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

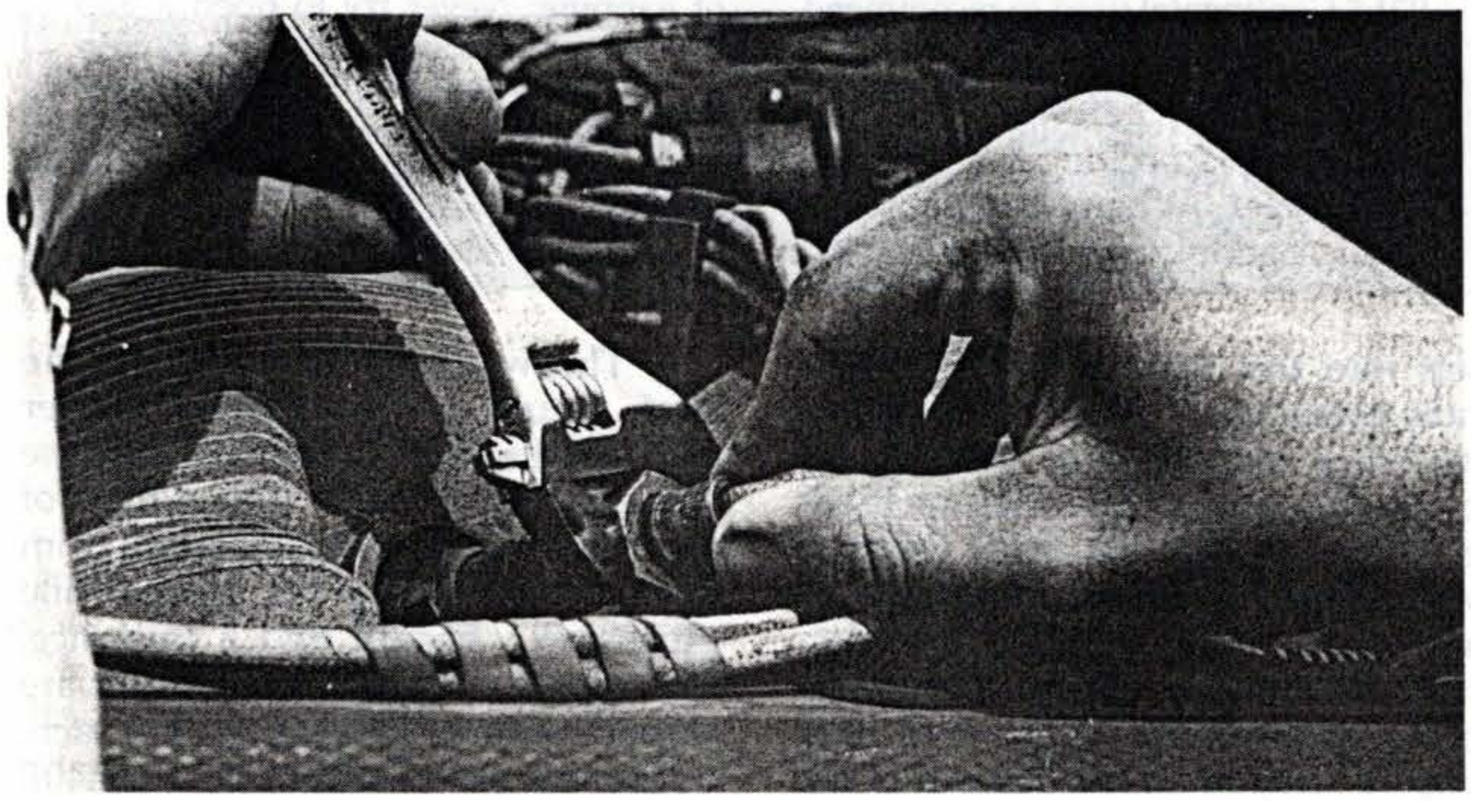
Spark plug R&I (removal and installation) is one of the simplest—and most important—techniques in the pilot's preventive-maintenance repertoire. Knowing how to get plugs in and out is basic to diagnosing cylinder problems, troubleshooting a bad runup, monitoring the effectiveness of one's leaning regimen, 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 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.

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

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.



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.

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.)

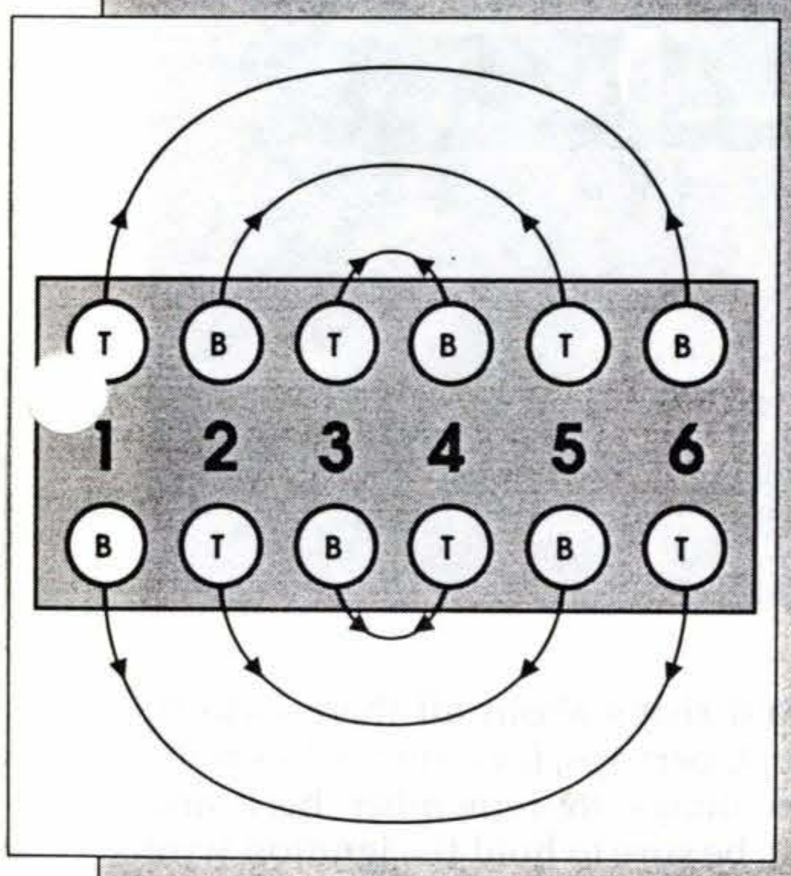
On a *four*, swapping plugs top for bottom and side for side will *not* result in proper rotation. If the firing order is 1, 3, 2, 4, then it's obvious that if 1 fires +, the magneto output will be 1+, 3-, 2+, 4-. Hence, you *don't* want to swap 1 for 2 or 3 for 4, because the polarity is the same. Instead, 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.

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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,

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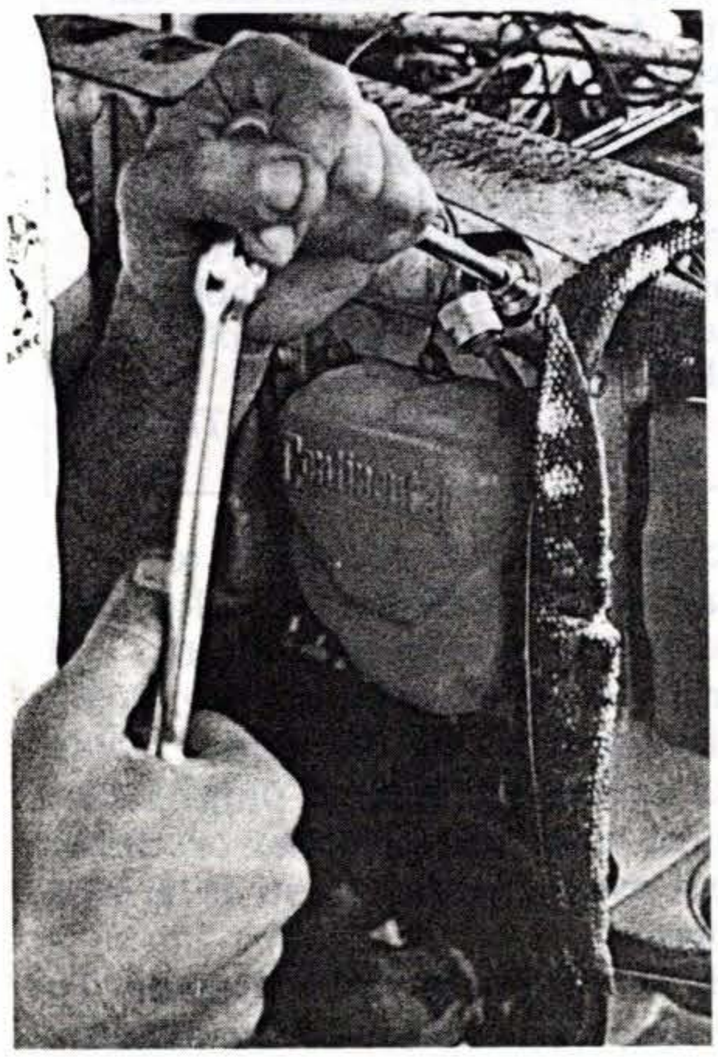
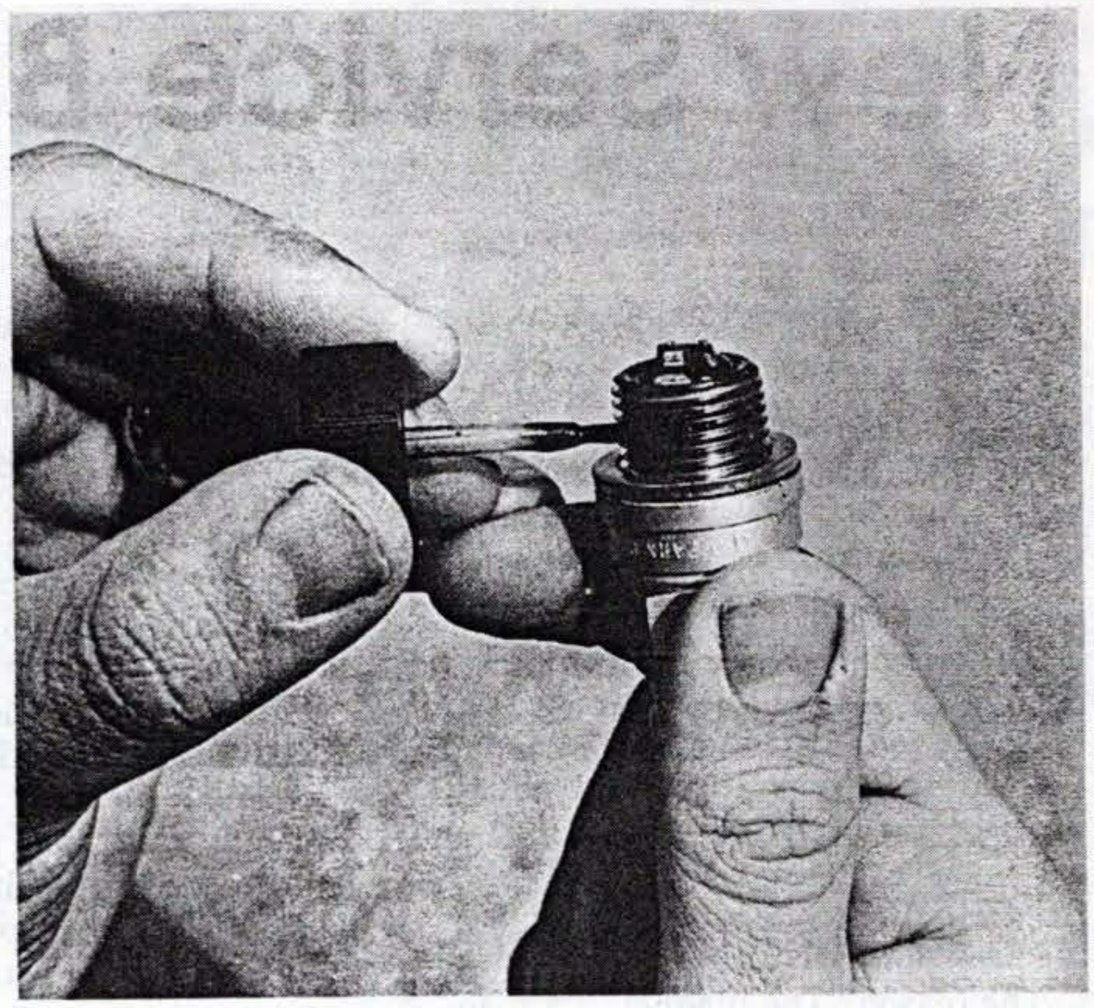
you should start with clean threads (in the hole and on the plug itself), and *use a thread lube*—either Champion No. 2612 ($2.25 from Chief, above), or engine oil, preferably Mobil synthetic. If you don't clean the grit out of all threads, your installation friction drag will be artificially high and 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.

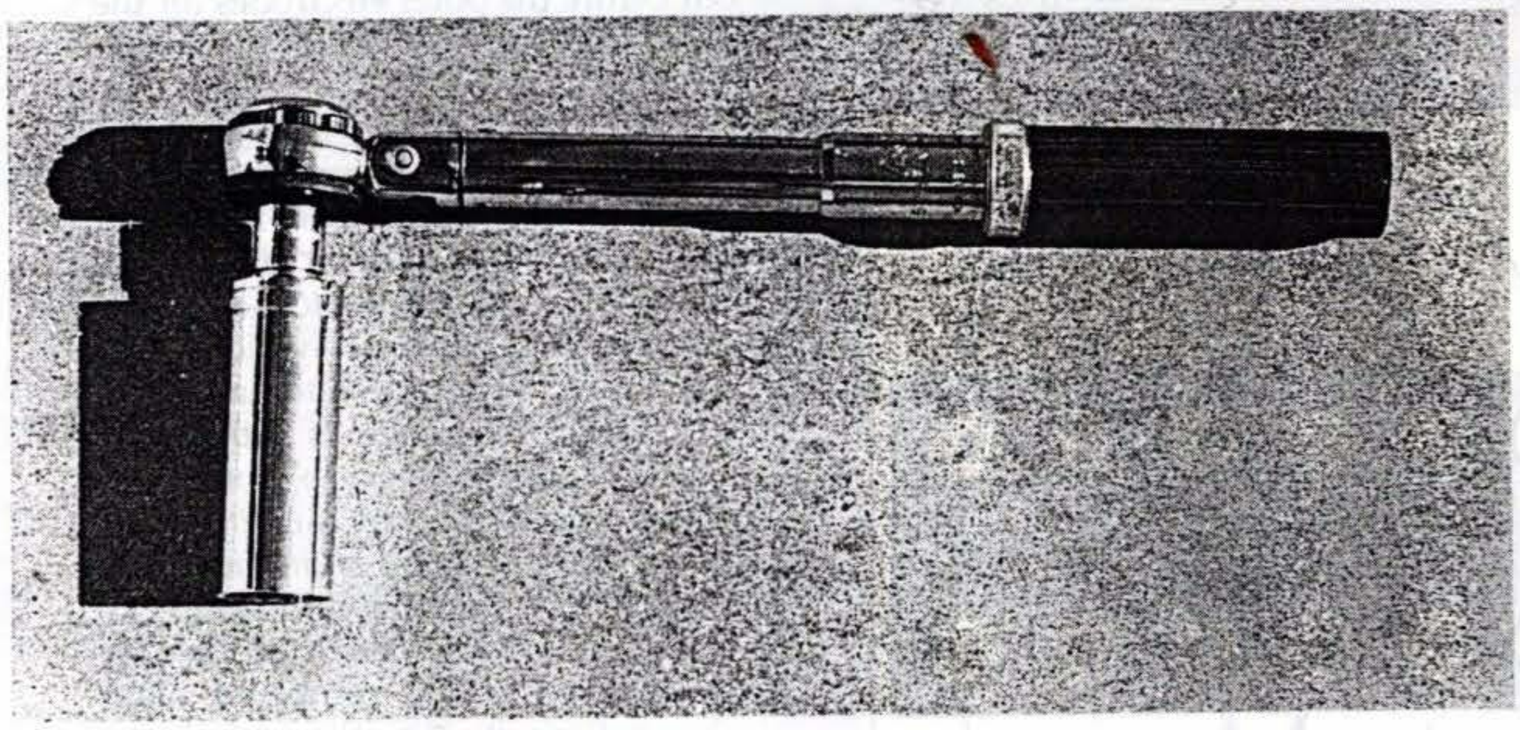
9. Thread plugs into place by hand. Save the socket and torque wrench for the last minute. Putting plugs in by hand avoids any possibility of crossthreading, and gives you a valuable doublecheck of thread condition. If you can't turn a plug almost all the way down by hand, then there's something wrong: 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.



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

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).