time in the rotational cycle, you could observe what effect the vibration has on the prop and predict wfere the apparent "lump of material" must be located on the rotating

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Contributing Editor John Loughmiller is a Certified Fright Instructor (Double-Eye variety) perpetrating unspeakable horrors on students in the Louisville, KY area.

Chadwick Balancing Tricks

Although the principal use for the Chadwick machine (properly called the Vibrex System) is to balance props and rotorblades, it can be a useful diagnostic tool for other engine ills as well.

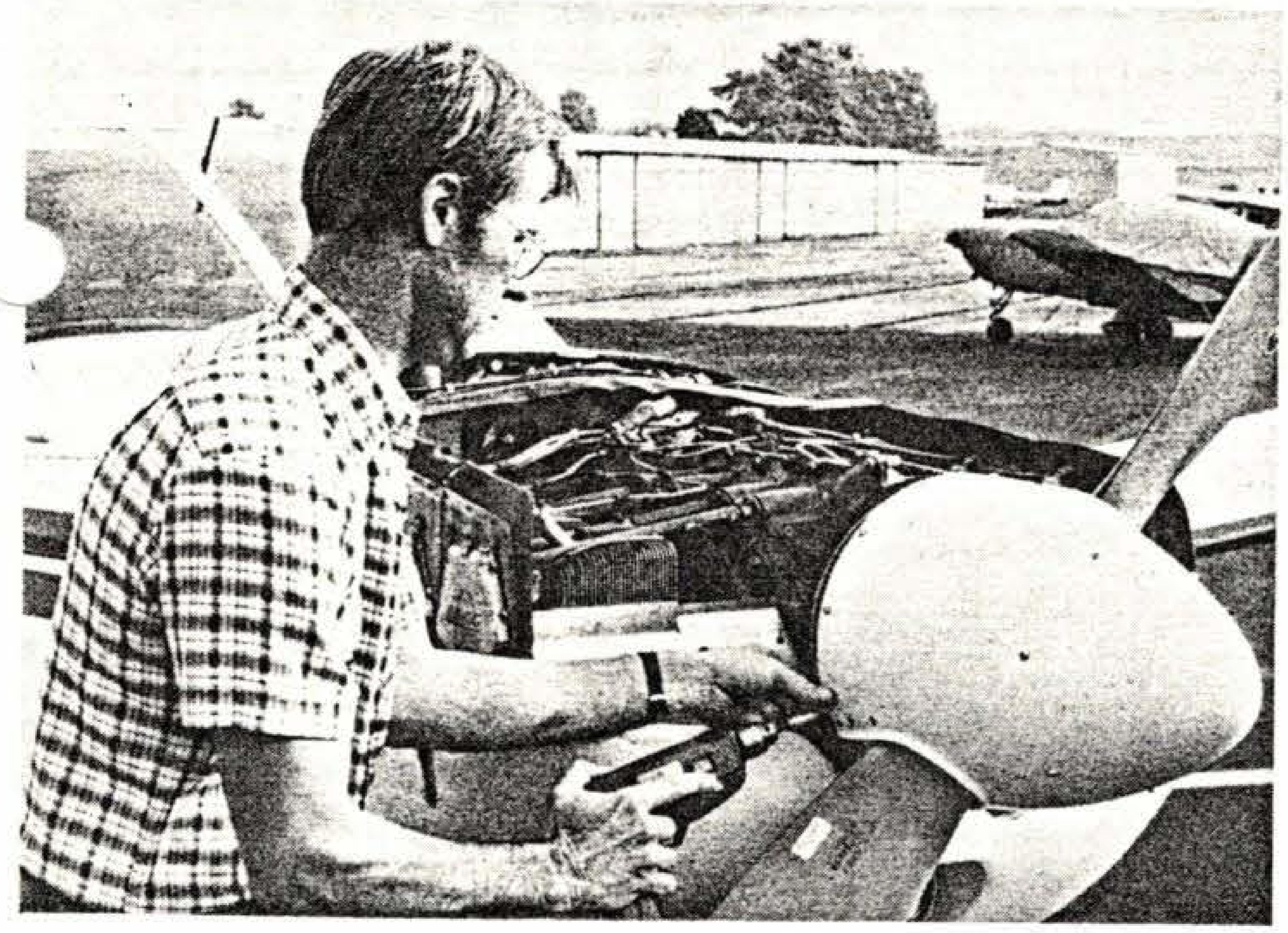
The Chadwick balancer has the ability to look at inputs from two accelerometers at one time, which means the engine (or rotor system, in the case of a helicopter) can be examined in detail to determine precisely where, along the rotational axis itself, the greatest vibration is occurring. By instrumenting the fore and aft ends of the engine instead of just one end, and examining the amplitudes of the deflections, a good guess can be made as to the location of the problem.

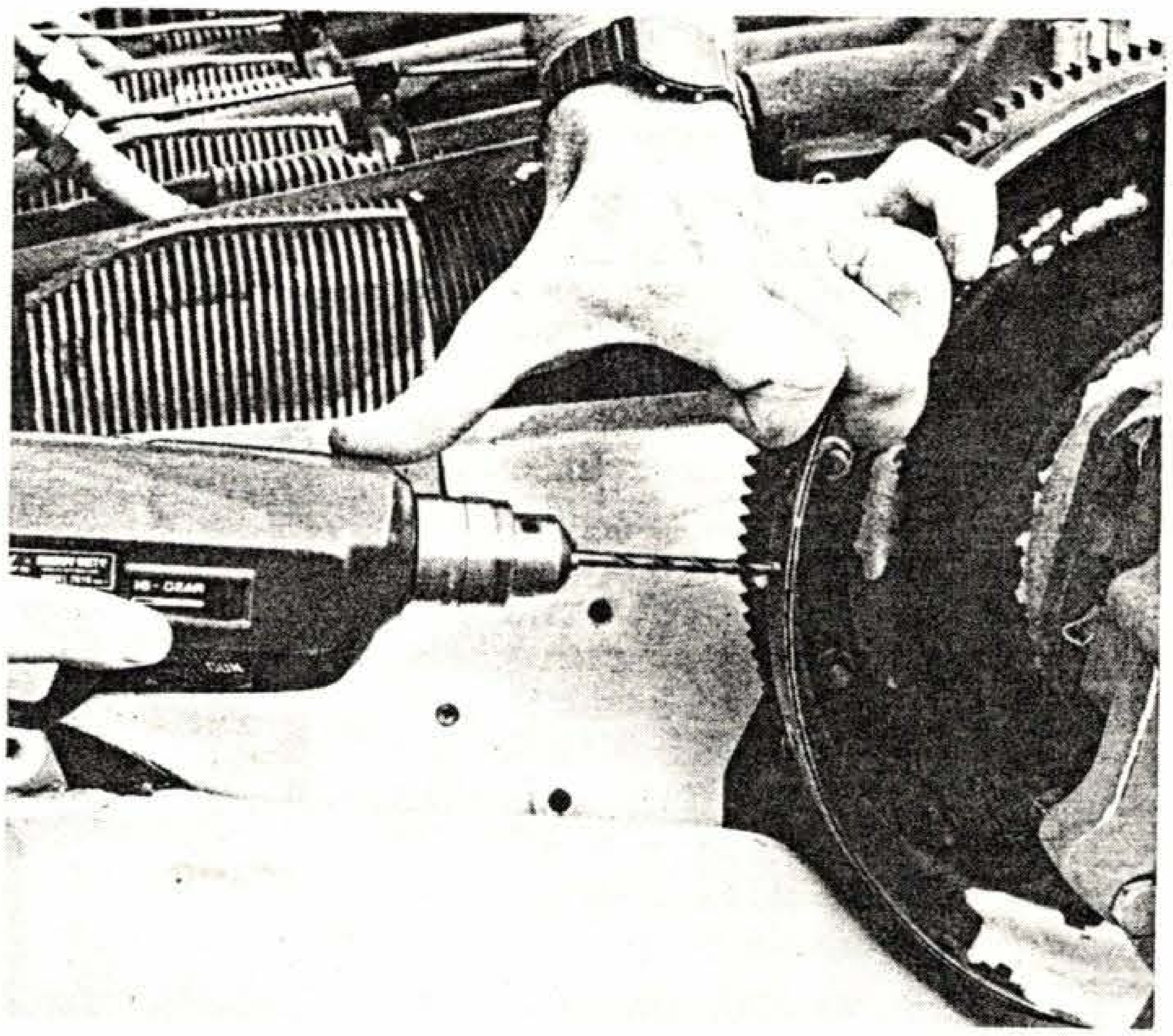
Another trick is to run the engine at one rpm and examine the half-rate product of that rpm. In the accompanying article, 2,200 rpm was the chosen prop/crankshaft speed. At that speed, the operator would look at the 1,100-rpm component, because it is there that camshaft and rod/piston problems would show up. Because four-cycle engines operate on the suck/squeeze/bang/blow principle (with half a rev for each portion of the cycle), there are components moving around during the overall process that aren't contributing to the power output at that particular time. These components can be monitored for vibration by looking at the half-rate frequency (1,100 rpm).

As stated in the main article, you can't balance out rod, piston, or camshaft problems with prop spinner weights, but you can certainly check further once you know about the problem. For example, if the half-rate product were high and other symptoms were present (high oil usage or low compression), you might want to pull cylinders and investigate further.

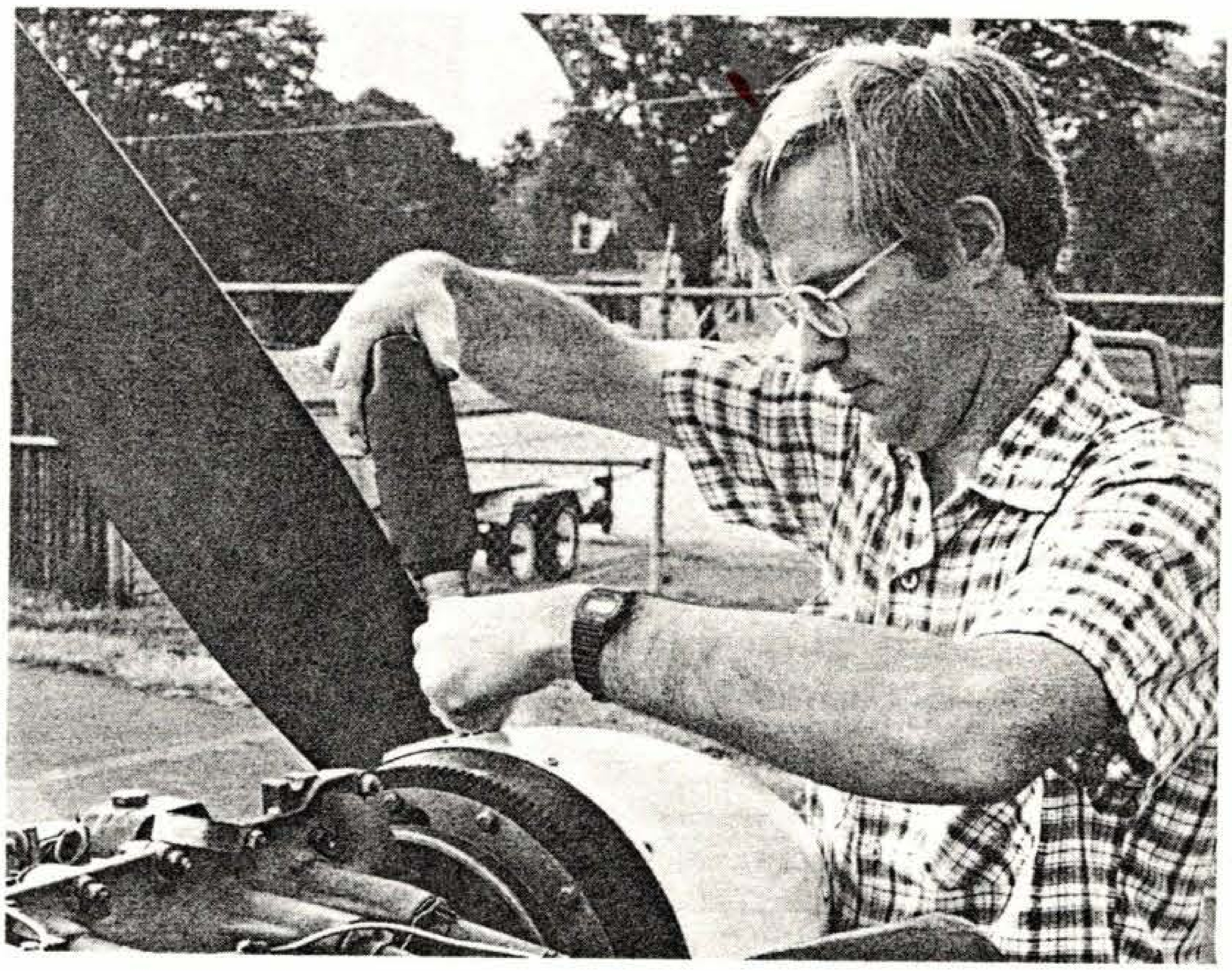
Half-rate products can be more serious than full-rate (first order) vibrations in many cases, since they can indicate hidden problems that only a top or major overhaul can cure. A spalled camshaft or a bad accessory drive gear is best discovered on the ground, if possible.

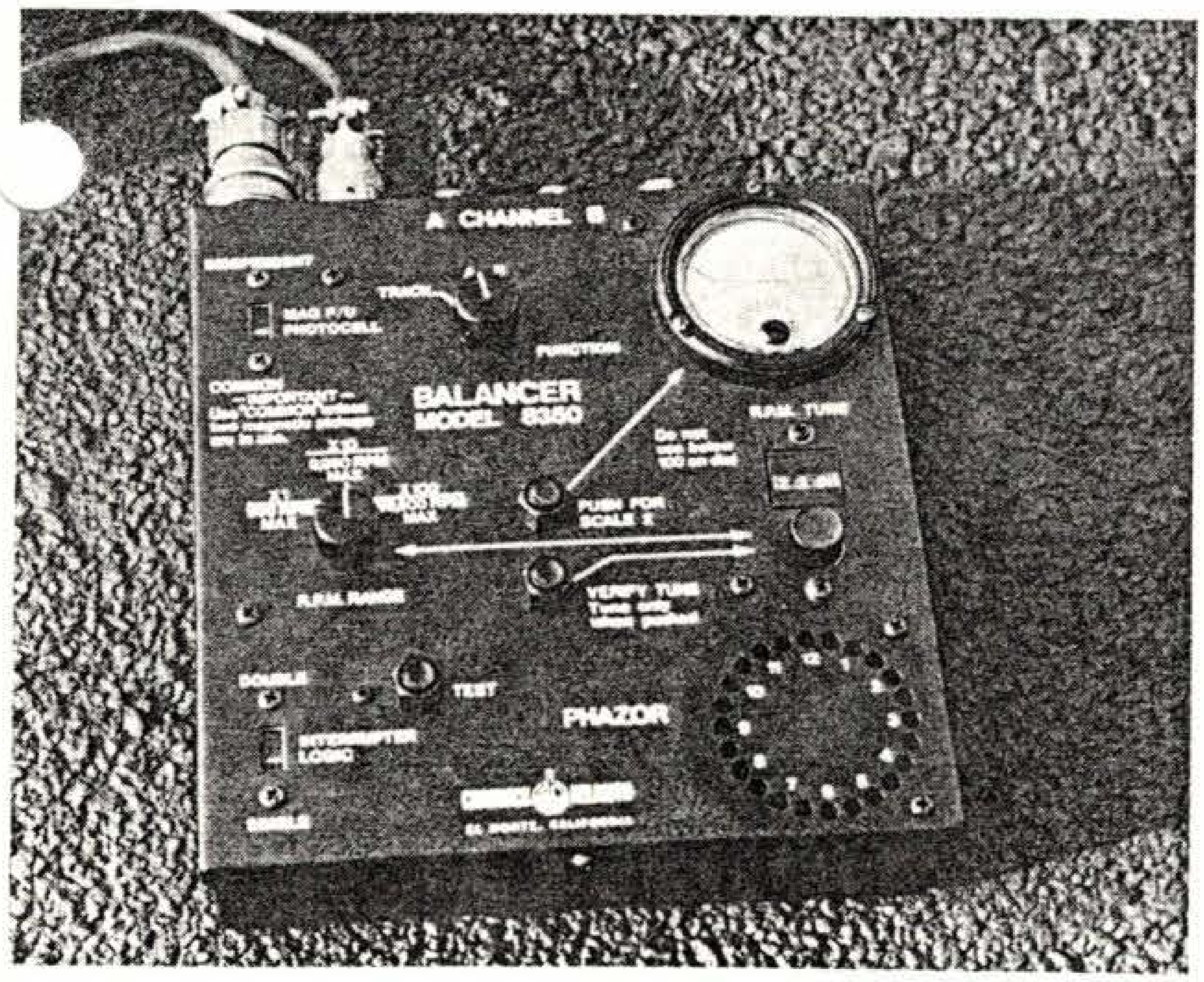
As they say, it's always better to be in the hangar wishing you were flying than the other way around.—*JL*

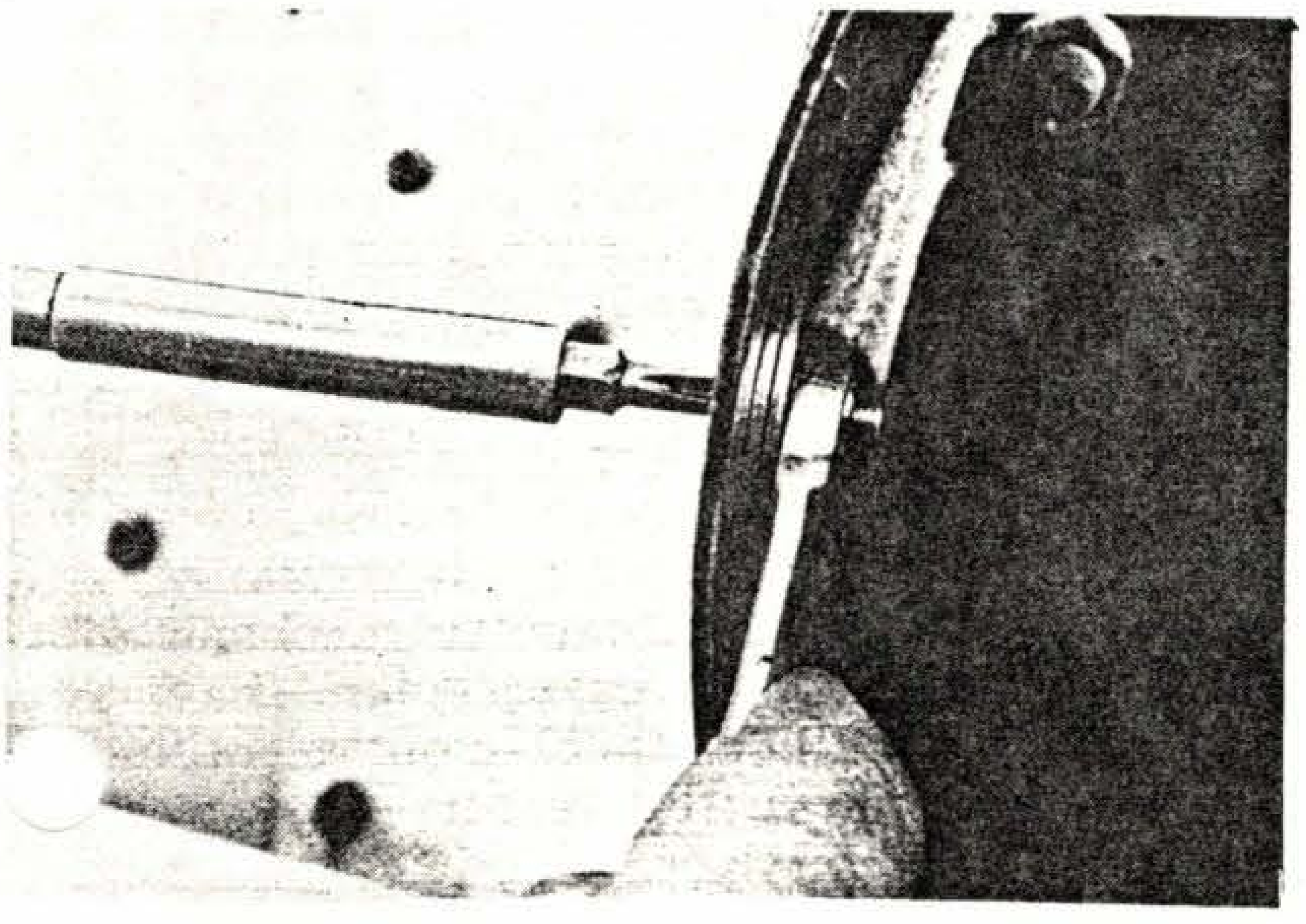


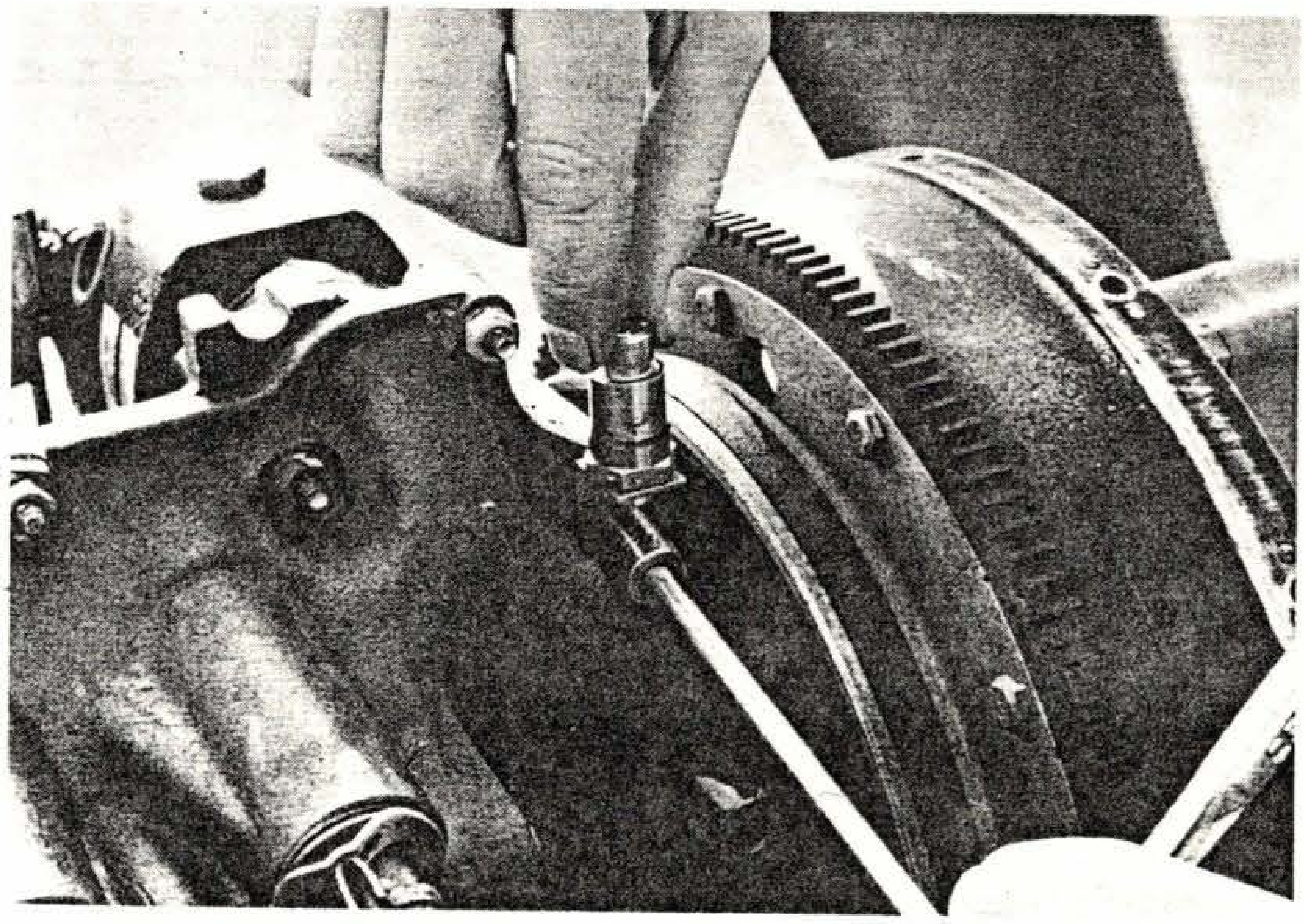


Clockwise from upper left: Mike Jones removes the spinner from the author's Piper Lance . . . . Balance weights are added to the prop spinner aft bulkhead. . . . . The strobe interrupter must be counterbalanced by its own balance weight 180 degrees opposite . . . . A tiny accelerometer mounted vertically at the front of the crankcase provides 'g' measurements . . . . Weights are attached by dedicated machine screws. Several engine runs may be needed (with successive spinner removals) to get the balance just right. . . . The Vibrex balance box gives readouts not only of vibration (in inches per second) but axial location.









PHOTOS BY JOHN LOUGHMILLER

disk that the prop has become. If you did all of these things, you'd have a Chadwick machine, and very possibly a patent infringement case to consider.

Hookup

After removing the top cowling and prop spinner from the Lance, Mike attached an acceleration-sensing transducer (or accelerometer) to the engine as far forward as he could. (He could have put it as far to the rear as possible, and the transducer would still work, but the measurements might be 180 degrees out of phase with the real world, so he stayed up front to keep it simple. Also, he could have installed the device horizontally or at an angle, but he prefers instead to mount it on top, again to keep it simple.)

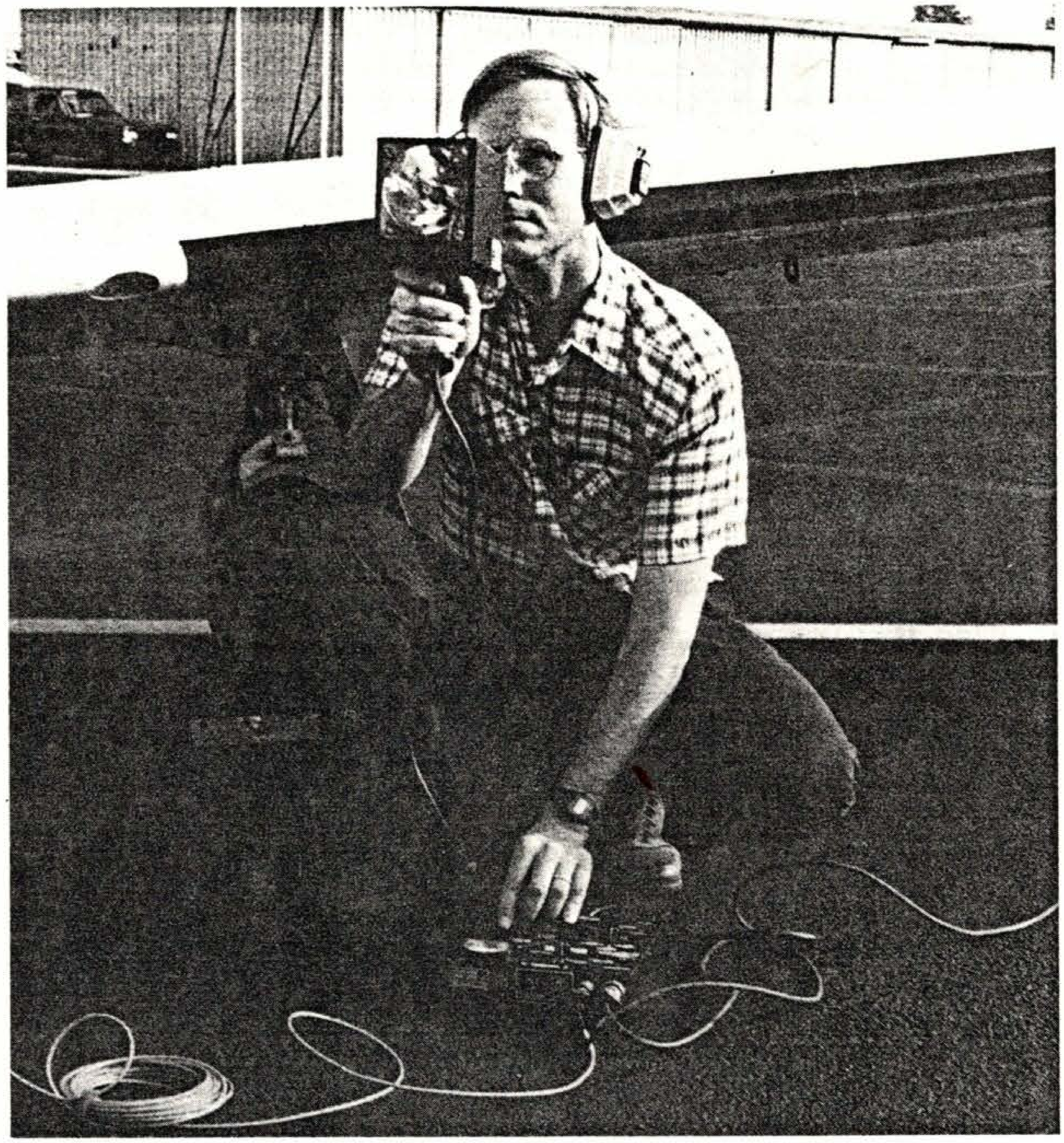
After Ty-Wrapping the leads to an engine mount, the first test run was made. The engine was started and run up to 2,200 rpm—or at least what was 2,200 according to my tach. (One of the bonuses of this procedure is that you find out the accuracy of your tachometer. Mine reads 70 rpm low, which explains why I always get better-than-book airspeeds.) In any event, the Chadwick machine said I had four times more vibration than I should have had. A deflection of zero inches is perfect; 0.1-in. is acceptable. I had 0.45-in. of deflection.

As Mike pointed the strobe light at the spinning prop, he was able to determine where he had to add weights in order to damper out the unbalanced condition. After shutdown, a countersunk hole was drilled into the aft prop spinner bulkhead. Without referring to anything, Mike fished three weights out of a container and screwed them in place inside the bulkhead lip. We fired up again.

At 2,200 rpm, the vibration had dropped to 0.08-in. deflection. We shut down, reinstalled the prop spinner—and the vibration went back up again when we again ran at 2,200.

Once more, Mike removed the spinner, and again—seemingly with no forethought—he found a couple of weights, attached them quickly to another point on the same spinner bulkhead, and reinstalled the spinner. The magic number was now 0.05-in. deflection, and Mike said it was time to quit.

The net result: the 800-rpm vibration that had always been evident was now diminished to the point of barely being noticeable. My cruise vibrations are for all practical purposes gone.



Mike Jones takes yet another reading from the Chadwick-Helmuth Vibrex box prior to making final adjustments to the author's plane. Up to half a dozen iterations may be necessary.

The engine seems much "happier" now, and my feet, after an hour in the air, no longer feel like they've been attacked by some deviate with a vibrating marital aid.

No Panacea

According to Mike Jones, the Chadwick balancer is no vibration panacea. Although it will disclose problems caused by camshaft unbalance, unbalanced pistons, and accessory case maladies, there's no simple way to balance out such problems short of splitting the case or pulling cylinders. Mike also cautions that if the crankshaft is out of balance at its rear end (where the dynamic counterweights are in many engines), it's unlikely that adding weights to the prop spinner will help. This is because a phase reversal occurs at the center of the engine. Mike warns that lots of other things besides crankshaft and prop imbalance can cause vibrations—things like chafing hoses, rattling exhaust pipes, tight control cables, missing cowl fasteners, and so forth.

For me, though, the Chadwick exercise was $130 well spent. The reduction in vibration can't help but extend the life of the engine, and prolonging engine life (postponing overhaul) is money in the pocket any way you look at it.

By the way, I asked Mike if he just got lucky when he hit the correct combination of weights for my problem on the first try, and he said no. He says he does it so often that he just knows what it takes. For the less knowledgeable, there is a table that recommends weights to be used for various unbalance conditions.

If you have vibrations you don't want to live with anymore, find yourself a competent mechanic with a Chadwick balancer and have your vibrations checked out scientifically. I believe the results will speak for themselves.

Dynamic Balancing: A Comanche Owner's Experience

I had always assumed that a heavy, rumbling vibration was natural in big-bore four-bangers. And certainly, the engine and airframe vibration I felt when flying my Piper Comanche 180 (with Lycoming O-360-A1A) *was* heavy compared to my experience in a Comanche 250 and a Bonanza. It seemed only reasonable that the six-cylinder engines would be smoother, having power strokes 120 degrees apart instead of 180, and a greater mass to dampen vibrational accelerations.

It now appears my original assumption was not correct. During a recent "owner-assisted annual" at Sky Acres Airport near Poughkeepsie, NY, I observed Jack Schneider performing dynamic propeller/engine balancing on several aircraft. This balancing is done with the engine running and uses a vibration acceleration transducer (or accelerometer) bolted to the engine, plus a synchronous strobe light, with a computer-generated readout of vibration intensity and the actual crankshaft rpm at several different engine speeds, with a recording of the imbalance's magnitude and apparent location. The imbalance is then corrected by adding weights to the light side of the prop spinner bulkhead.

Jack told me that he had heard nothing but rave reviews from aircraft owners who had had the balancing act performed. On hearing this, I made an appointment to have my Comanche balanced. How could I resist?

As a precaution, I first stripped the many years' accumulation of paint off the prop. (The layers were especially thick at the tips—exactly where weight would make the most difference.) Then I carefully and evenly repainted the prop.

Jack Schneider is a perfectionist when performing the balancing procedure, constantly and repeatedly checking and rechecking as he goes along. (The procedure is inherently labor-intensive, with many starts and stops.) Finally my engine ended up with counterbalance weights consisting of one extra-long bolt through the starter ring gear and several washers under it.

The bottom line? Performance changed in two very distinct and immediately noticeable ways. First, the airframe rumble and vibration are completely gone. (I mentioned to Jack later that I will miss the foot massage I used to get from the floorboards in flight.) Secondly, during ground acceleration and climbout, the engine power is distinctly smoother and feels stronger than ever, more reminiscent of the 250 Comanche or Bonanza, in fact, than of the O-360 Comanche—and would you believe I actually have a greater rate of climb than before at my usual climbout airspeed?

It's not unreasonable to expect longterm benefits from a good balancing job. Certainly pilot fatigue will be lessened—I've already experienced this. Reduced vibration can only mean less wear and tear on instruments, avionics, engine mounts, and a lot of sheet metal and rivets and fittings, too (not to mention the engine and propeller themselves).

Jack Schneider gets $175 for singles and $325 for twins for his balancing act, and in my book, it's the best bargain around. If you're on the East Coast, phone Sky Acres at 914/677-9353 for more information, or call the Chadwick-Helmuth Co. at 818/575-6161 for the name of an FBO near you.

—Don Jensen

Whence Cometh Chadwick-Helmuth?

El Monte, California is a quiet, stucco-fortified Mextown bastion of low tech, a beer-bottle's throw away from sunny Pasadena. Flanked by Rose Hills to the south and Mount Wilson to the north, and thus falling squat in the middle of L.A.'s noxious San Gabriel Valley, El Monte is remarkable only for the fact that it has a tower-controlled, County-operated, asphalt-covered airport with 5,000-ft. runway and instrument approaches. It's also home to Chadwick-Helmuth Co., manufacturer of the famed Vibrex Balancer.

For all the years I've operated out of EMT, I never knew Chadwick-Helmuth existed until 1984, which—not coincidentally—is when Dad bought the helicopter. You can't own a helicopter and not know about Chadwick, I don't care where you live.

All major helicopter manufacturers, without exception, recommend the Chadwick balancing system, and every slingwing operator who's not daft or incompetent knows the phone number of his local Chadwick rep by heart. Next time you see a helicopter on the ramp, take a close look at the rotor mast. Chances are at least 50-50 you'll see Strobex interrupter vanes and a magnetic pickup permanently attached to the ship.

Chadwick-Helmuth is no fly-by-night operation; the 80-employee company has been around since 1954. Originally a manufacturer of environmental test equipment, C-H got its first big break when nearby Hughes Aircraft asked them to figure out a way to balance and track the rotor system of a new helicopter. A strobe system was developed to aid tracking, and when used in conjunction with tiny accelerometers, the Strobex system, it was discovered, could be used to visualize two-dimensionally the balance requirements of a whirling rotor. Thus the Vibrex system was born.

Over the years, the Vibrex balancer has been adapted to propeller system diagnostics for everything from Gulfstream I turboprops to Beech Bonanza and smaller airplanes. The Chadwick-Helmuth exhibit has long been a familiar sight at the HAA and NBAA shows; now their prop-balancing demo is a crowd favorite at Oshkosh each year.

What claims does the company make for its equipment? "Our experience over the years shows that 80 percent of the propellers we balance result in a *substantial* improvement," one company spokesman explains. What's more, he says, "About one propeller in five is out of balance enough to induce some kind of damage—leaky oil coolers, cracked or broken exhaust manifolds, sheet metal and cowling cracks, turbo mounts broken, or wire harness damage."

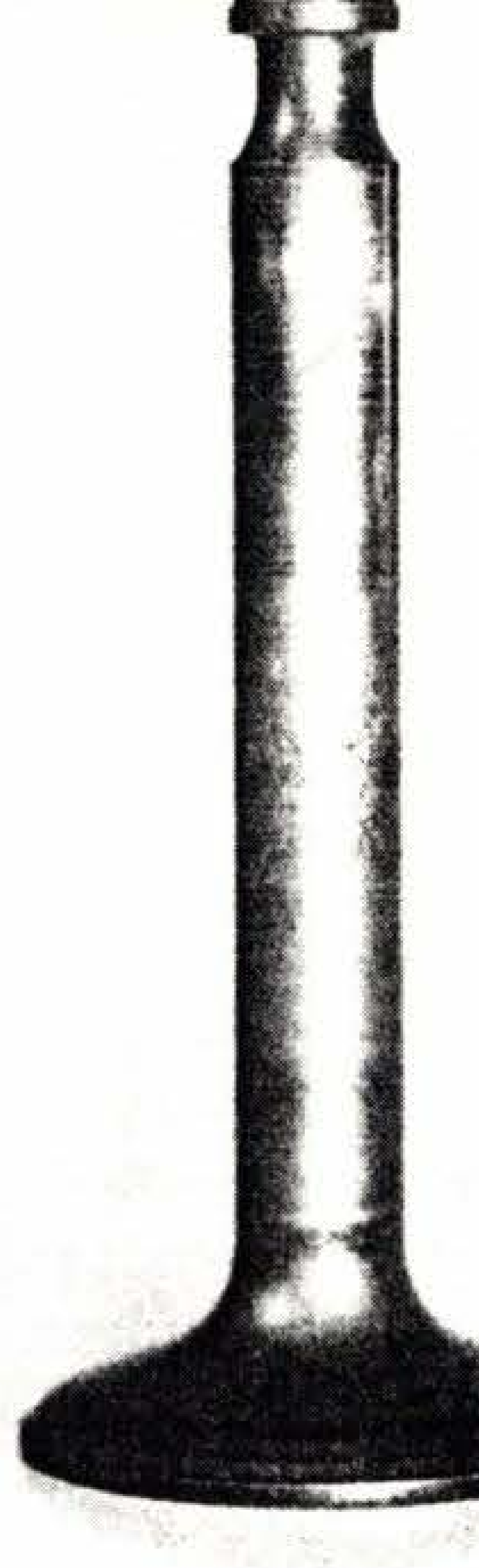
Balance should be checked, says Chadwick, whenever a propeller is overhauled, after an engine is overhauled, when significant repairs are made, or whenever unusual vibrations are evident. Agreeing with this are Allison, Garrett, Hartzell, Mitsubishi, Short Brothers, Swearingen, and a list of other users that reads like Who's Who in Aviation.

At $5,000-plus for a ramp-ready kit with all the options, the Vibrex system will balance everything except your checkbook. For more information, contact Chadwick-Helmuth Co. at 4601 N. Arden Dr., El Monte, CA 91731 (phone 818/575-6161; Telex 194271), James R. Chadwick, President.

—Kas Thomas

Valve Erosion in Lycoming Engines

Will there ever be a cure? Superior Air Parts, armed with German know-how, says yes



The P/N 74541 sodium-filled valve is used in almost every low compression engine Lycoming makes.

by Kas Thomas

Lycoming hasn't exactly had the best of luck with valve-trains. Between the O-235's pushrod problems, cam and lifter troubles with the O-320-H and O-360-E, and a vexacious fleet-wide problem with valve-sticking (not only in the O-320 but a wide variety of models), Lycoming has had more than its share of valvological distress.

One problem that just won't go away is the old thermal erosion (or "80-octane valves in 100-octane engines") bugaboo. Mounting evidence now suggests, in fact, that thermal erosion and head cracking have never been worse in parallel-valve Lycomings. Particularly hard-hit are engines with P/N 74541, P/N 76081, and P/N 75068 exhaust valves—which is to say, just about every low-compression engine with a Lycoming data plate, from 150-hp O-320 to parallel-valve O-540.

Thermal erosion of Lycoming valves is an old problem. Extensive testing of O-290 and O-435 engines (to determine optimum valve/guide combinations to reduce erosion) was done by Lycoming after World War II under the auspices of the Ethyl Corporation and the U.S. military. (See the paper by Robert V. Kerley in SAE Quartlerly Transactions, Vol. I, No. 2, April 1947.) The deleterious effect of leaded fuels on exhaust valves has been known to Lycoming for well over 40 years.

Valve erosion in the civil fleet wasn't much of a problem for the years 1945 to 1970, because 80/87 avgas (with only 0.5 gram of lead per gallon) was plentiful, and it met the needs of the majority of operators whose engines were originally certified on that fuel. (The few high-performance engines that required 100/130 avgas did well with it; but then, TBOs for big engines, in the Viet Nam years, were only 1,200 hours or so.) The problem came when oil companies began phasing out 80/87, and owners of low-comprssion engines were forced to turn to 100LL (with quadruple the lead content). All of a sudden, valve erosion was a Big Problem.

Lycoming issued Service Bulletin No. 404 in September 1976 specifically to address this situation. Lycoming attributed some of the erosion problem to overleaning, but nevertheless mandated repetitive inspections of valves for operators using high-lead fuel in 80-octane engines (regardless of leaning procedure). Under S.B. 404, engines that'd gone past the 1,000-hour mark and spent more than 25% of that time on grades of fuel higher than 80/87 were to get repetitive 100-hour inspections of exhaust valves for rim cracking, necking, and burning. The inspection procedure: "By means of a borescope or other suitable optical device, examine the exhaust valve through the spark plug hole. Especially look for sharp, well-defined, carbon-free rim formed on the face of the valve around the outer circumference." Cracks were known to form radially around the feathered edges of eroded valves, eventually resulting in a pie-shaped piece of valve coming loose in service, if the condition was not caught in time.

Lycoming's 1976 bulletin introduced a "cure" for the valve-erosion phenomenon in the form of P/N 74541 valves (which had already been used in Lycoming's higher-compression engines, with good success). The P/N 74541 exhaust valve was essentially the same as the older, low-compression-engine P/N 75068 valve—both were sodium-filled and made of XB-type steel—but the P/N 74541 valve had a nichrome overlay on the head end for better resistance to lead oxide attack. Lycoming thus encouraged owners of 80-octane engines to convert to the P/N 74541 exhaust valve at the earliest opportunity.

There is little question that the P/N 74541 valve is more erosion-resistant than the old P/N 75068 valve it replaced. (NTSB reached precisely this conclusion last June after reviewing over 200 reports of valve distress in O-320 engines. See LPM, Sept. '87, pp. 8-10.) But unfortunately, erosion and rim cracking are still problems in low-compression Lycomings, even with the P/N 74541 valve. (Some actual failures reported by LPM readers were recounted in September 1986, pp. 17-18, and June '87, pp. 19-20, involving O-360-A and TIO-540-C engines, respectively.)

Failure Mode

Where erosion bad enough to cause head cracking has occurred, the big end of the valve generally has a black, mottled, crusty appearance suggestive of over-heating. Wear along the edge of the valve face is typically quite advanced, with a sharp, feathered edge formed on at least part of the circumference. Stress risers form along the thin edge, eventually causing fatigue cracks to appear and progress radially inward toward the stem. Before the cracks can reach the center (stem) portion of the head, however, overload failure causes a fragment (usually representing a third or more of the valve face) to break off. When this happens in flight, EGT for the cylinder drops; also, the piston crown gets peened as the valve fragment ricochets around on its way out. In turbocharged aircraft, the turbo generally incurs fatal shrapnel damage.

Heat and lead (from 100LL) are the main culprits in the above scenario. Lead combustion products are extremely corrosive at temperatures of 1,500 or more degrees Fahrenheit; in fact, the higher the temperature, the more rapid the corrosion. (See SAE Quarterly Transactions, April 1947, pp. 253-260.) Leaning to peak EGT under sustained high-power cruise sets up conditions ideal for corrosive attack.

Considering the harsh operating environment—and the ever-longer TBOs being seen by the fleet—it's a wonder more valves don't fail on the way to TBO. It may well be that the only thing preventing early failure of P/N 74541 valves (particularly those being subjected to worst-case conditions) is the sodium cooling feature. (In a hollow, sodium-cooled valve, molten sodium inside the valve stem physically carries heat from the head to the stem during reciprocation of the valve.) Without sodium to carry heat up the stem, the valve head takes on thermal loads for which it may or may not be designed. Continental gets around the problem in its solid-stemmed valves by making the valve head itself massive and constructing the valve entirely of Nimonic 80A (or lately, Nimonic 90) superalloy. Unfortunately, the Lycoming P/N 74541 valve has a less massive head design and the low-nickel steel of which it is made is not suited to ultra-high-temp operation.

In short: If either the nichrome face overlay is breached, and/or the sodium cooling feature is lost, severe erosion and head cracking are virtually certain to be the outcome.

Superior Air Parts' ad for the improved SL17540 valve (a direct replacement for Lycoming P/N 74541 and LW19001) touts strengthened keeper groove, extra head metal, and patented zirconium gas process for filling stem with sodium.

Low-Sodium Valves

In late 1986, overhauler James Wyatt of Homestead, Florida installed all-new P/N 74541 valves from Superior Air Parts in his Skyhawk's engine. (Actually, the valves were not genuine Lycoming parts but were PMA equivalents, P/N SL74541, made at the same Eaton plant that Lycoming's valves are made at.) The engine had hardly gotten through the break-in period when—at a little over 100 hours since major—an exhaust valve failed on takeoff.

"Thankfully, I wasn't over the Ever-

(continued on next page)

(Continued from previous page)
glades," Wyatt muses. "The valve broke clean across the face, just like that picture in the July LPM. The head simply failed."

Wyatt returned the valve to Superior. Superior, in turn, determined that the valve broke due to "uneven valve seating which caused leakage and burning in the valve face area." This conclusion was based on the observation that there had been "extreme wear to the valve lock pieces and lock area of the valve."

Wyatt didn't buy this explanation. Instead, when he got the failed valve back from Superior, he sent it off to a commercial lab—QC Metallurgical, Inc., of Hollywood, Florida—for analysis. When the lab report came back, it laid blame for the failure on "thermal and possibly some bending stress." But there was one other interesting finding: "Also noted when cut [open] was that the valve stem was not filled with sodium."

Superior's Charles Dedmon told LPM that it was "extremely unlikely" that an Eaton-manufactured sodium valve could contain no sodium. (A senior Lycoming engineer we talked to echoed this sentiment. "The amount of sodium in each valve is closely controlled during manufacture," he told us. "Plus, Eaton x-rays the valves before releasing them to Lycoming, and Lycoming has its own quality-control checks.") Dedmon wouldn't totally rule out the possibility, however. "I haven't been to the Eaton plant since they moved a couple years ago," he confided, "but the last time I was there, I saw how the valves are made, and I can tell you this: The sodium is put in by hand, in the form of a pellet."

Dedmon pointed out that sodium doesn't have to be totally absent for valve cooling to be impaired; improper guide clearances, or loss of sodium to internal corrosion in the stem, can also have the same effect. The latter comes about when entrapped water vapor—retained in the valve stem during manufacture—reacts with the sodium (and valve metal) to form scale buildup along the inside of the sodium chamber.

How big a problem is scale buildup? TRW's Thompson Valve subsidiary in West Germany (which produces sodium-filled valves for numerous OEMs worldwide) considers it serious enough that its engineering staff developed and patented a zirconium-gas evacuation process for the manufacture of sodium-filled valves, specifically to avoid scale buildup problems. Superior now has valves made in West Germany using the zirconium process.

Phillips' Findings

Additional evidence for variations in the amount of usable (unreacted) sodium inside Lycoming's sodium-filled valves comes from, of all places, Phillips Petroleum. Two years ago, at the height of the X/C II oil controversy (in which X/C II oil was thought by some to be implicated in valve-sticking), Phillips acquired a number of corroded Lycoming valves, sent in by disgruntled owners. (Phillips paid for replacement valves for many of these same owners.) The corroded valves are still in Phillips' possession. Many of them have been subjected to x-ray analysis. A few were sectioned. Not all contained the same amount of sodium.

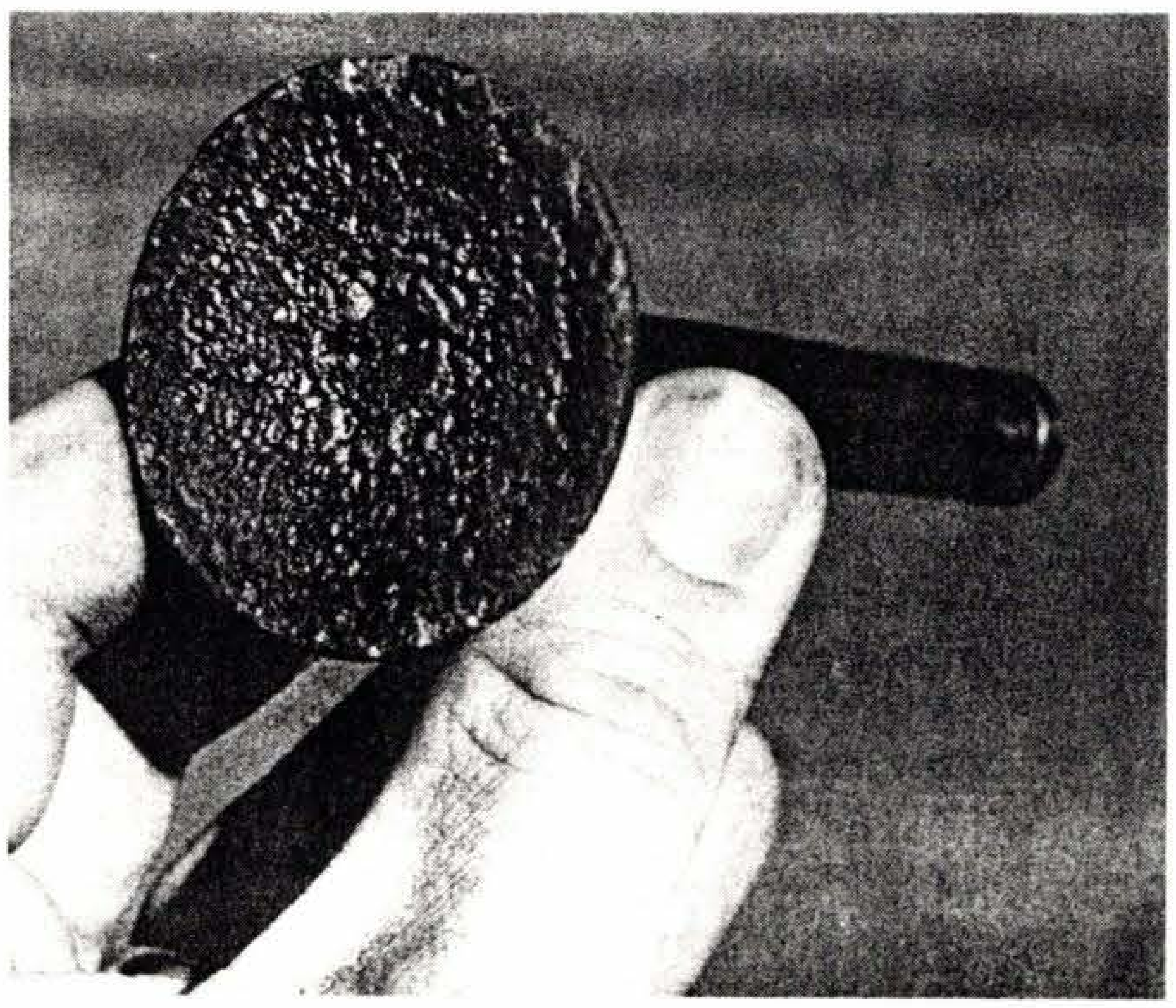
"I don't think we ever found one that had no sodium at all inside," a Phillips spokesman told LPM. "In fact, I tend to regard our results as inconclusive, because of the small numbers, and because of the difficulty in interpreting the x-ray results." The problem in interpreting the x-ray photos, the spokesman remarked, was due in part to variations in surface thickness of adhered sodium inside the valves. In other words, scale buildup in the sodium chamber may have been a factor.

The Phillips man we spoke to was reluctant to state flatly that Lycoming valves varied dramatically in sodium content. But Phillips' research to date has been unable, by the same token, to rule out scale as a factor in valve overheating, and overheating as a factor in deposit buildup. It is just possible that X/C II was the victim of a valve problem, rather than the cause of one.

The Solution

Lycoming and Superior Air Parts have each acted to remedy the head-erosion problem in P/N 74541 valves. Lycoming superseded the P/N 74541 valve with P/N LW-19001, which is dimensionally similar to its predecessor but constructed of Nimonic 80A. (The Nimonic alloy is approximately 75% nickel, and—unlike steel—retains good tensile strength and resistance to corrosion at temperatures of 1,500 to 1,600 degrees Fahrenheit). The P/N LW-19001 valve is approved for all parallel-valve Lycomings (provided ni-resist guides are used); list price is $299.50 each.

Superior Air Parts has taken a somewhat different approach, superseding its version of the P/N 74541 valve with an entirely new part number: SL17540. The SL17540 valve (introduced in May 1985) is made in West Germany for Superior. It sells for $150, dealer net; aircraft-owner net will be more, depending on dealer markup. (Linda Lou, Inc., will sell the valve direct to owners for $190. Phone 1-800-824-9912.)



Lead amalgamation claimed this valve at low total time. Burning and rim cracking would eventually have led to outright failure. Note the chipped or spalled appearance and the loss of material at 12 o'clock on the face.

32T .10 using old O-235-L2C

Q

...d

...thers and can thus be regarded as the ...." Leaving this cylinder as the selected ...der, enrichen the mixture and monitor the ...he readout peaks, you are at peak EGT on ...nder.

Obvi... ...he best way to monitor all cylinders is with a fulltime all-cylinder readout. Alcor, KSA, and Insight are the only companies offering all-cylinder EGTs at the moment, and Insight's GEM is the only system capable of reading out EGT *and* CHT (and TIT, for turbocharged planes) simultaneously. The GEM, we realize, is prohibitively expensive for most 152 owners. Still, it's the Mercedes-Benz of EGTs. If it's Mercedes quality you want, expect to pay a Mercedes price.

I am building a Lancair 235 powered by a (used) Lycoming O-235-L2C which was removed from a Cessna 152. Would you recommend installing P/N LW-18729 (2,400-hr) pistons on this engine? With 1,700 hours TT, this would mean more than doubling the time-remaining until TBO (from 300 hours up to 700) in my case. If I do the piston swap, does this mean putting the pistons in without new wrist-pins and rebushing the con rods, or is that usually included? Also, can the cylinders be rehoned to break the glaze without screwing up the nitride layer? The engine presently has Slick 4281 and 4050 magnetos (the former with a 5-degree lag angle). Since I'll be using a wooden prop instead of a metal one, will the 5-deg. impulse angle cause starting problems? Any help you could give would be appreciated.—D.S., CA

Lycoming sells a kit (P/N 05K19614) containing four long-TBO pistons, new rings, cylinder seals, logbook label, and appropriate gaskets, for $638.20 (correct as of late summer, subject to change without prior notice; contact Linda Lou Inc. at 1-800-824-9912 for possible discount pricing). The kit (which we think is a good idea, by the way) does not come with rod bushings or wrist pins. Normal practice is to drive the wrist pin out with a drift and install the new piston (rings already fitted), reusing the same wrist pins and bushings. (The bushing is a press-fit in the rod and doesn't come out.) Rehoning to break the glaze is common practice any time a cylinder is off for any reason. Get a local FBO to do the work; FAA-certified repair stations may not want to give your cylinders back if they find one or more to be out of specs for bore, choke, etc.

Will the Lancair's wooden prop mean using a different impulse coupling?

Of course, you *could* just keep your present pistons and fly to 2,400 hours anyway; but since you're dealing with a 1,700-hour engine, it's better to take the jugs off and see what you've got than to fly in total ignorance. While your jugs are off you can take a look at the camshaft and see if any lobes are soft. (As you know if you've been reading our A.D. Oultook feature, numerous instances of cam-lobe distress have been reported in the O-235-L2C recently.) The LW-18729 piston is a definite improvement over LW-13623 (which you've got now). The latter has shown a tendency to crack in service. The crack rate is not high (we wouldn't ground a plane for not having the new pistons), but it's better to have the improved part nonetheless.

You've raised a good point with your question about impulse lag angle versus propeller construction. The lighter-weight wooden prop will definitely have an effect on cranking rpm, and the O-235 has shown a definite sensitivity to cranking rpm in terms of ease of starting. (Cessna went to a different starter armature—to *slow down* the starter—in the 152 after its initial introduction in 1978.) Without knowing what kind of starter you'll be using, we can only advise you to proceed by trial-and-error. If your present mag/starter combination doesn't give reliable starting, go to an M-3100 impulse coupling, which has a 15-degree lag angle (about $125 through any Slick dealer). First, of course, be sure your engines' ignition timing is set properly (20 degrees BTC); impulse action shifts with errors in mag timing. Also be sure you're using an ignition switch that cuts out your non-impulse mag (the 4050) while cranking. Otherwise, use two impulse-coupled mags.

Best of luck with the Lancair. Let us know how the project turns out.

I very much enjoy your publication and would appreciate your opinion on a matter concerning my aircraft. I own a 1978 Piper Lance from which the shimmy dampener has at some time been broken off without any other damage to the nose gear. My mechanic said that as the whole nose gear fork must be replaced to repair this, it wasn't worth tackling until I sell the plane, as in his opinion this aircraft does not need a damper. So far, he seems to be right, because there is no shimmy on takeoff and only a bit of mild shimmy on braking. I have not been able to compare it with other Lances and cannot remember whether this is a greater shimmy than before. In any case, how important do you regard the shimmy dampener on this aircraft, and what are the short and longterm consequences of operating without one?—R.F., Ontario

The short-term consequence (obviously) is mild shimmy; in addition, your aircraft no longer conforms to the PA-32R-300's "type design" under FAR Part 23, which means your airworthiness certificate and insurance may be null and void. The longterm consequences could be quite serious. We'd advise installing another dampener at once, but check with another AME first to get a second opinion on whether the strut can't be fixed *in situ*. Barring a field repair, check with salvage sources. A used PA-32 nose fork shouldn't be too hard to find.

Jan or Apr 88

Flying Engine w/o Logs 35E (.10)

Q&A

My 1969 Cherokee 140B has just shy of 3,700 hours on the tach, and presumably 1,700 SMOH (three owners and 900 hours ago, the logs were lost; an A&P started anew by assuming that an overhaul took place at 2,000 hours). The engine runs like a champ, giving book performance, one quart of oil burned every 15 hours, etc. I intend to run this engine as long as it is sound, at a rate of 100 to 200 hours a year. But eventually it will have to be overhauled, and I want to know: Do I rebuild this core, since it's doing so well? Do I trade it for another rebuild? Go for a factory reman?—J.S., VA

First find out if the oil-pump ADs (75-08-09 and 81-18-04) have been done. If a positive determination of the compliance status of these ADs cannot be made from existing logbooks, you'd be wise to overhaul the engine asap. The 1975 oil-pump directive (75-08-09, per Avco Lycoming S.B. 381 and 385C) pertains to Woodruff-key-drive-type pumps. The 1981 AD (81-18-04, ref. Avco Lycoming S.B. 456B) pertains to sintered-iron pump impellers, which were installed in a large number of Lycoming engines (of various models) between 1970 and 1981. Sintered impellers are a definite hazard and should be removed at the earliest opportunity (the A.D. is generous in allowing a 2,000-hour life).

In 1969, when your engine was originally made, sintered-iron impellers had not yet gone into production. You probably have them, however, if your engine was overhauled prior to 1982. (The only way to be sure you don't have them is to open the accessory case, take apart the oil pump, and see what you've got. This is most conveniently done at major overhaul.)

Unless you know for sure when your engine was last overhauled, you could well be in violation of A.D. 81-18-04 right now and not know it.

Frankly, we'd feel a little queasy flying behind an engine with no record of ever being overhauled in 19 years and 3,700 hours. How sure are you that your engine has, in fact, ever been overhauled? The presence of green, yellow, or orange paint on your cylinders—either at the base, or on the fins between the top spark plug and the barrel—would indicate that at least a top overhaul has been done. (Green signifies a .010-oversize grind; yellow signifies .020-oversize jugs; and orange signifies chrome-plating.) Pull the rocker covers off and see if you can read the exhaust valve P/N off the stems. If you've got P/N 75068 valves, the engine is original; if P/N 74541, it's been worked on since leaving the factory. (The presence of flangeless valve guides would also mean the cylinder has been reworked since 1969.) Unbroken factory putty on cylinder hold-down nuts would, of course, be *prima facie* evidence that the engine's never been torn down.

At what point do you overhaul the engine on a "lost logs" 140B?

A lot of service bulletins have come and gone since 1969. Bringing your engine up-to-date at overhaul time could entail considerable cost. In view of the engine's uncertain history, we'd recommend either a Lycoming factory overhauled exchange engine or a factory reman. With the former, you do not get new logbooks, but you do have the satisfaction of a factory entry in the logs showing that the engine has been thoroughly updated, incorporating all applicable service bulletins and ADs. (Also, you have a factory warranty equivalent to that of a new engine.)

With a factory reman, you get new logs (the engine is officially "zero time")—but you pay a rather steep price for that status ($10,455, exchange). However, if you buy through Linda Lou, Inc. (formerly associated with Norm Bender), the factory-overhauled engine is only $6,260, and the reman is only $2,270 more ($8,534 exchange). Considering the new-engine warranty, the no-extra-charge service bulletin compliance, and the added resale value in going from no logs to factory logs, we'd strongly advise taking a factory overhaul over a field overhaul, in your case.

For more information, call Linda Lou directly at 1-800-824-9912. She can quote prices on any and all Lycoming models, in addition to providing info on shipping, accessories, handling of core deposits, etc.

Recently, we bought two Continental IO-470-U engines (for my Cessna 310) from a supplier who obtained them from a geared-up aircraft. On taking possession of the engines we overhauled them both. Some 30 hours later, oil was noted coming from the area of the front crankshaft seal. On subsequent investigation, both engines were found to have cracked crankshafts. In view of pending legal action, we are wondering whether it is possible that damage incurred in a prop strike can take 30 hours to show up as cracks (the seller of the engines says it's impossible)? Also we'd like to know: During overhaul, when a crank checks okay for straightness (runout), and a Magnaflux inspection shows no faults, what else can one do to assure that the crank is safe?—E.P., WA

Teledyne Continental Service Bulletin M84-16 (superseding M71-5) pertains to prop strike damage. The bulletin is only a page long and, for the most part, isn't very helpful. It does say that while not every prop strike requires a teardown, *sudden stoppage* (as in a gear-up landing) does require complete engine disassembly and inspection to detect damage to the crankshaft, prop flange, counterweights, and crankcase bearing saddles. "The