Master Modeler Series

RADIO CONTROL

AIRPLANE ENGINE GUIDE

by Dave Gierke

Your Complete Source for Engine Setup, Tuning and Maintenance

- » Choosing the best engine for your plane
- » Mounting and installation techniques
- » Getting your engine to run right every time
- » The best way to break in your engine
- » Prop selection and balancing
- » Maintenance do's and don'ts

From the Publishers of
MODEL Airplane NEWS

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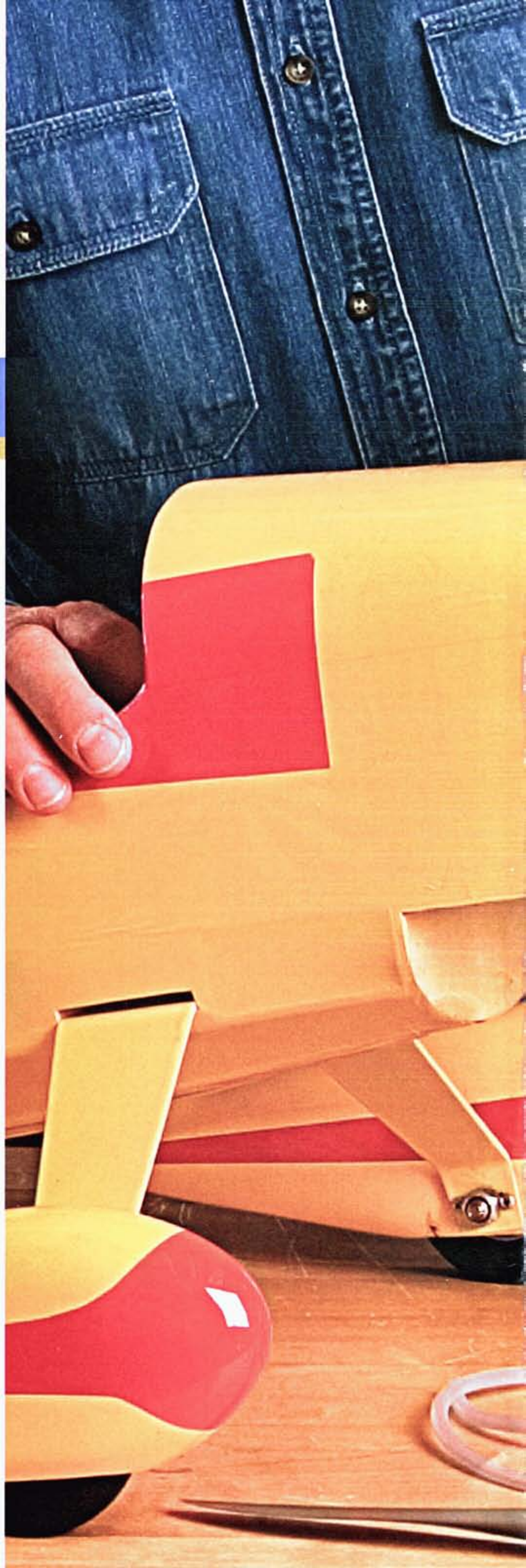


Shoestring
WYNN'S
FRICTION
PROOFING
OIL

INTRODUCTION by Dave Gierke

Critics say that engines are loud, smelly, and difficult to start. They're messy; they vibrate; they pollute the planet. They need fuel, plugs, batteries, and—occasionally—a fire extinguisher. Their performance is inextricably linked to changes in altitude and atmospheric conditions ... and these are only a few of the reasons why we love the internal-combustion engine!

Useful internal-combustion engines have been with us for more than 120 years. By 1900, the 4-stroke engine had emerged as the dominating prime mover for the fledgling automobile; it beat out the steam engine and the electric motor. During this same period, rudimentary 2-stroke engines were adapted for motorcycles, motorboats, chainsaws and numerous types of lawn equipment. In 1934, the first mass-produced miniature airplane engine, the Brown Jr., sparked the rush to model aviation by America's youth.

Today, after more than 70 years of development and optimization, miniature-engine technology has matured. Nevertheless, successful engine operation depends on additional requirements, including fuels, propellers, engine mounting, fuel-delivery systems, performance tuning and more. "Radio Control Airplane Engine Guide" is designed to enlighten the novice and add to the experienced modeler's bag of tricks.

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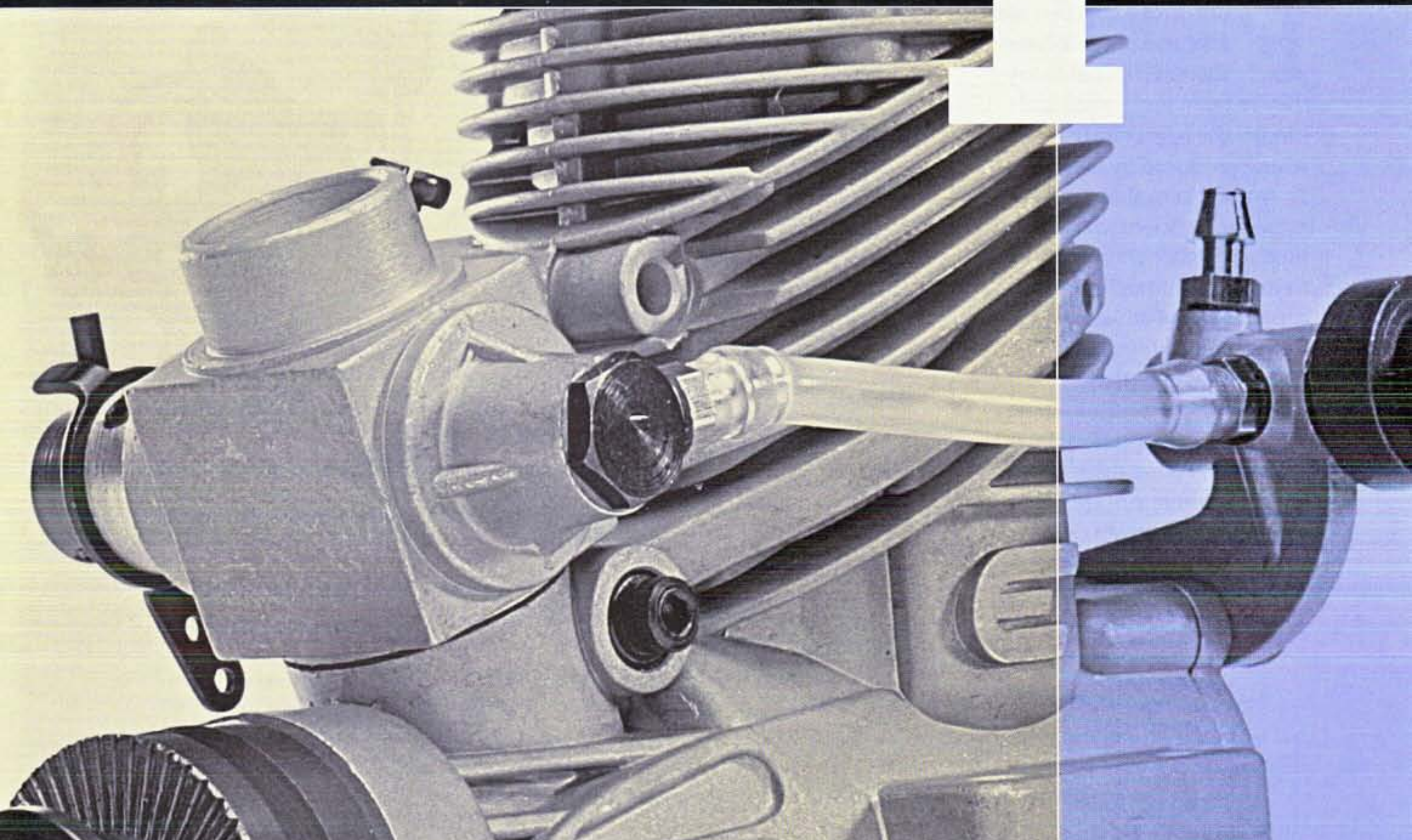

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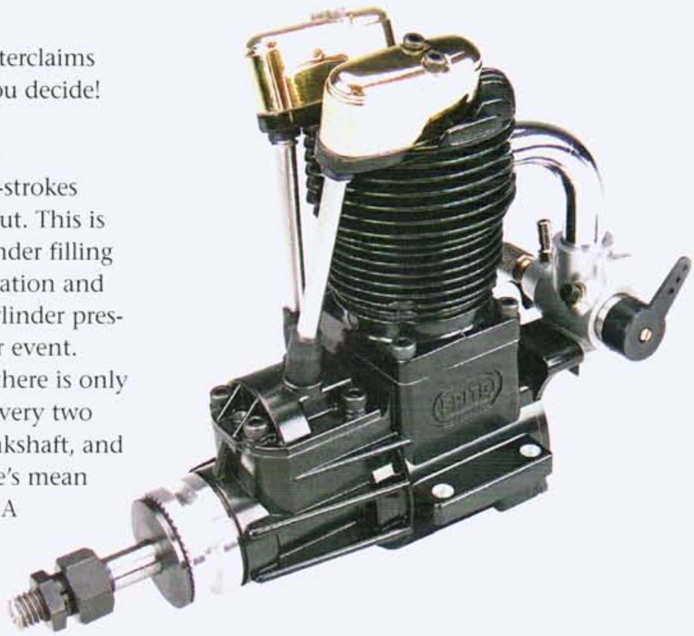
4-stroke power—what's the advantage?

BY DAVE GIERKE · ILLUSTRATIONS BY PAUL PERREAULT

Four-stroke engines: some love them, some hate them. Proponents say they're quiet and sound scale (unlike the aggravating, high-rpm whine produced by 2-strokes). They also claim that 4-strokes are more fuel-efficient, run cooler and produce higher crankshaft torque to turn large propellers. Detractors contend that 4-strokes are heavier and less powerful than 2-strokes and that because they have more parts, they demand additional care and are proportionally more expensive. Four-strokes are also said to be more susceptible to corrosion than 2-strokes. Which of these claims and counterclaims are true? We report; you decide!

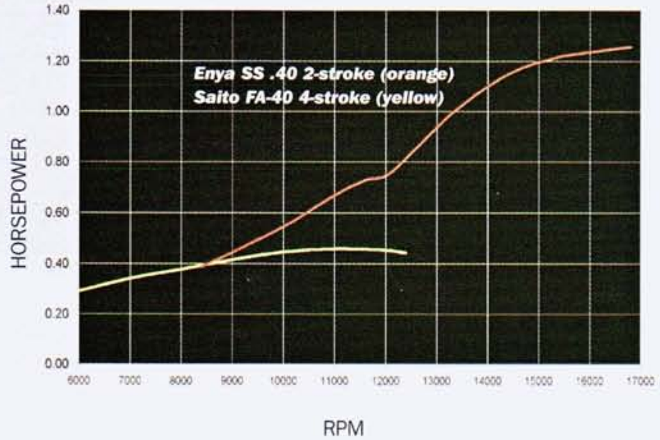


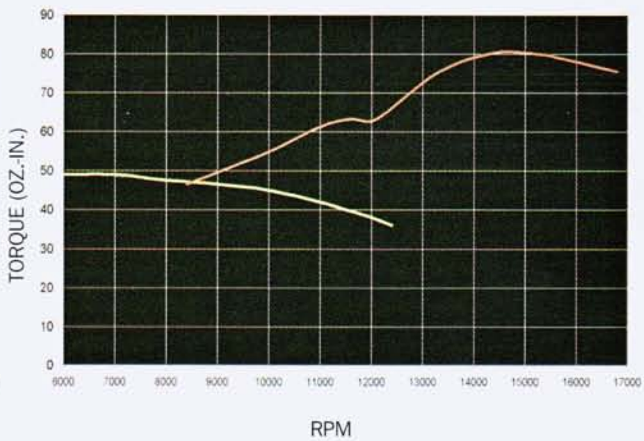
POWER

It has been said that 4-strokes offer high-torque output. This is based on superior cylinder filling during the intake operation and the resulting higher cylinder pressures during the power event. Although this is true, there is only one power stroke for every two revolutions of the crankshaft, and this reduces the engine's mean torque figures by half. A comparison of the torque produced by representative

2-stroke vs. 4-stroke power curves

Two-stroke engines ultimately produce more horsepower than 4-strokes of equal displacement, as illustrated by the power and torque curves of the Enya SS .40 2-stroke (red) and Saito FA-40 4-stroke (green). But peak power isn't everything; with a .40-size airplane, the 2-stroke produces more horsepower at the extreme high end of the rev range, but that power is generated above the usable rpm for most flyers. At anything below about 9,000rpm, the 4-stroke is actually stronger.



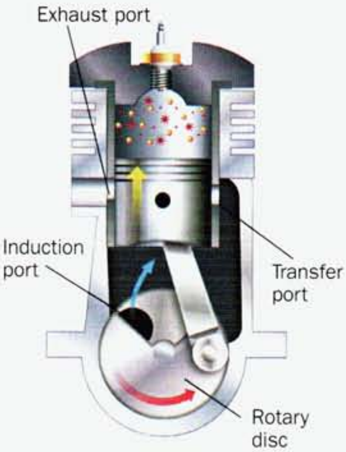


examples of similar displacement 2- and 4-stroke engines shows this (see "2-stroke vs. 4-stroke power curves" sidebar).

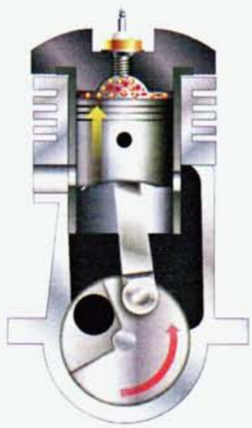
Production 4-strokes from the late '70s and early '80s were underpowered compared with 2-stroke engines of the same cylinder displacement. In almost three decades of technical progress, highly developed forms of the 4-stroke engine have at last caught up to the competition 2-stroke: horsepower numbers were increased during this period by improving the engine's volumetric efficiency (breathing), increasing the valve lift and duration, and enlarging the valves and ports. Tinkering with combustion-chamber shapes also improved power while it stifled combustion defects such as detonation. Continued 4-stroke development focuses on supercharging and oxygen-bearing fuel components such as nitromethane. At the 2003 AMA Nationals, participants in several classes of RC Aerobatics predominantly used the O.S. 1.40 (RX or EFI) 2-stroke engine or the YS 140 (L or DZ) 4-stroke. Both use propellers of similar sizes and operate at about the same flight rpm; this indicates that shaft power is about the same for both types. The O.S.

2-stroke operation

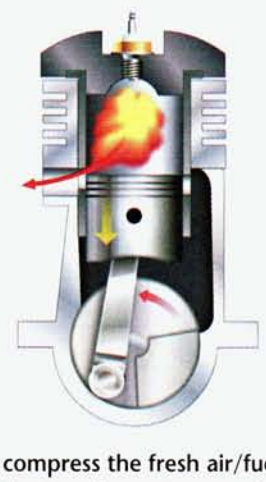
To understand how a 4-stroke engine operates, it helps to know how its glow-ignition 2-stroke counterpart works.



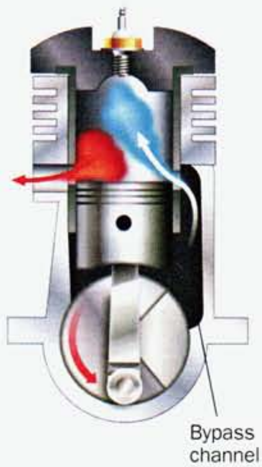
1 The crankshaft has rotated away from BDC (bottom dead center) and has moved the piston up and closed the transfer and exhaust ports. The air/fuel mix from the previous cycle is trapped above the piston. The induction disc starts to uncover the induction port. As the crankcase volume increases, a partial vacuum forms and atmospheric pressure pushes air through the carb, where it's mixed with fuel and enters the crankcase.



2 As the piston nears TDC (top dead center) on the secondary compression, the air/fuel mix reaches auto-ignition temperature and combustion occurs. The momentum of the rotating components carries the piston beyond TDC, where the expanding gases provide peak pressure. Meanwhile, the rotary induction valve is almost closed as high-pressure combustion gases push the piston away from the cylinder head.



3 The piston moves to a point at which the power event ends and the exhaust port opens. The time between exhaust-port opening and transfer-port opening is called "exhaust lead." It provides time for the high-pressure exhaust gases to begin exiting the exhaust port. The induction valve is still closed; this allows the piston to compress the fresh air/fuel mix in the crankcase until the transfer port opens. The mixture then flows from the crankcase to the cylinder above the piston.

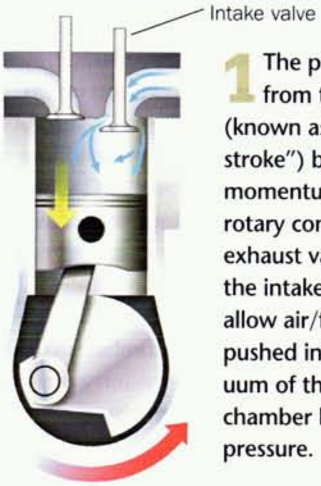


4 The exhaust and transfer ports are both open, and the previously compressed air/fuel mix flows through the bypass channel and transfer port and chases the tail-end gases out through the exhaust port. The 2-stroke may be simple in terms of its mechanical components, but the flow of energy through its systems is very complicated.

uses a tuned exhaust system (supercharging from the exhaust side), while the YS uses crankcase-pumped supercharging with 30-percent nitromethane fuel. The noise levels of the most advanced 4-stroke designs are on a par with similarly developed 2-strokes, although proponents of the 4-stroke engine claim that the low-pitch exhaust damps the

4-stroke operation

While the 2-stroke engine has a power event for each revolution of the crankshaft, the 4-stroke requires two crankshaft revolutions to create a power event. Stated another way: at a given rpm, the 4-stroke produces half as many power events as the 2-stroke. The other primary difference between the two types involves the way gases are moved into and out of the mechanism: the 2-stroke uses piston-controlled ports; the 4-stroke uses cam-actuated poppet valves.

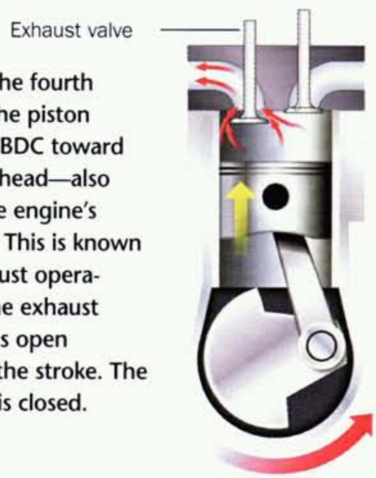


1 The piston moves away from the cylinder head (known as the "intake stroke") because of the momentum of the engine's rotary components. The exhaust valve is closed and the intake valve is opened to allow air/fuel mixture to be pushed into the partial vacuum of the expanding chamber by atmospheric pressure.

2 The second stroke is when the piston moves away from BDC toward the cylinder head. During this "compression event," the piston's motion is again extracted from the momentum of the engine's rotary components. Both the intake and exhaust valves are closed as the trapped air/fuel mixture is squeezed into the relatively small combustion chamber prior to ignition. The ignition of the mixture occurs somewhat before TDC, as it does with the 2-stroke engine.

3 The expanding high-pressure combustion gases push the piston away from the cylinder head toward BDC. Known as the "power, or expansion, operation," it represents the only stroke in the cycle that produces (rather than consumes) power. The intake and exhaust valves are closed.

4 During the fourth stroke, the piston moves from BDC toward the cylinder head—also driven by the engine's momentum. This is known as the "exhaust operation," and the exhaust valve remains open throughout the stroke. The intake valve is closed.



high-decibel effect on the human ear. The Academy of Model Aeronautics disagrees; noise attenuation must be applied equally for all internal-combustion engine types.

4-STROKE RECOMMENDATIONS

If you own or plan to buy a 4-stroke, read the directions supplied by its manufacturer. The additional information presented here is provided to help you avoid potential problems and enjoy running your engine.

• **Fuel.** Most modern 4-strokes operate on methanol-based (alcohol) fuel. Why? Primarily because of cost. The simple glow-plug ignition system works well with methanol (catalytic action) but not with gasoline, which needs an expensive spark-ignition system. In fairness, gas and spark proponents argue that over the long run, it's cheaper to buy the ignition system and run relatively inexpensive, fuel-efficient gasoline; glow fuel doesn't provide good mileage and it isn't cheap. From a safety perspective, gasoline is more dangerous than alcohol fuel owing to its volatility; having a fire extinguisher nearby is a must.

• **Lubrication.** Crankcase-scavenged 2-strokes are lubricated by the oil in their fuel; this is also true of most 4-strokes. Petroleum-based oil doesn't mix with alcohol, so glow-plug engines use fuels that contain synthetic or castor oil or a combination of the two. The oil percentage recommended varies with manufacturer. O.S. Engines suggests no less than 16 percent oil by volume; YS Engines points to 20 percent as its standard and to 24-percent, low-viscosity (thin) oil for its high-performance 140 DZ model; Saito specifies that castor oil should be used as part of the total lubrication content.

Two-stroke oil passes through the engine unburned (mostly) and serves two functions: it lubricates all the internal parts, and it cools by transferring heat from the hottest components, such as the piston, to the lubricant that passes out of the engine during the exhaust operation. Lubrication does the same for the 4-stroke, but with one difference: since the 4-stroke produces only one power stroke for every four strokes of the piston, in all but the most powerful designs, it naturally runs cooler. This has prompted many to think that a 4-stroke requires less lubricating oil. Cylinder pressures are, however, very high during the power operation; adequate lubrication is critical to the wristpin, crankpin and connecting-rod bushings. Higher oil percentages also offer a degree of safety with a lean needle-valve setting.

• **Nitromethane.** Adding nitro to methanol-based fuels increases power, improves idle and produces a better transition from idle to wide-open throttle for most engines, including 4-strokes. The percentage of nitro recommended varies with manufacturer and/or distributor. Bill Baxter of Hobbico suggests the use of 10- to 15-percent nitro across the board for all O.S. 4-strokes. YS recommends 20 percent for its 4-strokes. Again, check your engine's instructions.

Most commercial fuel blenders offer both the lubrication and the nitro content suggested by the engine manufacturer.

• **Glow plug.** In the beginning of the modern 4-stroke era, no one thought that the glow plug would work. With three non-firing strokes, how could the platinum-alloy wire element in the plug be expected to maintain its temperature? The original O.S. FS-60 was fitted with a special "hot" plug designated the "F," and it's still produced and used in all O.S. 4-strokes. The F plug is different from other 2-stroke "hot" plugs because its long snout extends into the combustion chamber. Within the snout, the wire element is directly subjected to elevated temperatures during combustion, exhaust and compression, and that helps it to maintain ignition temperature from cycle to cycle. There are several versions of the original F plug on the world market, but your choice of glow plugs should be dictated by your engine manufacturer's recommendations.

• **Propeller slippage.** Because 4-strokes are prone to detonation (a damaging, high-pressure spike

Development of the 4-stroke

The first mass-produced, commercially available, miniature 4-stroke engines available in the U.S. were manufactured by the Feeney Engine Co. of Chicago. Announced in a full-page ad in the April 1940 edition of *Model Airplane News*, the engine was available in three cylinder displacements: 0.604, 0.914 and 1.18ci. Like most modern 4-strokes, these spark-ignition, single-cylinder designs used pushrod-actuated overhead valves. Feeneys were crudely constructed, and wary modelers soon rejected them as gimmicky, overpriced, overweight, poor performers. The company was forced to cease manufacturing because it had wartime government contracts and faced shortages of crucial materials.

Although the 4-stroke has a long history after the Feeney, the most significant event was the release of the O.S. FS-60 in 1976. This was the first 4-stroke to achieve widespread acceptance. It used a glow plug and ran on ordinary 2-stroke fuel, so the transition from 2- to 4-stroke was easy: no spark ignition, no gasoline and oil—no hassle! The FS-60 developed less than half as much power as its highly refined, 2-stroke counterparts of similar displacement, and it was promptly dismissed as inferior by competition fliers. Sport fliers, however, were quick to recognize the FS-60's attributes: quiet, relaxed flying for slower models and great fuel economy. The FS-60 looked like a 2-stroke except for its rear housing, which contained the camshaft, two exposed rocker arms and two thin pushrods behind the cylinder. A well-built engine, the FS-60 remained in production for seven years. After seeing modelers' enthusiastic responses, other manufacturers jumped on the bandwagon, and Kalt, DAMO, Shillings, Saito, Enya and Webra soon followed with their versions of the single-cylinder 4-stroke.

Used for sport planes, scale models and aerobats, 4-strokes were soon popular with model-aviation enthusiasts around the world, but with a 10cc (0.61ci) cylinder-displacement limit, they were not competitive against the high-horsepower 2-strokes used in Fédération Aeronautique Internationale (FAI) competition. In 1981, the rules were changed, and that leveled the playing field. While the 10cc limit remained in force for 2-stroke engines, scale RC models could now use up to a 15cc (0.915ci) 4-stroke, and RC aerobats could use up to a 20cc (1.22ci) 4-stroke. This was great news for manufacturers of 4-strokes, and they plunged into design and development.

For FAI and national competition, 2-stroke engines are now allowed the same displacement limit as 4-stroke engines. A steady improvement in design, manufacture and operation of the most advanced 4-strokes is responsible for this change.

in the combustion chamber) and considerable variations in torque delivery throughout the operating cycle (especially in single-cylinder engines), propeller hubs tend to slip against the serrated face of the engine's prop driver. This can loosen the prop nut and result in a "thrown" prop. A number of solutions have been incorporated to prevent this. Pinning the prop driver to the rear face of the prop hub was an early solution. Another method involved the use of full-length machine screws that extended through the prop washer and prop hub and into the drilled and tapped prop driver behind it. Four or six equally spaced screws are used with the prop nut at the front of the crankshaft.

Keeping the prop nut tight is another problem. O.S. and others use a second self-locking prop nut (jam nut) to minimize the chance of a propeller's being thrown. Check prop tightness after every flight. Because of torque and detonation, the prop—even a pinned or machine-screwed prop—will still tend to slip slightly. Wooden props can also split at the hub and cause a catastrophic failure if attention isn't paid to the grain in the hub area; wood grain should never be parallel to the pins or the machine screws.

During wide-open engine operation, a prop might be thrown because detonation (identified by its "pinging" combustion noise) reverses the piston's direction before it reaches TDC. In 4-strokes, severe detonation causes the prop shaft to immediately stop spinning—with predictable results. Even the best prop-restraining systems are sorely tested by the relentless force of inertia.

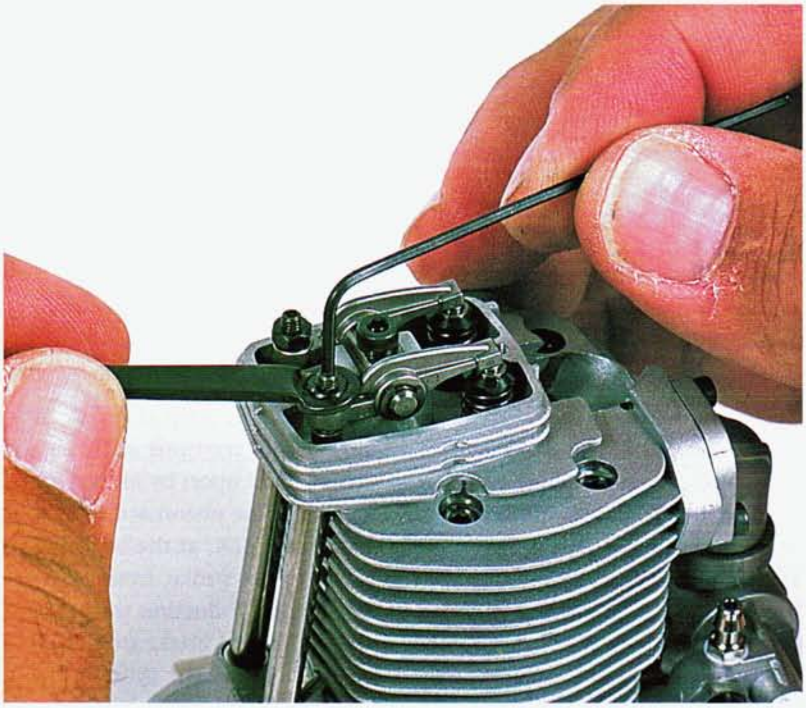
TO PREVENT DETONATION

• Don't squeeze the last rpm out of the engine by over-leaning the high-speed needle valve.

• Run a couple of hundred rpm on the rich side of peak. If you hear pinging during needle-valve adjustment, immediately back it off rich.

When you run any engine—especially a 4-stroke—the only safe position is behind the beast; be sure to also direct helpers and spectators accordingly. Using a fuel with a lower nitro percentage will help to minimize detonation. Reducing the propeller load by using a prop with a smaller diameter and/or pitch will also help.

Since detonation rarely occurs at partial throttle, you may avoid throwing a prop by snapping the throttle closed at the first indication of pinging. Atmospheric conditions also play a role with detonation: hot dry air promotes it, and cool, humid conditions discourage it.



MAINTENANCE

The number-one maintenance problem associated with all model internal-combustion engines is corrosion: the rusting of the internal parts. With 4-strokes, this is especially difficult to control because the crankcase, which houses the ball bearings, crankshaft, camshaft, camshaft surfaces and timing gears, is partly sealed.

There's a controversy about why these components rust. Is it the result of the corrosive gases generated during the combustion process? Could it be promoted by the hygroscopic (water-attracting) action of the methanol in the fuel? Is there a problem with the modern synthetic lubricants in the fuel? Does brass (the tube and "clunk" in the tank) react with fuel components to produce an acid that encourages rust? Maybe it's a combination of these or something not yet considered. One thing is certain: to control rust, before you put your engine away, you must purge the crankcase of residual fluid and replace it with after-run oil. Over the past quarter century, a consensus has gradually evolved.

At the end of every flying session, run the engine at a peaked wide-open throttle for about 20 seconds, and then pull the fuel line off the carburetor (if you can). Using a syringe, inject rust-inhibiting oil through the crankcase breather fitting and rotate the propeller. Tip the engine in various directions to ensure complete component coverage.

Eight to 10 drops of oil dripped into the glow-plug hole while you turn the engine over will lubricate the valve components and ensure that the meehanite (iron) compression ring on the piston is taken care of.

The amount and type of oil you use in the crankcase will depend on the engine's displacement and the recommendations of its manufacturer. Example: for a 10cc (0.61ci) engine, I would use about two tablespoons of Marvel Mystery Oil. Bill Baxter of Hobbico's engine-repair department also recommends Marvel Mystery Oil, Marvel Mystery Air Tool Oil, automatic transmission fluid and a non-graphite gun oil. He says that if the engine is new, WD-40 is an excellent choice. Clarence Lee points out that WD-40 isn't recommended for engines that have already rusted because it breaks rust free of the parts and allows this abrasive iron oxide to wreak havoc on components.

FINAL THOUGHTS

Although the 4-stroke engine isn't the newest prime mover on the block, it offers a bright future for modelers in terms of performance, noise abatement, realism and product longevity.

4-stroke valve timing

BY DAVE GIERKE

The 4-stroke's intake and exhaust valves don't actually open and close at top dead center (TDC) and bottom dead center (BDC) (that is, every 180 degrees), even though, in theory, they do. In modern high-performance designs, engineers extend the intake and exhaust periods by opening valves early and closing them late. For example: the intake valve always opens before TDC at the end of the exhaust operation, and the exhaust valve always closes after TDC at the beginning of the intake operation. This extension results in both valves being open at the same time around TDC. Known as "valve overlap," this seems counterproductive to efficient, powerful operation, but it isn't.

There are two reasons for this extension of the intake and exhaust periods. First, poppet valves do not open and close instantly; like all mechanisms, they require time to move from one position to another. In many 4-strokes, the crankshaft must rotate as much as 30 degrees before the valve is opened to 10 percent of its total lift. Restricted valve openings restrict gas flow.

If the valves could open and close instantly, TDC and BDC still wouldn't be the best choices for their opening and closing; therefore, the second reason to extend the intake-open and exhaust-open periods involves the inertia of the gases involved. Inertia is often defined as, "A body at rest or in motion will continue in that state unless acted upon by an outside force." As the piston accelerates away from TDC at the beginning of the intake stroke, fresh air/fuel gases in the induction tract (the carburetor and intake manifold) are pushed into the cylinder by atmospheric pressure, but because of inertia, this isn't immediate. Moving slowly at first, the induction gases try to catch up with the rapidly accelerating piston; next, the piston decelerates rapidly as it nears BDC, but the mixture charge is now moving rapidly because of the inertia of its motion. If intake-valve closure is delayed until after BDC, the cylinder will continue to fill even as the piston begins its sweep toward TDC on the compression stroke. Extending the induction period maximizes cylinder packing and enhances cylinder pressure, crankshaft torque and engine power.

The principles of inertia also apply to exhaust gases. The exhaust valve opens before the piston reaches BDC (toward the end of the power event), and this allows the still pressurized cylinder gases to leave the engine. Dumping a bit of tail-end power-stroke pressure may seem counterproductive, but the tradeoff saves some of the rotational momentum that would otherwise be used to help scavenge exhaust gases. Because exhaust-gas acceleration and cylinder scavenging begin early, the slowing of the piston near TDC allows the formation of a negative pressure zone in the combustion chamber. The intake valve is opened before TDC, and the partial vacuum promotes the delivery of a fresh mixture before the piston begins its intake stroke. Like the intake valve (which closes after BDC), the exhaust valve's closing after TDC enhances cylinder scavenging for the same reason: the inertia of the exhaust gases. The valves' opening and closing points affect the engine's ability to fill the cylinder with the fresh air/fuel mixture that is necessary for good torque and power production. The ideal valve timing will, however, depend on the type of engine under consideration by the designer: high-rpm, maximum-power-output engines require valves that open early and close late. Fuel-efficient, lower-power engines need valves that open and close closer to the dead centers with reduced valve overlap and less chance of the gases mixing and for reversion (exhaust escaping through the intake valve and into the intake tract).

With 2-stroke cycle port timing, the same events take place in the 2-stroke engine but are completed in one crankshaft revolution; you can imagine why events overlap, gases occupy the same space and the exhaust mixes with fresh air/fuel mixture.

glow plugs exposed

BY DAVE GIERKE · PHOTOS BY PETE HALL · ILLUSTRATIONS BY RICHARD THOMPSON

With the advantage of 20-20 hindsight, I suggest that the glow plug is the most important invention associated with the 70-year production history of the model-airplane engine. In its present form, the glow plug has been produced for more than half a century. Although glow plugs are diminutive and simple in appearance, the science behind their design is surprisingly complex. Numerous magazine articles have been written about glow plugs over the years by authorities such as Nathan Gordon (1940s), Walton Hughes (1950s), Ted Martin (1950s), Bill Netzeband (1960s), Peter Chinn (1960s to '80s) and Clarence Lee (1960s to present); nevertheless, controversy and uncertainty continue concerning how to select and operate them.

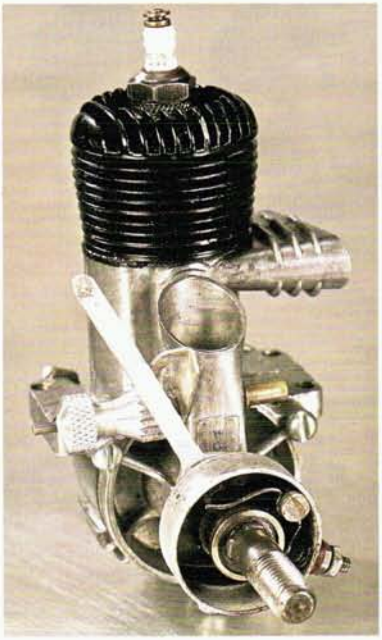
Turning the compression adjustment lever clockwise (as viewed from the top) increases this model diesel engine's compression ratio; turning it counter-clockwise lowers the compression.

With the cylinder head removed from the engine, the long-reach standard glow plug should be flush with the upper surface of the combustion chamber (as shown).

As engine tuners, we are required to understand a bit of science and technology associated with the glow plug, along with an ability to observe, listen and analyze how it affects engine operation. Before addressing these issues, let's investigate two glow-plug dilemmas: does your engine need a short- or long-reach glow plug, and will an idle-bar glow plug improve performance?

SHORT- VS. LONG-REACH GLOW PLUGS

Short-reach plugs are intended for smaller engines with thin heads. If you use a long-reach plug in a short-reach head, it would encroach on the combustion chamber. In the days of baffle-top pistons and wedge heads, the plug might contact the piston at top dead center (TDC). With modern flat-top pistons and hemispherical combustion chambers, the extended plug would merely increase the engine's compression ratio and possibly cause pre-ignition due to hot-spot formations on the exposed threads. Conversely, if you use a short plug in a thick, long-reach head, you'll reduce the engine's compression ratio and, possibly, its power. The engine's instruction manual almost always stipulates which plug is required. If in doubt, remove the cylinder head and check how far the plug projects. The bottom of the plug should be flush with the top of the



With the drive washer, prop washer and shaft nut removed from this antique Ohlsson & Rice .23 spark-ignition engine, you can see the interior of the ignition-timer mechanism. By the mechanical action of a cam that's machined onto the crankshaft inside the timer housing, a movable electrical contact opens and closes against a stationary contact. By moving the timer lever that's attached to the timer housing, the engine's ignition point (spark) may be advanced (lever moved up) or retarded (lever moved down) in relation to TDC.

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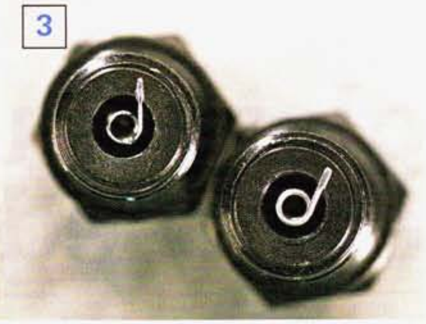

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1. This Merlin glow plug type 2001 features a nickel-plated plug body and a cold rating. The type 2005 has black-oxide plating and a hot rating. Merlin offers several other plugs with temperature ratings that range from very cold to very hot. 2. The nickel-plated Fox Standard long plug is rated medium. The nickel-plated Pro Series no. 8 is rated cold. The no. 8 plug has a smaller cavity diameter. Fox, a longtime manufacturer of glow plugs, has many other reaches and temperature ratings that include: Std. Long (hot); Std. Short (medium); and Std. Short (hot). 3. The black-oxide-plated Novarossi C4-S plug is rated hot. The black-oxide-plated C8-S is rated very cold. The only discernible difference between the two is the diameters of their wire elements; the C8-S's element is thicker. Novarossi also offers a C5-S (cold), C6-S (cold) and a C7-S (very cold). 4. The nickel-plated O.S. A3 plug is rated hot; the nickel-plated no. 8 is rated cold, and the black-oxide-plated R5 is rated very cold. O.S. also offers an A5 plug that is rated medium. 5. The nickel-plated Enya no. 3 plug is rated hot; the nickel-plated no. 6 plug is rated cold. Notice the thicker wire element in the no. 6 plug. Enya also offers a no. 4 plug that is rated hot and a no. 5 that is rated medium.

combustion chamber. If you're using an idle-bar plug, no more than the bar should extend into the chamber. If any threads show, change to a short-reach plug. Keep in mind that short-reach plugs can easily strip the threads in the aluminum alloy head, so tighten them carefully! Long-reach plugs are less likely to strip the threads, but they still have the potential to do so. Other than depth of the thread, there is no other significance to a glow plug's reach. Short-reach plugs are generally used in engines of .15ci displacement or less.

IDLE-BAR GLOW PLUGS

Idle-bar glow plugs are intended for use with engines that are equipped with throttles. While idling, 2-stroke engines have a tendency to form a pool of liquid fuel in the crankcase; this is called "loading." When the throttle is snapped open, the puddled fuel rushes through the cylinder transfer ports, impinging on the wire element of an unshielded plug and instantly quenching it. In theory, the idle bar is designed to deflect the stream of liquid fuel away from the plug's element. If your engine experiences a rich, erratic idle and/or a rich "flameout" during transition to wide-open throttle (WOT), try an idle-bar plug. If an engine doesn't need to be throttled (e.g., in certain racing events), it doesn't need an idle-bar plug. Idle bars protrude into the combustion chamber, disrupting normal flame propagation and potentially causing pre-ignition. Pre-ignition, a combustion defect, can originate from hot spots that form on the edges and corners of the idle-bar and cause the air/fuel mixture to ignite earlier than intended (see the sidebar, "The Idle-Bar Glow Plug: Treating the Effect" on p. 13) and potentially causing pre-ignition. Pre-ignition, a combustion defect, can originate from hot spots that form on the edges and corners of the idle bar and cause the air/fuel mixture to ignite earlier than intended.

TEMPERATURE RATING AND SELECTION

Glow-plug temperature rating and selection are more complicated and more difficult—but not impossible—to understand and to master. As I see it, there are six parts to the question:

1. How does the glow-plug engine ignite fuel?

Crankcase-scavenged 2-stroke glow engines have relatively low compression ratios, averaging between 7:1 and 9:1 with an alcohol (methanol)-dominated fuel blend. Methanol's ignition temperature (725 degrees F) cannot be reached by the engine's compression alone; something else is needed to attain this temperature. The maximum possible temperatures at compression ratios of 7:1, 8:1 and 9:1 are: 692, 755 and 815 degrees F, respectively; because there are losses associated with compression leakage and heat transfer to the cylinder wall and head (plus other factors), these theoretical temperatures are never realized. Here's where the glow plug comes into play. For engine startup, electric current passes through the plug's coiled-wire element, causing it to incandesce (glow) orange-white, producing a temperature in excess of 1,500 degrees F. When the engine is cranked over by hand or with an electric starter, the air/fuel mixture ignites in the combustion chamber. If the mixture ratio is within the range of combustibility, the engine will continue to fire, becoming self-sustaining. When the starting battery is removed, the plug element continues to glow and the engine continues to run.

2. How do glow plugs work?

Glow-plug ignition of the air/fuel mixture is controlled by three factors: combustion, catalytic action and compression. Combining the first two factors produces an element temperature that's high enough to ignite the engine's compressed air/fuel mixture, providing sustained (cycle-to-cycle) operation.

Heating the coil via combustion causes the glow-plug element's temperature to soar to over 1,500 degrees F. Although it cools rapidly, a significant portion of this temperature is carried over to the next cycle.

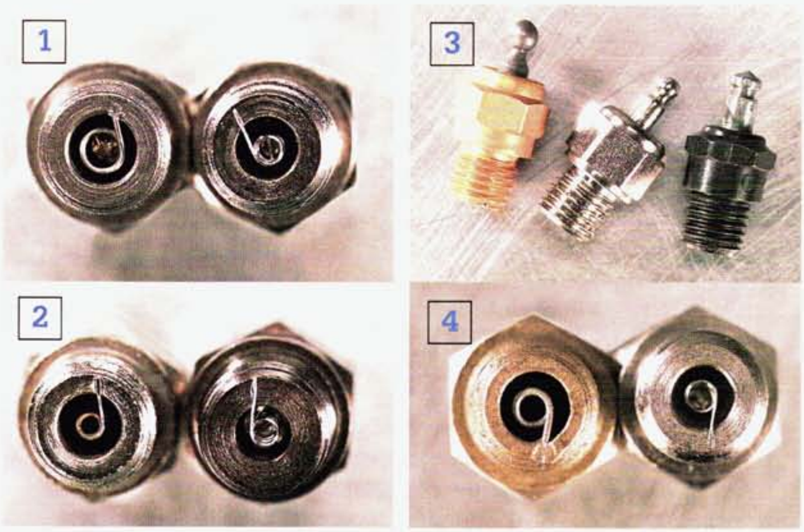
When alcohol vapor interacts with platinum (silver-white metal), an exothermic (heat-release) reaction takes place. Acting as a catalyst, platinum is not physically changed by the reaction, but its temperature increases. Therefore, the platinum-alloy wire element experiences a further increase in temperature as the vaporized air/fuel mixture is transferred into the cylinder and during compression. (Note: due to platinum's brittle state at high temperatures, a platinum-iridium or platinum-rhodium alloy is used to improve element longevity.)

Although the glow engine's compression process cannot raise the temperature of the plug's wire element to the ignition point for methanol-based fuel, it still has an important role to play. By compressing the gaseous air/fuel mixture, its internal energy (heat) is increased; heating speeds up the motion of reactive molecules and produces something we call "compression conditioning." The thermal theory for ignition suggests that burning starts only when the gaseous mixture becomes hot enough, and the molecules collide often enough. Some of these collisions result in an ignition reaction at the glow-plug element.

3. Why do we need glow plugs with different temperature ratings?

Some call the glow-plug engine a fixed-ignition-point design, but nothing could be further from the truth.Unfortunately, this myth confuses the glow-plug temperature-rating issue; sweep it from your mind.

Spark-ignition engines control ignition-point timing with a mechanical or electronic advance-and-retard system. Crankcase-scavenged model diesel



1. The number of coils within the plug cavity represents the total length of the element wire. Note the single coil (left) compared with the multiple-coil element. 2. The size of the element cavity affects the plug's rating. The small cavity (black-oxide plug) helps reduce the temperature rating; the large cavity (nickel-plated) helps increase the temperature rating. 3. The type of plating used for the plug body helps control the temperature of the element wire. Nickel plating reflects heat (infrared radiation), and that helps retain the element's temperature. Black-oxide plating absorbs heat, so it helps reduce the element's temperature. The qualities of Rossi's copper-plated R.A. (cold) plug fall somewhere between those of nickel-plated and black-oxide-plated plugs. 4. The diameter of the plug's wire element helps to determine its temperature rating. Smaller-diameter wires tend to increase the element's temperature, and larger-diameter wires tend to reduce its temperature. Larger-diameter wire is more durable than small-diameter wire—an important glow-plug design factor when you use fuel that has a high nitro-methane content in high-performance engines.

SPECIAL GLOW PLUGS

NELSON PLUGS. In the late '70s, control-line speed flier Carl Dodge modified a GloBee plug into the first two-piece chamfer-nose (angled) design. Although the new design produced superior engine performance compared with conventional 1⁄4-32 plugs, the reason for this increase remains unclear. The problem with the 1⁄4-32 plug seems to be associated with its screw threads being exposed to high-pressure combustion gases, all the way to the sealing washer. Dodge's two-piece plug differs from the conventional glow plug in terms of fastening and combustion-gas-sealing methods; when the threaded retainer sleeve is screwed tightly into place, the chamfered nose of the element body matches a similar surface within the head, producing a sealed and seamless transition with the combustion chamber.

Above, left to right: Nelson's two-piece, GloBee-type, chamfered-nose plug closely resembles the original Carl Dodge innovation of the late 1970s; it's available in STD (standard), heavy STD and with a heavy (cold) coil. The one-piece, chamfered-nose Nelson plug is the granddaddy of all "turbo" plugs; the STD is rated medium. Henry Nelson also makes an HD (heavy duty) that's rated cold. The nickel-plated plug with the relatively small nose chamfer is the O.S. P6 "turbo" (hot). O.S. also makes a P7 (medium) and a P8 (cold). The black-oxide-plated plug is a Novarossi "Turbo Ultra" (C8TGF) that's rated very cold. Novarossi also makes a C7TGF (cold) and a C6TGF (medium).

In the early '80s, Henry Nelson was the first to offer a one-piece plug that incorporated a chamfered nose to match an angled seat within the head, as with Dodge's design. As before, the gas seal occurs before the fastening threads. Today, these chamfer-nose units have 11⁄32-32 threads and are known to airplane-racing enthusiasts as "Nelson plugs" and to RC car modelers as "turbo plugs." In conjunction with Ohlsson, the assembler, Nelson also produces a version of the original GloBee two-piece plug for various speed and racing competition events.

4-STROKE PLUGS. Four-stroke cycle engines are required to retain their plug-element temperatures throughout the exhaust and intake strokes before entering the compression event and the next ignition point. To accomplish this, 4-stroke plugs must have a very high temperature rating. In 1977, O.S. Engines was the first to successfully incorporate a glow plug (type F) into a mass-produced 4-stroke cycle engine: the revolutionary FS-60 single-cylinder design.

Most 4-stroke glow plugs are characterized by an extended nose projecting into the combustion chamber.

Because of their location, the nose and wire element are exposed to higher temperatures than a standard plug, extending their useful temperature to the next ignition point.

Special glow plugs for 4-stroke engines (left to right): the O.S.-F plug is the granddaddy of all 4-stroke glow plugs and the originator of the extended-nose concept of temperature retention; the Merlin "Hosenose" plug incorporates interesting internal cavity dimensions and element design; Enya's latest entry features traditional technology.

engines control ignition timing by mechanically adjusting the compression ratio through a movable head known as a "contra-piston." Although adjusting the glow engine's ignition- point timing isn't as obvious, it happens regularly by changing variables such as the propeller load, nitromethane content, lubricating oil content, compression ratio and glow-plug temperature rating. The engine's mechanical condition and even the weather conditions play a role. We adjust an engine's ignition point to attain the optimum peak-pressure point ("sweet spot") after TDC that ultimately produces the best engine performance and longevity. Changing glow plugs within the "hot to cold" range is often the first adjustment made to an engine's ignition point.

4. How does a glow plug's temperature rating change the engine's ignition point?

"Heat range" isn't the best term to describe what transpires within the glow plug. Outside the world of science and technology, words such as "heat" and "temperature" are often used interchangeably; unfortunately, however, they don't have the same meaning. Without belaboring the point, I'll just say that I prefer to use the term "temperature rating," which is more scientifically correct for describing how the glow plug advances or retards an engine's ignition-point timing. As long as you understand that the traditional words "hot" and "cold" actually refer to temperature, you can call the phenomenon anything you wish! There are times when "hot" and "cold" are less clumsy to use.

Example: assume that a "hot" (high-temperature-rated) glow plug has replaced a "cold" (low-temperature-rated) plug. How does this affect the engine's ignition-point timing? The ignition point advances; that is, it occurs earlier in the compression event. Why does this happen? During normal engine operation (with the starting battery removed), the "hot" plug's higher element temperature allows the compressing air/fuel mixture to arrive at its ignition temperature before that of the "cold" plug. Recall that plug-element temperature is the result of combustion temperature and catalytic-action temperature, with compression conditioning of the air/fuel mixture acting to initiate combustion. The opposite happens when a "cold" plug replaces a "hot" plug: the lower temperature of its wire element requires more compression conditioning of the air/fuel molecules to reach its ignition temperature. This takes place closer to TDC and therefore acts to retard ignition-point timing.

With dozens of glow-plugs brands available on the world market—each offering a range of temperatures—incremental changes to the engine's ignition-point timing can, theoretically, be made. Later, we will investigate the promise and the reality of "sweet spot" engine tuning by glow-plug temperature rating.

5. How do manufacturers make glow plugs "hot" and "cold"?
A plug's temperature rating depends on many factors, including:

- Element alloy specifications: platinum iridium or platinum rhodium and alloy percentages.
- Element dimensions: wire-gauge size, length, coil diameter, number of coils.
- Plug cavity and geometry (e.g., diameter and depth).
- Position of element in cavity.
- Plug-body finish: reflective or absorbing.

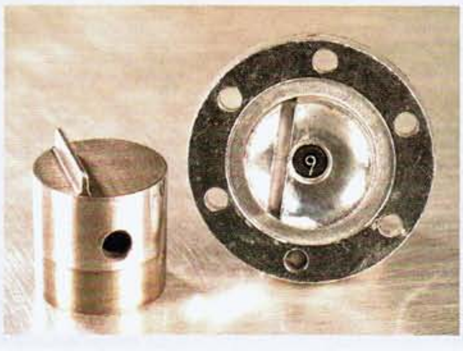
The platinum-alloy element is usually the focus of attention when enthusiasts discuss a plug's temperature rating. The conversation often goes something like this: "This plug has a thick wire element, and it doesn't have many coils, either; it's a cold plug." This is likely, but many other factors contribute to a plug's

The idle-bar glow plug: treating the effect

Early cross-scavenged 2-stroke engines were equipped with piston baffles that deflected fresh air/fuel mixture toward the glow plugs, making them susceptible to element quenching during idle and throttle-up. The common boost-transfer-port variation of the modern Schnuerle-ported engine often exhibits this same problem.

The idle-bar plug is a stopgap measure that treats the effect rather than the cause of element quenching. Plug-element quenching results from poor mixture control during throttle-down/throttle-up and idling, in addition to the engine's inability to keep fuel vaporized in the crankcase. Simple model airplane engine carburetors are not up to the task of maintaining the correct air/fuel ratio throughout its range of throttlability. Complex automotive-type carbs couldn't do it; that's why the auto industry moved to fuel injection when solid-state electronic technology became available.

An important—and often overlooked—factor concerns fuel vaporization in the crankcase. Vaporized fuel mixed with available air is in the best possible physical state (a gas) in preparation for combustion. If all the fuel is vaporized, crankcase "loading" and plug-element quenching would not occur. Unfortunately, methyl alcohol requires a lot of heat to change from a liquid state to a gaseous state, so the engine's crankcase quickly cools, and thus limits, the fuel-vaporization process while forming a pool of liquid fuel. One solution to this dilemma is to heat the crankcase, but this severely reduces the engine's ability to transfer a dense mixture charge into the cylinder. Although inconsequential at partial throttle, wide-open-throttle performance suffers greatly, with a 20- to 25-percent reduction in brake horsepower. Someone should invent a crankcase heater that works only when the engine is throttled, so we could throw away the inefficient idle-bar glow plug! While we're waiting, avoid directing cool air over the crankcase (below the cylinder fins) of your cowled 2-stroke engine; this promotes crankcase loading.



Above: this Super Tigre fuel-metering (twin-needle valve) carburetor illustrates a major technical advance in controlling the engine's air/fuel mixture during idle and throttle-up during the 1960s. Despite improvements in carburetion, crankcase-loading and plug-element-quenching continue to plague RC engines. Left: modern engines use Schnuerle transfer ports (usually two) and a third boost port. The boost port is usually angled toward the head causing plug-quenching problems during idle and throttle-up, similar to the baffle-piston configuration. Bottom: Older (cross-scavenged) engines were susceptible to plug quenching during idle and throttle-up, due to transferred air/fuel mixture being directed toward the wire element by the piston baffle.

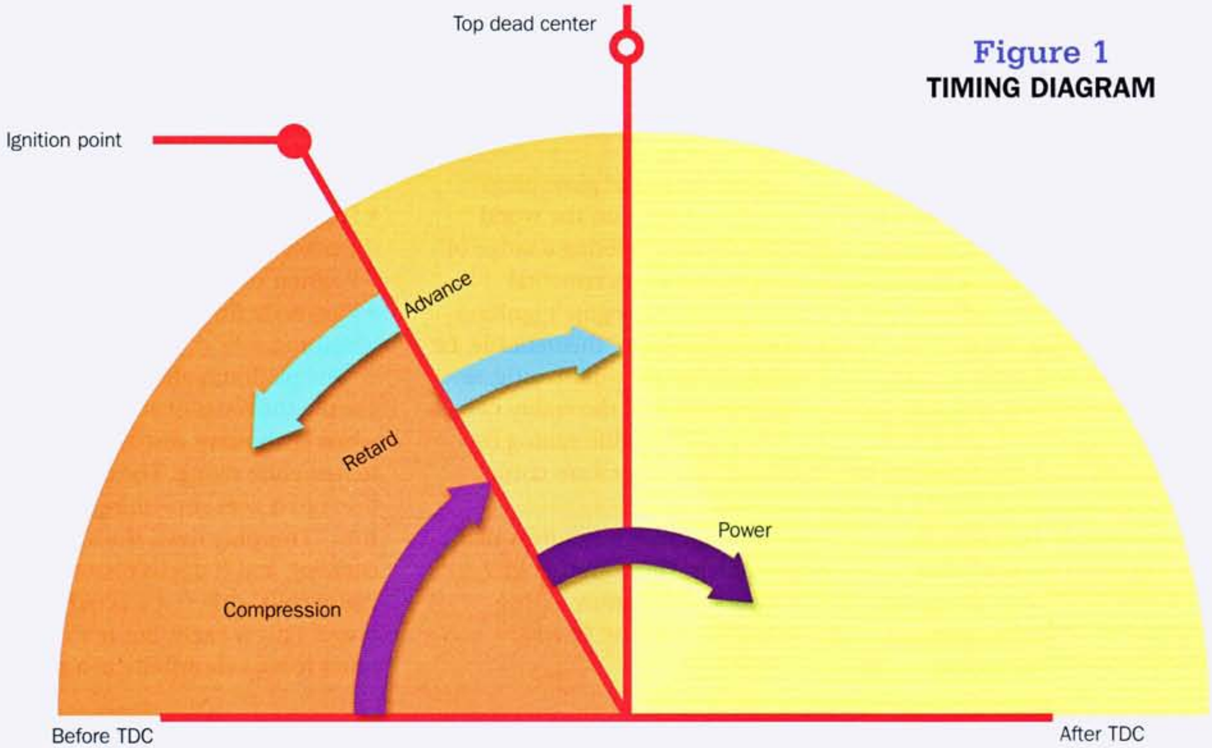


Figure 1
TIMING DIAGRAM

temperature rating. My friend Clarence Lee once wrote:

"As simple ... as the glow plug appears to be, it is actually more complicated than you might believe. You can't just stick a piece of platinum wire in the machined body and expect it to work. I had a hand in the development of the old Veco glow plug and can speak with some authority on this. You can completely change the characteristics [temperature rating] of a glow plug by using either a black-oxide or nickel-plate finish. With all of these variables, just think of all the possible combinations you can come up with for experimentation."

The difficult part of glow-plug design comes with assigning a value to each variable; things change when the variables interact! By modifying the plug's finish, how much will its temperature rating change? What about the length of the element wire in relation to the diameter of the element cavity? How about the thickness of the element wire compared with the number of coils, etc., etc.? Although no single factor determines a glow plug's temperature rating, some generalizations can be made:

- A small-gauge element wire tends to raise the plug's temperature rating.
- A small-diameter plug cavity tends to lower the plug's temperature rating.
- A reflective finish (nickel plating) within the plug cavity raises the temperature rating.
- An absorbing finish (black oxide) within the plug cavity lowers the temperature rating.

Left: typical glow-plug cross-section. Plugs' designs, materials and fabrication techniques vary with their producers.

• Extending the element coil beyond the plug body elevates the temperature rating.
• Pushing the element into the plug cavity lowers the temperature rating.

Thermodynamics research engineer Frank Vassallo says, "There are some very complex interactions taking place inside a glow plug." I think you get the picture. At the risk of offending glow-plug designers and manufacturers, there are no glow-plug experts. Glow plugs represent a form of black art, where empirical knowledge (trial and error) reigns supreme. In the end, determining the engine's ignition point in relation to TDC is probably the best method of evaluating a glow plug's relative temperature rating (see Figure1).

There are other design considerations besides the glow plug's temperature rating. The physical dimensions of the wire element determine the voltage that must be applied to the plug to achieve white-orange incandescence for engine startup. There are also issues of element attachment, electrical insulation, center electrode retention and high-pressure gas sealing.

6. What's the best way to select a glow-plug temperature rating for my engine?
Manufacturers supply us with glow plugs that have been assigned specific temperature ratings. Unfortunately, these ratings differ among manufacturers. An example of this discrepancy is the McCoy no. 59 glow plug that's rated "hot." Experience has shown that the McCoy's ignition-point temperature rating is equivalent to the Rossi R5, which is rated "very cold." In a perfect world, all glow plugs would be neatly arranged, from the highest temperature rating to

Nitromethane: its effect on ignition point

There has been some discussion on whether nitromethane advances or retards an engine's ignition-point timing. I'll attempt to clarify this issue with the following example:

Problem: after the engine has been started and the glow-plug battery removed, the rpm immediately drops by 300 as indicated by an accurate tachometer.
Analysis: an rpm drop suggests that the ignition-point timing is retarded (late), compared with when battery heating was applied; this produces a later peak pressure point (after TDC) with reduced cylinder pressure, torque and brake horsepower.

Solution: a retarded ignition point may be corrected in a number of ways including the installation of a hotter plug.

The dilemma: since nitro is very slow burning, adding it to the fuel blend would seem to further retard the ignition point, moving the peak pressure point even farther away from its after-TDC sweet spot. Therefore, why does increasing the fuel's nitro content advance the ignition point?

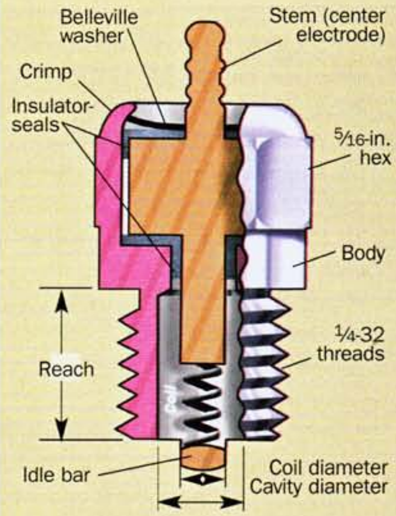
THE THEORY

By increasing the percentage of nitromethane in the fuel blend, we are certain that there is an additional cycle-to-cycle heat release from the combustion process. The extra heat shows up as a temperature boost to the glow plug's wire element, adding to its catalytic action. The increased temperature forces the relatively "cold" plug to act "hotter," initiating an earlier (advanced) and corrective ignition point.

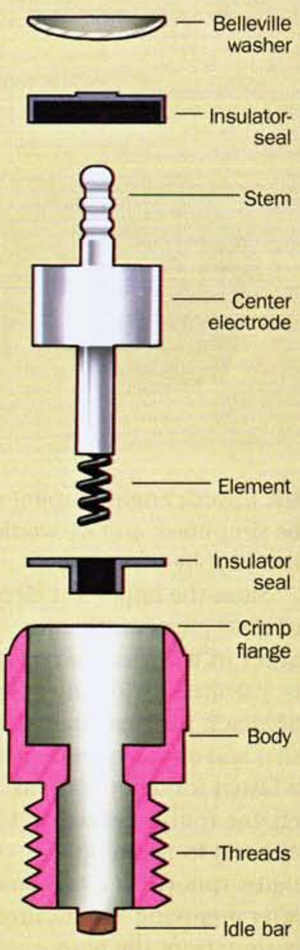
The opposite is true concerning a plug that's too "hot," where the engine begins to detonate when the needle valve is leaned toward peak rpm. A "colder" plug will retard the ignition point. Reduced nitro content, however, will also retard the ignition point by reducing combustion heat release and lowering the plug element's temperature, making the "hot" plug act "colder."

Finally, "cold" glow plugs (usually with thicker wire elements) hold up better under the elevated temperature and pressure rigors of high-nitro (more than 30 percent) fuel blends. "Hot" plugs usually have smaller-diameter wire elements and are susceptible to melting or mechanical damage under these conditions.

GLOW-PLUG CUTAWAY

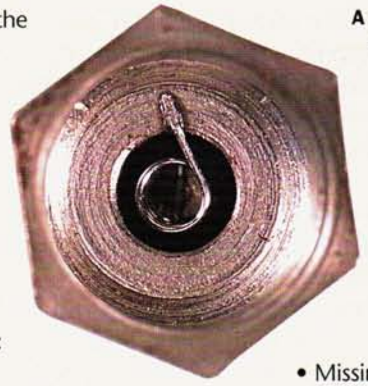


GLOW PLUG EXPLODED- PARTS VIEWS



"READING" THE GLOW PLUG

For decades, "reading" the condition of the glow plug has provided experts with information about the suitability of the plug's temperature rating as well as the engine's mixture setting. Because speed fliers and pylon-racing specialists often replace the glow plug after each run, they have the opportunity to inspect the plug's platinum-alloy wire element on a regular basis. Here's what you can learn from its physical condition:



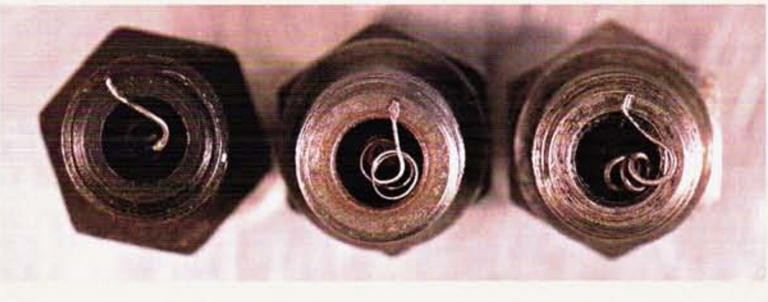
A relatively new-looking plug with a shiny coil and a clean cavity indicates that the engine has been run excessively rich and/or under-compressed.

• Shiny coil with a clean element cavity. The shiny coil indicates that the air/fuel mixture has been consistently rich or the engine is under-compressed. The clean cavity also suggests that the plug is relatively new.

• Gray coil with a brown or black element cavity. The gray element represents a microscopically pitted surface that could fail, i.e., a wire could break, at any time. The varnished element cavity indicates that the plug has been in use for quite some time, and its failure is imminent.

• Slightly gray coil with a slightly brown element cavity. This plug has been in use for a while, but indicates a satisfactory (slightly rich) air/fuel mixture setting—especially if the coil hasn't been distorted (as in sport flying). Note: to a speed or racing enthusiast, this plug, along with a slightly distorted element, indicates a nearly perfect run!

• Missing element, badly distorted element, or element pulled from the plug cavity. Many factors can contribute to these conditions, including a lean mixture setting, excessive compression ratio, elevated nitromethane content (fuel), too much propeller load, adverse weather conditions, or a combination of the above. Correction involves one or more of the following: use a lower-temperature-rated (colder) glow plug; lower the compression by adding a head shim(s); reduce the fuel's nitro content; and reduce the diameter and/or pitch of the propeller. Because a missing glow-plug element can ruin the engine's piston and/or sleeve, the cylinder head should be removed so that you can pick out any pieces of the wire element (a toothpick works well) that may remain on the piston, head, or cylinder wall before running the engine again.



Glow plugs with elements that are missing, badly distorted, or pulled from the cavity; everything that has happened to these plugs is bad!

the lowest; engine tuning would be simplified, and we would all live happily ever after.

Since the important elements of glow-plug construction (that affect its temperature rating) can't be calculated with any degree of accuracy, the best alternative is trial and error experimentation:
• Listen for detonation as engine rpm is peaked and allowed to warm up.
ngine rpm (with a tachometer) after removing the starting battery from the plug.
• "Read" the plug (see sidebar above, "'Reading' the glow plug").

An inexpensive, experimental method for determining the temperature rating of a glow plug has yet to be demonstrated. Here are some ideas. A glow plug's temperature rating could be determined if it were possible to accurately measure the engine's ignition-point timing in terms of degrees of crankshaft rotation before top dead center (TDC). The more advanced the ignition point, the "hotter" the plug (with all other variables constant). A cylinder-pressure transducer can do the job, but it must be extraordinarily fast to detect the first hint of pressure rise due to combustion. The necessary pressure transducer, data acquisition and software technology exist (e.g., Hi-Techniques Inc. REVelation), but the cost is prohibitive. Who is willing to invest $75,000 to establish a temperature rating system for glow plugs? Auto racing's Formula 1 and certain NASCAR teams use this technology to

Glow plug problems & solutions

Melted element from detonation. A glow plug's platinum-alloy wire element exists in the harsh environment of elevated temperature and pressure. If the combustion temperature exceeds the alloy's melting temperature (3,200 degrees F), as it would during prolonged detonation, it will melt. The solution is to identify and eliminate the cause of detonation (compression ratio is too high; nitromethane content in the fuel is too high; propeller load is too high; glow-plug temperature rating is too high).

Melted element from metal particles. Aluminum particles that contact the glow-plug element will combine with the platinum alloy, lowering its melting-point temperature and causing the wire to "burn" (melt) at that location. Aluminum particles usually originate from the engine's backplate, where they are scraped off by the end of the crankpin or connecting rod. This clearance problem can generally be corrected by installing a second backplate gasket.

Silicon poisoning. Silicon compounds in the fuel blend produce a glass-like deposit on the platinum-alloy wire element, causing it to slowly lose its catalytic action. Although the plug element glows brightly and continues to offer reliable start-up performance, its temperature rating slowly declines (turns cold), and the engine's ignition point retards. When the engine begins to experience idle-performance problems, it's time to replace the plug. Most reputable fuel manufacturers have stopped using silicon compounds as an anti-foaming agent, but some modelers still give each new gallon of fuel a "shot" of Armor All—a kiss of death to the glow-plug element!

Broken coil. Since it's impossible to balance a single-cylinder engine to run smoothly throughout its practical speed range, glow-plug elements have been known to break after having been literally "shaken to death." Vibration is often the culprit if the element wire looks new but a coil is broken. Somewhere within a narrow rpm band of the single-cylinder configuration, moderate to severe vibrations can be expected. Properly balanced multiple-cylinder engines are less prone to vibrate. Because most engines shake to one degree or another, it's important not to load (prop) them to operate within their vibration zone.

Leaking glow-plug gasket or stem seal. A leaking copper gasket or glow-plug stem seal can cause the engine to run lean, overheat and damage various internal components. Check for leaks by placing a drop of oil on the plug gasket and stem (center electrode) while slowly turning the engine over by hand with the propeller in place. Watch for telltale bubbles that verify the leak. If the copper gasket leaks, replace it. If the glow-plug stem seal leaks, replace the glow plug.

Increase glow-plug life and effectiveness

• When installing a new glow plug, save the package or write down the manufacturer, specifications (long; short; temperature rating), engine and date of installation. Most plugs lack identification, so why trust your memory?

• Never remove or install a glow plug with needle-nose or slip-joint pliers! This will butcher not only the plug body but also the engine's cylinder-head fins. Always use a glow-plug wrench.

Eliminating occasional thread imperfections with a ¼-32 die can prevent damage to the engine's cylinder head.

Keep track of your engine's glow plug. Keep the package, and record important information—date of installation, temperature rating, etc.

• Before removing a glow plug from the engine, clean the area of the head that surrounds it. A generous shot of cleaner from a spray bottle or a short spray of fuel from a syringe will usually clear the opening of any dirt or debris that might otherwise enter the engine as you remove the plug.

• Standard glow plugs have ¼-32 threads. There have been instances where incorrectly cut glow-plug threads have stripped the relatively soft aluminum alloy cylinder head, necessitating its replacement or the installation of a Heli-coil. Thinking ahead, engine experts check the threads of all new glow plugs with a ¼-32 die prior to installing them.

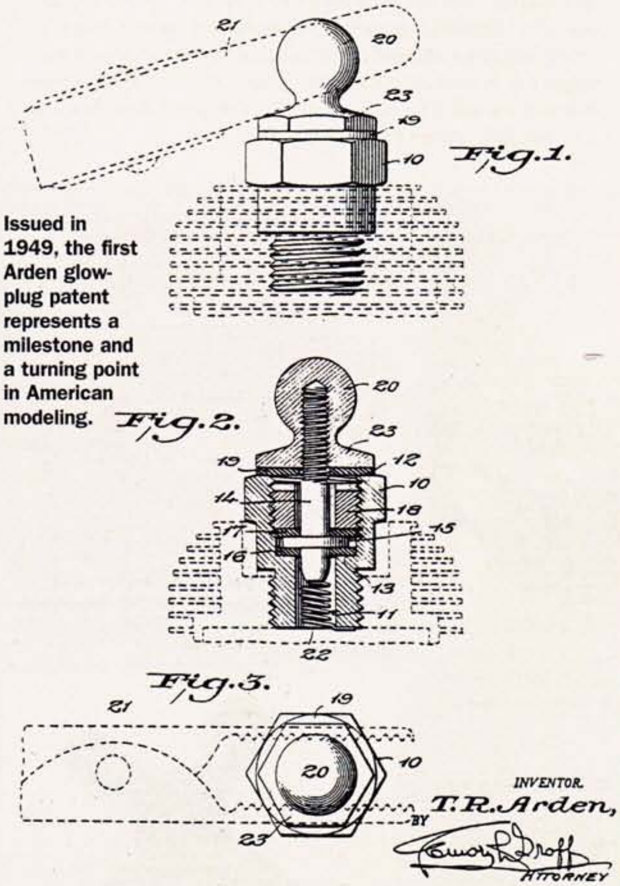

Using the correct glow-plug-removal tool minimizes the potential for damage to the plug and engine.

• When the engine is obviously flooded, turning over the engine with an electric starter may push the element to one side of the plug cavity; this can change the plug's temperature rating (making it colder), which alters the engine's ignition-point timing and performance. If the engine is flooded, take time to remove the plug from the engine and blow out the flood prior to restarting.

HISTORY OF THE GLOW PLUG

The statement, "There's nothing new under the sun" describes many aspects of technology, including the glow plug, which straddles the history of the internal-combustion engine. John Reynolds was the first to use a hot platinum wire (battery-powered) in his unsuccessful engine design of 1845. Nicolaus Otto, inventor of the first successful 4-stroke cycle engine, patented a platinum wire-bundle design that was mounted on a poppet valve in 1878. Even Dugald Clerk, inventor of the 2-stroke cycle engine, suggested using a grid of platinum wire within the combustion zone. Inventors rejected the use of platinum-wire glow ignition for reasons other than its effectiveness. In his excellent book, "Sparks and Flames" (Tyndar Press, 1997), Crawford MacKeand states, "The electric hot wire igniter ... presented an inordinately heavy load for the batteries of the period [1880s], and so would have required an expensive dynamo [generator]."

Thomas R. "Ray" Arden is credited with introducing the glow plug to model aviation in the summer of 1947. Shortly thereafter, in January 1948, he filed for a patent, which was finally granted in September 1949. By then, there were at least four companies manufacturing and selling glow plugs for the burgeoning glow-engine market in the U.S. The glow plug was considered by many to be the most influential patent in modeling history, but Arden didn't cash in on his invention; he was too busy defending it in the courts. As a matter of fact, Kenneth Howie of H&H .45 engine fame was granted a patent for an interchangeable "hot-coil" ignition engine in 1937. Unfortunately, because of WW II, Howie didn't get his engine into production until 1947. The H&H engine didn't sell well (in fact, it was a flop) because it looked old-fashioned with its obsolete side-port induction system and tall, two-piece



Issued in 1949, the first Arden glow-plug patent represents a milestone and a turning point in American modeling.

Above: besides the pioneering Arden glow plug, the McCoy Hot Point, Ohlsson & Rice Kwik-Start and Champion VG-2 plugs were very popular with modelers. Left: Arden introduced the first commercially available glow plug to modelers in the summer of 1947. Below: the heavy-duty element-support bar on Champion glow plugs was not designed to be an idle bar.

optimize the performance of individual cylinders on their racing engines.

There may be other ways to measure the ignition point, including an accelerometer mounted on the outside of the engine's cylinder, as suggested by engine authority Luke Roy. Could detecting the onset of the engine's shake be used to determine the onset of combustion?

Another tactic might be to run the test engine with a glow plug that has yet to be temperature-rated by adjusting the needle valve to its maximum rpm while allowing the engine to temperature stabilize. Shut the engine down. Next, switch to a spark plug and spark-ignition system. Restart the engine and allow it to temperature stabilize while retaining the previous needle-valve setting. By manual or electrical means, adjust the advance-retard mechanism to crankcase, but it ran great on its glowing platinum-wire element that was mounted horizontally, just below the cylinder head. Modelers, however, paid little attention; they were enthralled with modern glow-engine designs from Fox, McCoy and K&B, as well as the exciting new "baby" (½A) glow engines from K&B, Herkimer and Anderson.

After the courts upheld Arden's original patent, he next patented a glow plug with interchangeable hot and cold elements for those who wanted to experiment with various fuel blends. Complicated and expensive to produce, the new plug was a commercial failure due to an element-attachment problem. The hot/cold idea, however, represented the first attempt at controlling the glow engine's ignition-point timing by altering the plug's temperature rating. Arden glow plugs were the first to use platinum-iridium alloy elements, which proved to be tougher than pure platinum. By the mid-1950s, Fox and Enya began manufacturing glow plugs with platinum-rhodium alloy elements; it was claimed that they were less brittle and exhibited a superior idle.

The glow plug created excitement among modelers after 1947, but it generated sleepless nights for manufacturers of spark-ignition engines who were caught with large inventories. In his "The Glow Plug Engine, 1950-'65," the late Art Suhr summed up the dilemma: "Most [manufacturers] simply modified their [ignition] engines slightly and sold them as glow models. A common practice was to offer them as either a spark or glow model. The glow model was usually [sold] minus the [ignition] timer assembly and plastic tank, although a few companies modified the heads, connecting rods and other critical components."

For glow-plug manufacturers, the early days weren't exactly a picnic; they often experienced serious quality-control problems. Modelers were alarmed to discover electrical shorts, loose center electrodes, leaking seals and insulating materials that softened when heated. Electrical resistance varied within certain brands, indicating that adjacent coils within the element were touching. Reduced resistance increased the likelihood of burnout when connected to the starting battery. Modelers were advised by magazine columnists to inspect element coils and "adjust" them with a pin if they were touching! The learning curve for glow plugs, like that of any new technology, was steep.

A vintage K&B "greenhead" .19 (1952) fitted with K&B's early speed-control system. When operating from the low-speed needle valve, the engine was forced to run "4-stroking" rich. To avoid a sudden flameout, the first idle-bar glow plugs were employed.

IDLE-BAR PLUG

Liquid fuel directed at the glow-plug element during throttling (idle and acceleration) results in a quenching action. The idle-bar glow plug helped to partially resolve the problem. Although its origins are obscure, one thing is clear: Champion did not make a conscious effort to develop the technology. In fact, the Champion glow plug appears to be another splendid example of serendipity—the faculty for making fortunate and unexpected discoveries by accident. Ted Martin, an early engine expert who wrote for Model Airplane News in the early 1950s, said: "One apparently excellent means of securing filament [element] support is the use of a bar across the mouth of the plug, with the filament fused to its center, as featured in all Champion plugs. This bar, incidentally, is not a shield, and the Champion may be classed as a free-mixture-flow type." The first throttling, twin-needle valve, glow-ignition engines weren't produced until 1952—three years after the introduction of the Champion glow plug.

When the twin-needle engines of K&B, Fox and Cameron had difficulty transitioning to high speed from a very rich idle, it was discovered that the Champion glow plug offered better performance than plugs that didn't have an element attachment bar. Other plug manufacturers took note, and the idle-bar plug was born. Duke Fox is credited with introducing the one-piece idle bar glow plug in the mid-1950s. Prior to this, all idle-bar plugs used spot-welded bars that occasionally broke loose, causing catastrophic mechanical damage to the engine. Regardless, to this day, most idle-bar glow plugs continue to be spot-welded.

Left: the Fox idle-bar glow plug has been in production for almost 50 years. The bar is machined as part of the plug body and will not detach during the rigors of engine operation. Right: when spot-welded into place, idle bars have been known to come loose and cause catastrophic internal-engine damage.

obtain the same engine rpm. Shut the engine down. With the aid of a crankshaft-mounted degree wheel, carefully determine the ignition point in terms of degrees of crank rotation before TDC. Although tedious and time-consuming, this procedure might provide meaningful glow-plug temperature ratings that all engine-tuners could use.

With or without a temperature rating system, there is no "best" glow plug for all engines and applications. The good news—there is a glow plug that's best suited for your engine. The bad news—you need to hunt for it!

Special thanks to Frank Vassallo and Luke Roy for their valuable insights and suggestions that helped immensely with the theoretical and practical aspects of this undertaking.

gas engine starting guide

BY GERRY YARRISH

To properly operate and maintain models, you need support equipment that is up to the task. Two of the most important concerns with giant-scale models are safely starting the engine and handling the fuel (gasoline). When you switch from glow engines to gasoline burners, you have to change some of the equipment —start thinking big!

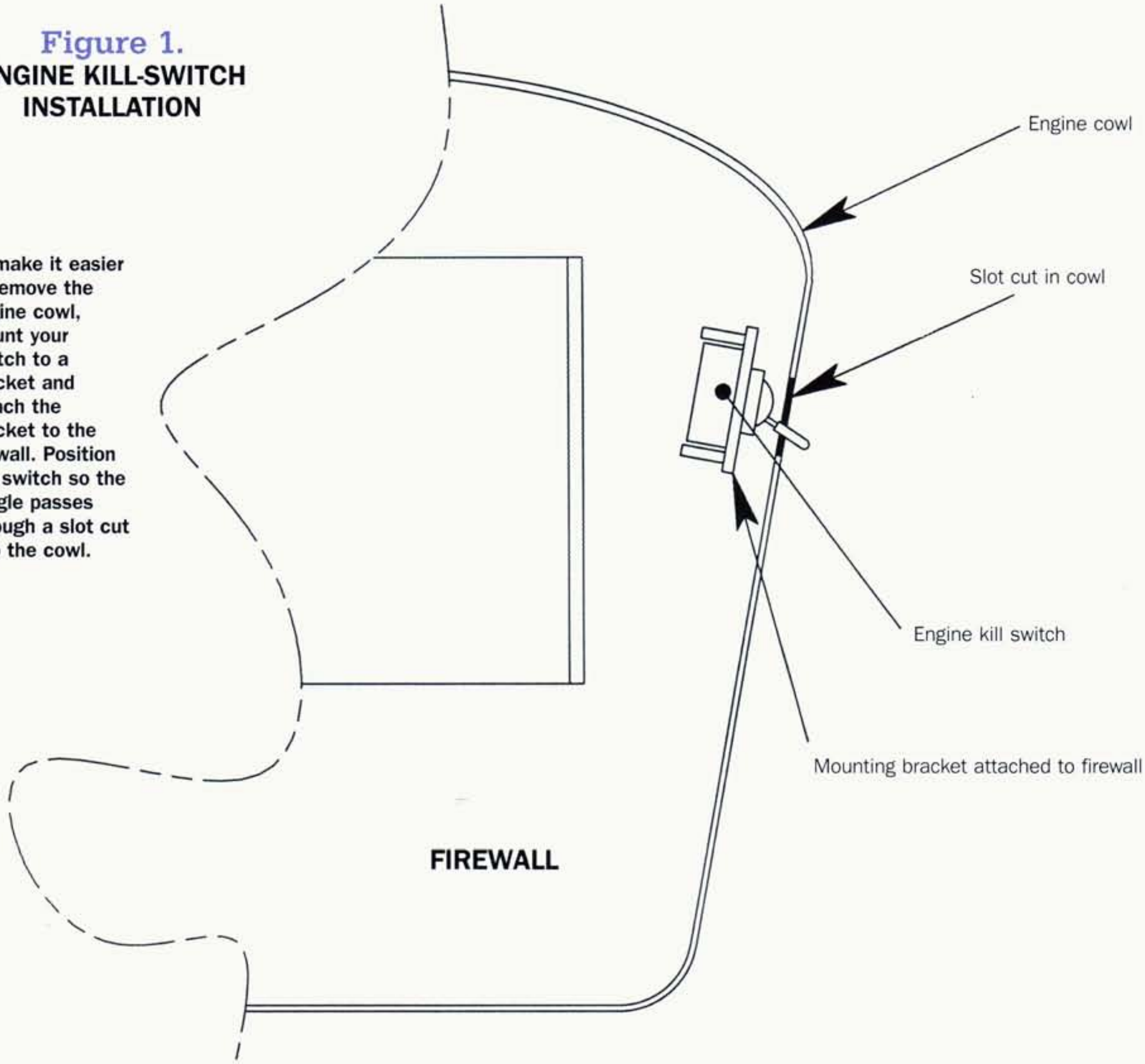
MIGHTY MEGATRON

Hand-starting gas engines is a common practice, but it is much safer to use an electric starter. The old 12V starters that easily crank a standard glow-powered 2-stroke just won't work when you attempt to start a big gas burner. One solution is the double-handled, 12/24V Megatron starter from Sullivan Products. The Megatron uses the same powerful Model 4 motor that powers Sullivan's popular model-boat starter, and it is equipped with dual handles; it is specifically intended for starting large RC airplane engines. The Megatron can start most gasoline engines with up to 8ci in displacements. The power switch is incorporated into one of the rubber-padded handles, and the steel end plates prevent the

This 40-percent Carden Aircraft Edge 540 is coming from the pits for another exciting flight. The 118-inch aerobat is powered by a Desert Aircraft DA 150cc engine and weights 35 pounds. When you build them this big, your support equipment has to be up to the task!

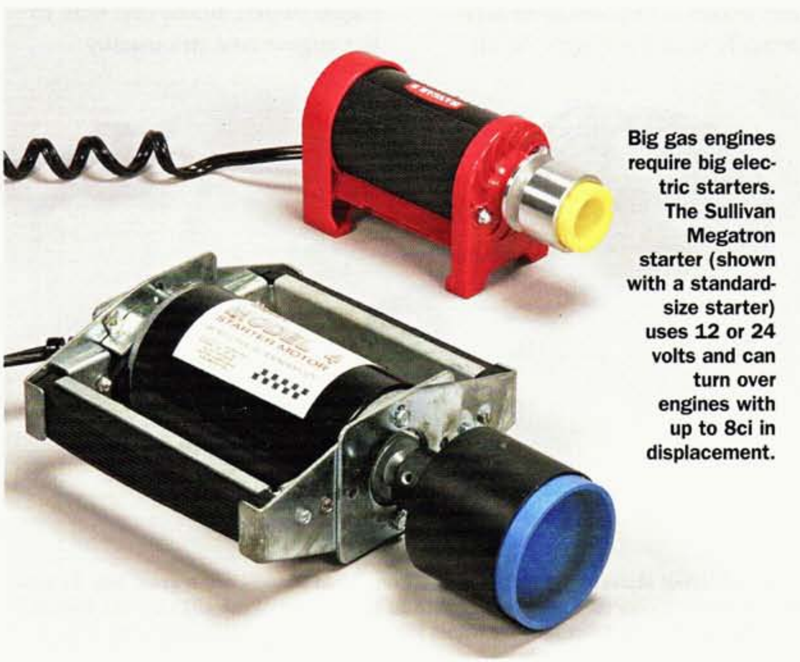
Figure 1.
ENGINE KILL-SWITCH INSTALLATION

To make it easier to remove the engine cowl, mount your switch to a bracket and attach the bracket to the firewall. Position the switch so the toggle passes through a slot cut into the cowl.



motor from slipping under load. The Megatron comes with a huge 3-inch aluminum cone and a sure-grip silicone rubber insert. The starter can operate on 12 or 24 volts and at a maximum of 100 amps. At 12 volts, its torque is 600 oz.-in.; at 24 volts, it's a whopping 1,200 oz.-in. It has a no-load rpm of 2,800 at 12 volts and 5,600rpm at 24 volts.

Two silicone rubber adapters are also available for the Megatron. The small adapter (item no. S636) is for 2¾- to 4½-inch-diameter spinners, and the large one (no. S637) fits spinners from 3½ to 6 inches in diameter. Give them a try!



Big gas engines require big electric starters. The Sullivan Megatron starter (shown with a standard-size starter) uses 12 or 24 volts and can turn over engines with up to 8ci in displacement.

ONBOARD STARTING

Another way to increase the safety factor is to install an onboard starter. The simplest is a spring starter that is attached to the aft end of the engine's crankshaft. It consists of a heavy-gauge spring, attachment bolts and a coupler containing a one-way roller bearing. After you have installed it, start your engine by simply rotating your prop about ⅓ of the way backward (clockwise) and then release it. The spring flips the prop counterclockwise in the same way as a Cox ½A engine is started. Though very simple, these spring-starter systems work very well and almost never wear out.

When it comes to all the "firewall forward" parts, it's important to use the correct equipment for the job and to always be careful—especially with gasoline-powered engines.

An engine kill switch is an important safety requirement for any IMAA flying event. Here, you see the toggle switch sticking out of a slot that I cut into my Pitts Special's engine cowl. The switch isn't anchored to the cowl itself; it is attached to the firewall with a plywood bracket.

SWITCH ON!

An easy-to-install, but often-neglected, safety device is the engine kill switch. A safety requirement at any IMAA-sanctioned event, an engine kill switch grounds the ignition system (magneto) to the engine case and makes it impossible to accidentally start the engine. With electronic-ignition-equipped engines, the same thing can be achieved by adding a switch to the system's battery lead. Several pre-made switch harnesses are available, but you can easily make your own out of parts from an electronics store. All you need are two lengths of wire and an on/off toggle switch. Route one wire to the engine case (it's usually attached under a bolt head with a wire lug), and the other one is connected to the magneto. Most magnetos have either a wire lead or a solder tab to which you connect the grounding wire. Keep the wires as short as possible.

To make removal of the engine cowl easier, attach the switch to the firewall with a plywood or aluminum bracket, and let the switch toggle pass through a slot that has been cut into the cowl (see Figure 1). Get into the habit of using the switch to shut off the engine, and make sure that it remains in the off position when the model is not in use.

Onboard spring starters, such as this one from Great Planes, are a great way to ease engine-starting chores. They are attached to the aft end of the engine's crankshaft and have a one-way roller bearing within the coupler.

PUMPING GAS

A typical gasoline fuel tank used in giant-scale models holds anywhere from 16 to 32 ounces of gasoline. It takes a long time to hand-pump this much fuel into our models, and a standard electric fuel pump is not an option. Gasoline is much more volatile than glow fuel, and electric pumps can cause sparks—not a good thing around gas fumes. What's the answer? How about a fuel pump specially designed for gasoline that contains no electric motor, diaphragm, bearings, or any other part that could create a spark? That's just what Sonic-Tronics has developed with its Nifty Gasoline Pump.

This totally sealed, solid-state unit is self priming and operates in only one direction, which is clearly labeled on its case. To empty your fuel tank, you must reverse the fuel lines. Reversing the battery leads with a switch will not operate the pumping mechanism; it won't hurt the unit, but it won't work. Because the pump produces a constant 6psi of flow pressure, Sonic-Tronics recommends that you use larger (1/8 to 5/32-inch i.d.) fuel lines and fittings in your model.

The Nifty Gasoline Pump operates on 12 volts and requires about 1 amp of power. The unit comes completely tested and ready to use, but you have to supply your own power connectors. To identify the wiring polarity of the pump, the negative lead is marked with a black band. Used with gasoline-compatible fuel lines and an approved gasoline-storage container, the Nifty Gasoline Pump makes your pit area safer!

The Nifty Gasoline Pump from Sonic-Tronics doesn't have any moving parts and is completely sealed. There's no danger of sparks, and this makes it ideal for use with giant-scale models.

Tap and Drill Guide

By the time you get really involved in giant-scale modeling, your supply of workbench tools will have grown to address more advanced aircraft-building tasks. Drilling and tapping metal brackets and fittings are a big part of giant-scale modeling, and having a good set of drills and taps is a necessity if you plan to do all the work in-house. Here's a list of basic tap sizes and their corresponding drill sizes.

Tap size	Drill size
2-56	No. 51
4-40	No. 43
5-40	No. 39
6-32	No. 36
8-32	No. 29
10-24	No. 25
10-32	No. 21
1/4-20	No. 7

troubleshooting gas engines

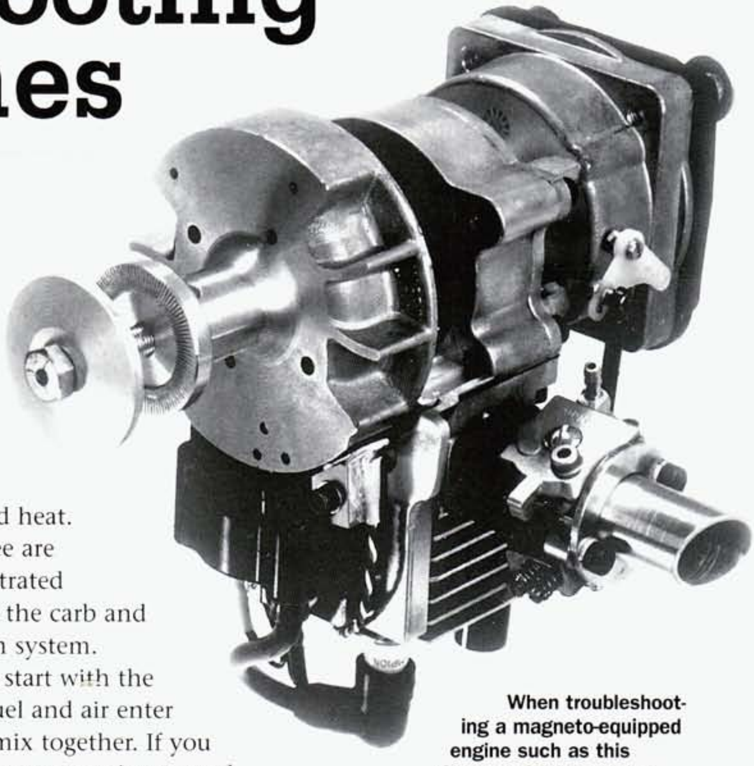
BY GERRY YARRISH

Gasoline engines are usually very easy to operate. Once they have been properly adjusted, the carb settings can normally be left alone for a long time. Sometimes, however, things can go haywire, and frustration replaces the joy of burning gas. Here are some of the more common problems and solutions associated with running gasoline engines.

TROUBLESHOOTING 101

When you're trying to figure out why an engine doesn't work properly, you need to take a look at the three basic elements that make up the "fire triangle": air, fuel and heat. All three are concentrated around the carb and ignition system.

Let's start with the carb. Fuel and air enter it and mix together. If you can't get your engine started, check the following.



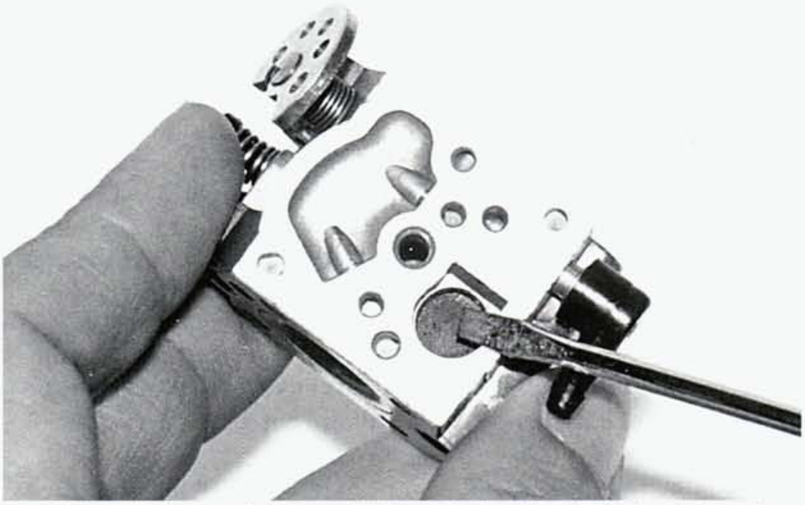
When troubleshooting a magneto-equipped engine such as this Cheetah 25 from Reid's Quality Model Products, check the three "fire" elements—air, fuel and heat (see text for details).

Needle valves. These should be about one turn out from fully closed for the high-end needle and about 1⅛ turns out for the low-end needle. Unscrew them completely to make sure nothing is blocking the fuel flow. Then screw them in fully and back them out accordingly.

Being able to trouble shoot your engine can save a day—or a weekend—of flying.

Fuel fitting. Make sure the fuel is flowing into the carb. A blockage here is most often the culprit. Also check to make sure that the fitting is not cracked or leaking. If it is, replace it.

Fuel pump. Place your finger over the carb opening (or close the choke), and flip the prop several times. Is the carb working and drawing fuel? If you have recently taken off the carb, make



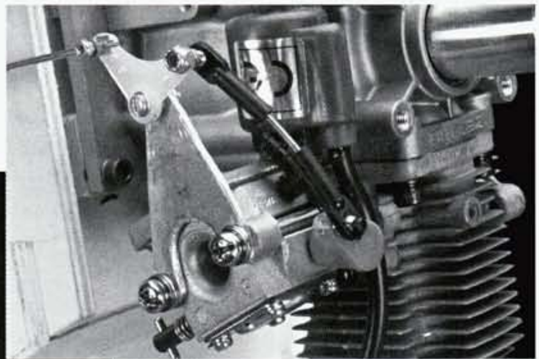
The fuel-inlet filter screen inside your Walbro carb should be checked and cleaned after each flying season. A bit of workbench maintenance can help you avoid a lot of frustration at the field.

sure that you have replaced it correctly and that the carb heat/spacer block is in the correct position. A small pressure-feed hole in the block allows crankcase pressure pulses to enter the rear of the diaphragm pump. If the hole in the carb and the hole in the block don't line up, the carb will not work. Also make sure that the holes are not blocked by debris.

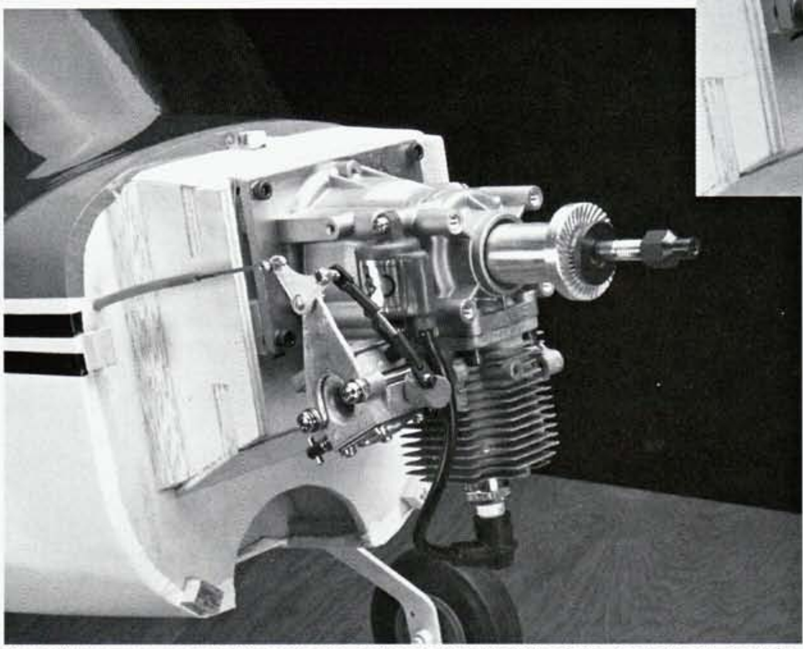
Fuel screen. The small fuel-filter screen in the carb can become dirty after several seasons of flying, and this can affect the engine's performance. Carefully remove the screen, flush it clean and replace it.

Fuel lines. The rich and lean conditions of the fuel mixture depend on how much air is mixed with the fuel. If the engine begins to sag and overheat, the mixture is getting too lean. A hole or cut in the fuel line can cause the mixture to lean out, so check the condition of your fuel system's plumbing. Start at the clunk, and work toward the fuel fitting. If you have an in-line fuel filter (a good idea), make sure it is tightly sealed. Also, gasoline is relatively cheap compared with glow fuel, so treat your engine to fresh fuel once in a while. If your gas can has been sitting in the garage all winter, dispose of the gas properly and mix up some new fuel.

Another possible—though uncommon—reason for the carb to stop pumping fuel is an air leak in the crankcase or cylinder. If your engine starts, runs briefly, then stops after you have squirted raw fuel or starter fluid into the carb, check whether any of the bolts that hold the cylinder to the case are loose. If you have installed a pressure tap in your case to run a smoke pump, make sure that it is properly sealed.



A closer look at this B.H. Hanson G-23 shows the use of Bruce Hanson's throttle-arm cap to attach the linkage to the butterfly pivot shaft. Simple and easy to use, the Hanson caps can be used on other gasoline engines.



Sometimes, you need to improvise to get your throttle linkage to work freely. On this Zenoah G-23-powered GSP.com Super Decathlon, a flat aluminum bracket has been attached to the carb to support the bellcrank.

IGNITION PROBLEMS

The most likely problem here is a dirty, fouled spark plug. Check the plug's condition often, and make sure that the insulator isn't cracked. Make sure the grounding wire and kill switch operate properly and, if you have an electronic-ignition system, make sure its battery is properly connected and fully charged.

Make sure that the magneto and flywheel gap is correct. For a quick check of the gap distance, I use three layers of 100-grit sandpaper for a makeshift feeler gauge. This may seem crude, but it has served me well for years. Spark-plug gaps seem less critical, and they work well from anywhere between 0.020 to 0.035 inch. Check the coil and the spark-plug wire to see whether they have frayed or cracked. Look inside the spark-plug boot, and make sure that the coil that fits over the top of the plug fits properly and "snaps" into place. If the boot fits loosely, arcing and erratic engine operation will result.

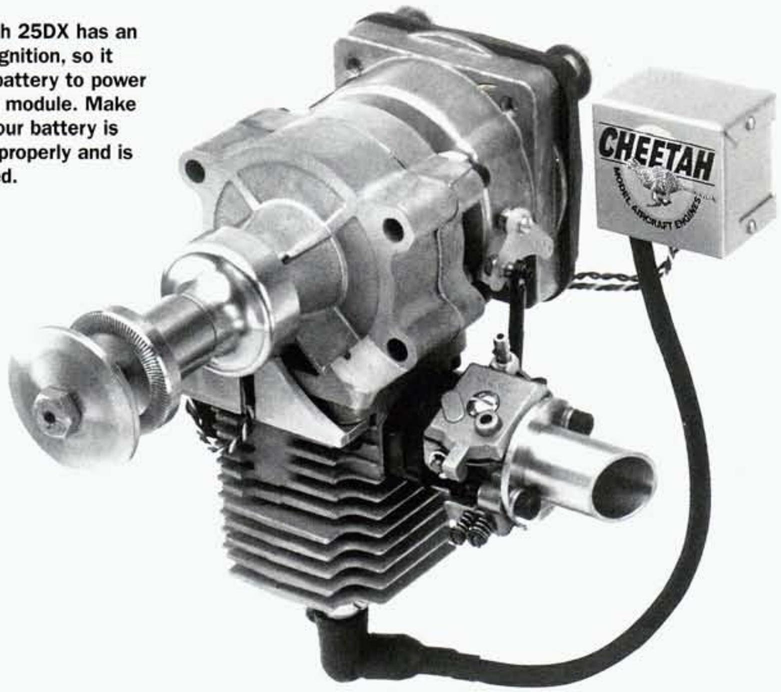
CUSTOM LINKAGE

An ongoing challenge for gasoline-engine users is making and installing throttle linkage. Most Walbro carbs have the industrial web-shaped throttle arm, and this requires you to devise some sort of throttle-linkage attachment. To make this job easier, Bruce Hanson of B.H. Hanson has made little, molded- plastic throttle-arm fittings that fit over the carb's butterfly pivot shaft. Inside the cap is a locking collar that fits over the Zenoah G-23 pivot shaft and is locked into place with a setscrew. As you can see from the photos, a simple ball link is all that's needed to connect it to the rest of the linkage.

In the inverted-engine setup, I used a simple, flat aluminum mounting bracket to support the throttle bellcrank; I attached the bracket to the engine with the carb-mounting bolts. The rest of the linkage is made from Rocket City ball-link clevises, a 4-40 threaded rod and some plastic Sullivan Nyrod. The hole in the cap's locking collar can easily be drilled out to fit other gasoline engines.

The G-23 that powers my Super Decathlon from Giantscale-planes.com is also from Bruce Hanson, who offers "hopped up" G-23s and other Zenoah engines. Stay tuned for more information on Bruce's engines.

The Cheetah 25DX has an electronic ignition, so it requires a battery to power the ignition module. Make sure that your battery is connected properly and is fully charged.



POWER & PROPS

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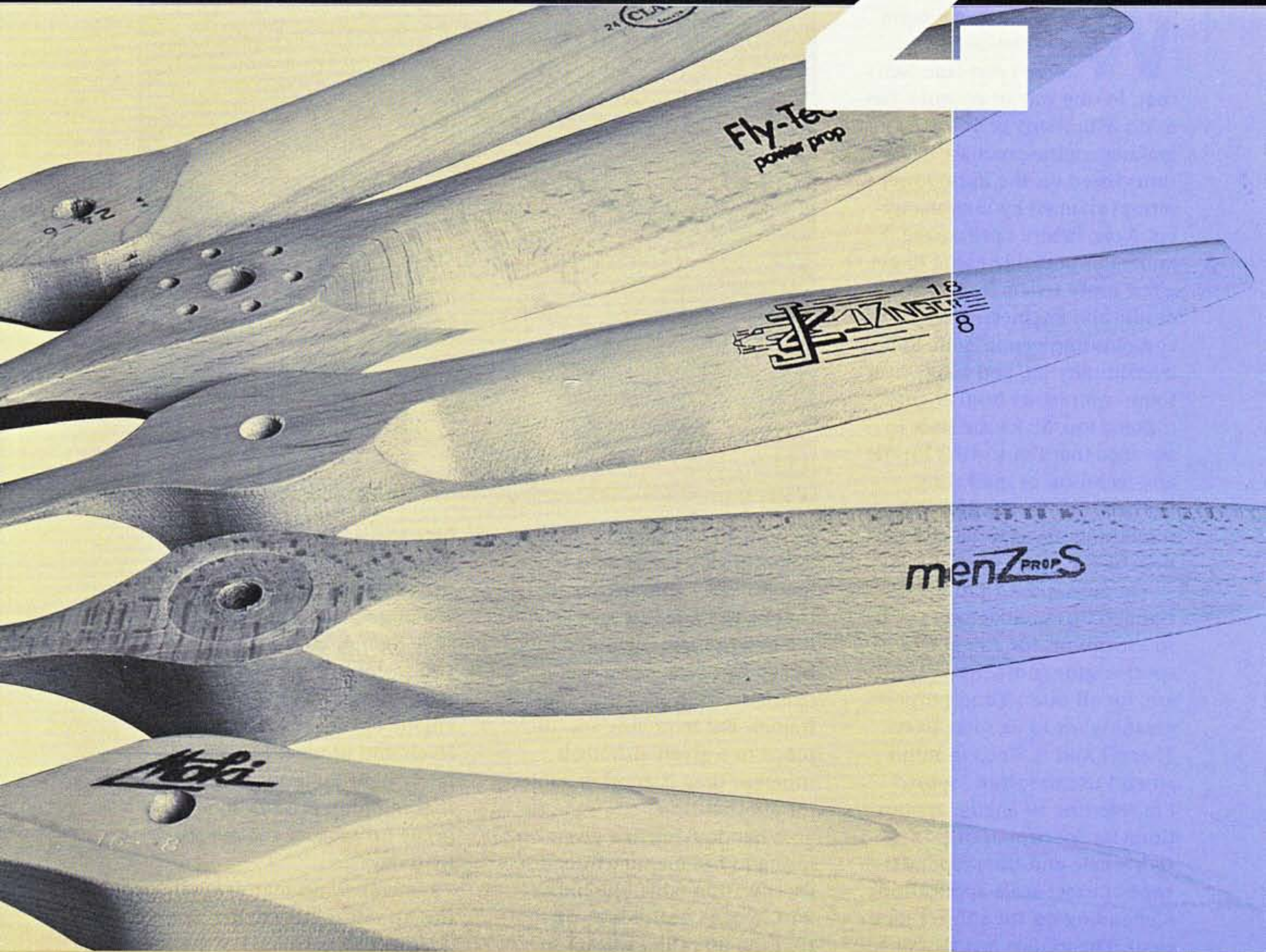
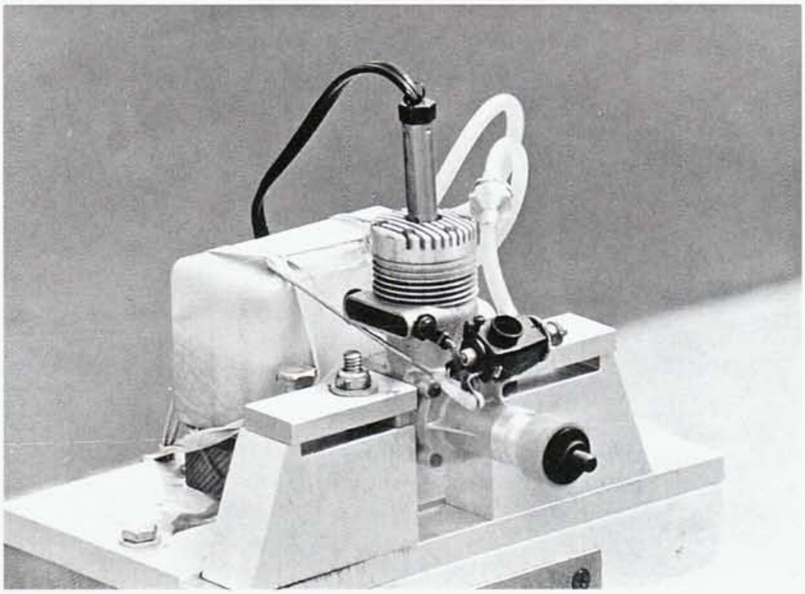


Please note: prices and sources subject to change.

the peak horsepower game

BY CHRIS CHIANELLI

We regularly get correspondence here at Model Airplane News that, in one way or another, has to do with many of you guys making engine-purchase decisions based on the horsepower ratings claimed by manufacturers. Now, before I get started, I know I'm probably going to get a few nasty letters from the scientific and engineering communities berating me for oversimplifying, and I may hear some complaints from engine makers, too. So let me state in advance that I'm sorry if I ruffle any technical or marketing feathers, but I really feel that something needs to be said to help us R/C sport flyers.

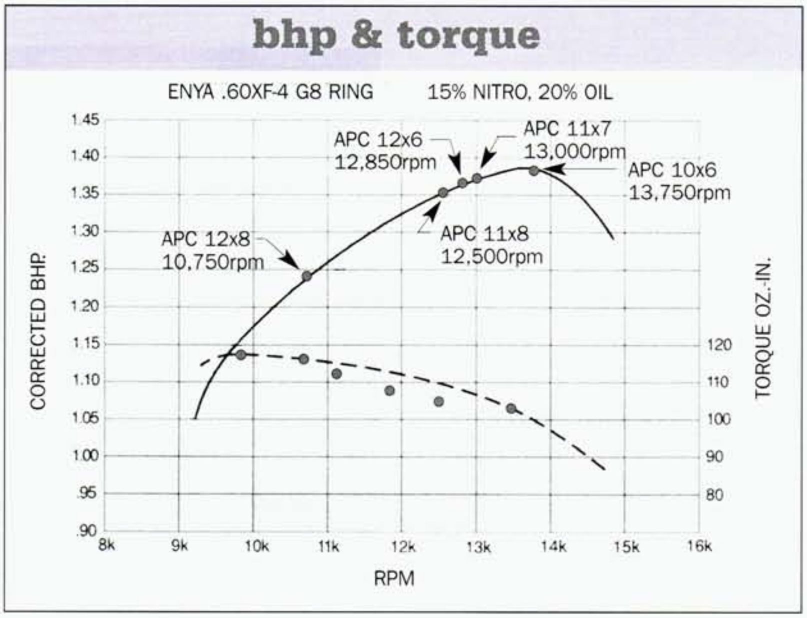


The horsepower ratings claimed by manufacturers in the specifications for any given sport engine (note, I said sport) are, for all intents and purposes, meaningless to us sport flyers. There; I said it. Keep in mind when I use the word "sport," I'm referring to engine applications for sport/pattern, sport/scale and the preponderance of exact-scale applications (depending on the subject modeled). The groups just described encompass some 85 to 90 percent of the prop-driven designs we modelers fly, and I'm sure that this is a conservatively low estimate. The exception, of course, would be engines manufactured by a company such as Nelson, whose engines' porting is specifically timed to run at much higher rpm because they're intended to turn small-diameter props, the potential of which can only be realized on comparatively very-low-drag airframes. But matching specific props to a given airframe's inherent drag is another subject for another time.

When looking at a given hp rating in the manufacturer's specification table, the important item to notice is at what rpm the hp rating was taken. Some manufacturers go as far as to state only hp with no rpm figure—shame on them! For argument's sake, let's say that the manufacturer's claimed hp figure for a certain engine is 2.3hp at 16,000rpm. I'm not here to dispute the accuracy of manufacturers' stated figures or their marketing motives for wishing to state the highest possible figures, but I am asking you to consider the propeller that will be needed to allow the engine to turn these high rpm levels and produce commensurately high hp levels. You'll find that the prop is far from appropriate for most of the models we fly today.

Remember, no matter what the hp rating, an engine alone does nothing for us. It's the prop that produces sufficient thrust to fly a specific airframe. And the best prop to do the job needs the right combination of hp and torque.

All too often, we forget about torque (which can be defined



This shows the horsepower curve (solid line) and torque curve of an Enya .60 XF, one of the best sport engines available (in my opinion), with standard muffler. Note: while peak horsepower is obtained with an APC 10x6 prop, this prop is far from optimum for the .60-size models we fly.

If you know the torque curve of your engine (whether from published reviews or manufacturer's literature), do this: prop the engine to operate within the top 10 percent of its peak torque, but above 10,000rpm. Peak torque for the Enya is 118 oz. at 9,800rpm. Ten percent of this is about 12 oz.-in.; 118-12 = 106 oz.-in. Track the torque curve to 106 oz.-in. and you see (correction factors considered) this falls roughly between 12,500 and 13,000rpm.

Note: the APC 12x6, 11x7 and 11x8 fall right in this rpm range and are optimum for the sport/scale and sport/pattern models we fly.

simply as "twisting force"—in the case of our engines, a twisting force at the crankshaft). Torque is force times radius (t = f x r); the force being supplied by the piston via the rod, and radius being the distance from the center of the crankpin to the center of rotation of the crankshaft. It's this twisting force that determines how quickly an engine will accelerate from one rpm to a higher rpm.

While an engine may produce high levels of hp with a small prop, it's the right combination of torque and horsepower that enables it to turn a prop of sufficient size to overcome the drag presented by our models as they move through the air.

If the engine delivers adequate horsepower throughout its operating range (rpm), sport models generally work best at lower than peak horsepower rpm, where torque is high—the domain of larger props. The only caution pertains to overloading the 2-stroke engine. A good rule suggests keeping rpm above 10,000; otherwise, without special modifications, engines tend to overheat and become erratic below this rpm range.

For most of us modelers, larger props—definitely larger than those used to obtain maximum peak horsepower ratings that look good in a spec chart—are far more efficient at producing the thrust needed to fly our models. For happy modeling, the things I feel you should look for when making a buying decision are reliability, good throttle response, good idle, quiet operation, vibration levels and, of course, good metallurgy for longevity. Just my opinion; let me know yours.

the power factor

BY DAVE GIERKE · PHOTOS BY DAVE GIERKE

For a long as I can remember, engine manufacturers have advertised horsepower ratings for their products. Unfortunately, this activity has degenerated into a meaningless game of one-upmanship, possessing little—if any—technical merit.

As I complained about this sad state of affairs to my neighbor and partner in aeronautical investigation, Frank Vassallo (remembered by readers of this column as "Professor Physics"), he politely but impatiently allowed me to finish my ranting before he exclaimed: "Dave, the model aviation community has suffered long enough!" Wagging his forefinger for emphasis, he continued, "In the never-ending quest for truth, it's time to arm your readership with a simple, yet elegant, weapon from the uncompromising discipline of physics: the power factor."

Immediately above: careful adjustment of the primary needle valve ensures peak rpm for each propeller tested. Above right: record the peak rpm for each of the propellers tested. Rpm data and the bhp constant allow the power factor equation to predict horsepower.

"Wow, professor!" I exclaimed. "You mean there's something that can help curious modelers learn the truth about engine horsepower?"

"Yes, Dave; there's a simple relationship between engine power and propeller rpm."

"What's the relationship, professor?"

"Not so fast, Dave. You're not getting off that easy! I'll provide an illustration. When I've finished, you tell me the relationship. Fair enough?"

"Oh, no, here we go again—Classroom Dynamics 101." (Professor Physics always enjoys a lively game of "Know your concepts.")

The professor snatched a calculator from my workbench and scrutinized it closely, probably suspicious that it was the TV remote control he had mistakenly attempted to use a few years ago. He finally rejected it and pulled out instead a well-worn slide rule from its holder on his belt. After flashing through some calculations, he proceeded to outline the problem on the portable chalkboard he keeps in my shop for impromptu teaching sessions such as this.

"OK, Dave: here's the situation. We have two engines: a sport .35 equipped with a muffler and a racing .40 fitted with a tuned pipe. We've run them both on the same propeller, an APC 9x6. Both were operated at wide-open throttle with the needle valve carefully peaked for maximum rpm." With a hint of a smile, the professor continued, "The little sport engine spun the APC at a respectable 10,000rpm. At this speed, the dynamometer tells us that it's producing 0.25bhp. Conversely, the hot racing engine developed 2.00bhp while turning 20,000rpm." With a sardonic grin, he asked, "What is the relationship between power and rpm?"

Note: over the years, I've tested hundreds of model airplane engines on a homebuilt instrument known as a dynamometer. From its operation, the accumulated torque and rpm data allow the calculation of brake horsepower (bhp). The term "brake" indicates that an absorption unit (dynamometer) of one type or another was used to load the engine during an actual test. Occasionally, a manufacturer will supply a torque and bhp graph from its own "dyno," but this is rare. Because the first production gas engines were applied to free-flight model airplanes in the 1930s, the task of providing such information has been left to high-performance engine enthusiasts and magazine columnists.

Although uncomfortable when put on the spot by the professor, I tried to act as though I enjoyed the challenge. "Let's see; the rpm increased by 10,000, and the horsepower improved by 1.75." I could feel the perspiration forming on my brow. "Ah, let's see ... as the rpm doubles, the power increases eight times."

"That's correct. Now, the relationship; what is it?"

I gazed at the numbers on the dusty board, anxiously searching for a delaying tactic. Just as I was about to excuse myself to mow the lawn, a thought flashed through my mind: wait a minute, I've seen this before. It's a ... that's it! "I've got it!" I shouted, "It's a cube relationship! Power increases as the cube of the rpm!"

"Good," said the professor, "But take it easy; this isn't a revelation. In fact, it's quite simple." As the professor erased the board with one hand, he scribbled the general power factor equation with the other:

$$\text{Power} = \text{constant} \times \text{rpm}^3$$

"Now that I know the answer, that really was a simple problem, professor. But how does the power factor help modelers unscramble the horsepower-rating mess? After all, your example used dyno horsepower data for both engines."

"I'm getting to that, Dave. Let's use some new rpm and horsepower numbers for the same engines using the APC 9x6 propeller." As his chalk clattered on the slate, he muttered, "The .35 engine produces 0.22bhp at 9,000rpm, and the .40 turns 18,900rpm. OK; can you solve this one?"

"I don't know; you didn't give the horsepower for the .40."

"That's the point, Dave! If you know the rpm for each engine on the same prop and the horsepower for one of them, the power factor allows you to predict the unknown horsepower." With hands on hips and looking somewhat annoyed, he continued, "Here's the version of the power factor equation that everyone can use to ferret out the horsepower frauds," as the chalk again danced across the board.

$$\text{Power} = \text{constant}\ (\text{rpm})^3$$
$$P_2 = \text{bhp}_1\ (\text{rpm}_2/\text{rpm}_1)^3$$

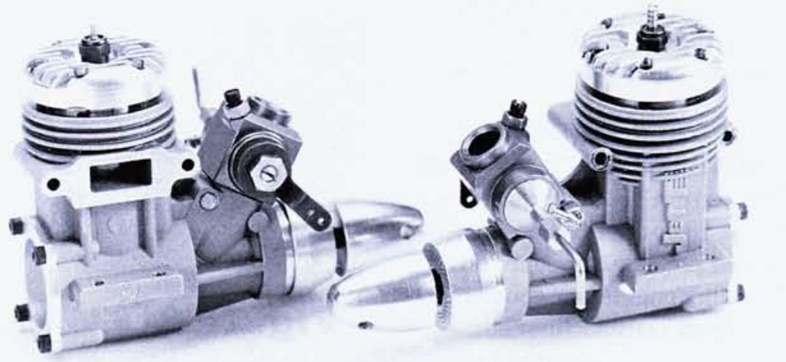
"By multiplying the constant—known bhp—by the cube

A REAL-WORLD EXAMPLE

When I reviewed the Sport-Jett .46 in the June '99 issue of *Model Airplane News*, I also took a look at the Sport-Jett .50. Although I didn't run the Sport-Jett .50, I was able to predict its horsepower from propeller rpm provided by the factory. This is possible because power is proportional to the cube of the rpm ratio of two engines using the same propeller. Therefore, if you know the rpm for each engine and the horsepower for one, you can accurately determine the horsepower of the other. According to Dub Jett, the Sport-Jett .50 turned an APC 11x5 at 15,800rpm. During my tests, the .46 turned the APC 11x5 at 15,000rpm. The Sport-Jett .46 bhp curve (Figure 1) indicates that 1.40bhp is produced at 15,000rpm. Substituting this data into the power factor equation produces an accurate horsepower prediction for the Sport-Jett .50 (see box above right).

$$P_2 = \text{bhp}_1\ (\text{rpm}_2/\text{rpm}_1)^3$$
$$P_2 = 1.40\ (15{,}800/15{,}000)^3$$
$$P_2 = 1.40\ (1.053)^3$$
$$P_2 = 1.40\ (1.167)$$
$$P_2 = 1.63\text{hp} @ 15{,}800\text{rpm}$$

The Sport-Jett .46 and Sport-Jett .50 have the same outside physical dimensions. As might be expected, the .50 develops more power than the .46 and is considered to be the "animal" of the series by designer/manufacturer Dub Jett.



of the rpm ratio—unknown hp rpm divided by the known bhp rpm—the unknown horsepower can always be determined." Again, the professor's chalk rattled across the board.

$$P_2 = bhp_1\ (rpm_2/rpm_1)^3$$
$$P_2 = 0.22\ (18{,}900/9{,}000)^3$$
$$P_2 = 0.22\ (2.1)^3$$
$$P_2 = 0.22\ (9.261)$$
$$P_2 = 2.04\ hp\ @\ 18{,}900rpm$$

With his obligation to physics temporarily satisfied, the professor returned his slide rule to its holder with a flourish reminiscent of a medieval knight, and said, "You can handle the routine material, Dave; I must be on my way. Other dragons to slay, you know." With that, he swiftly turned and exited the shop while muttering something about the problem of squeaky shopping-cart wheels.

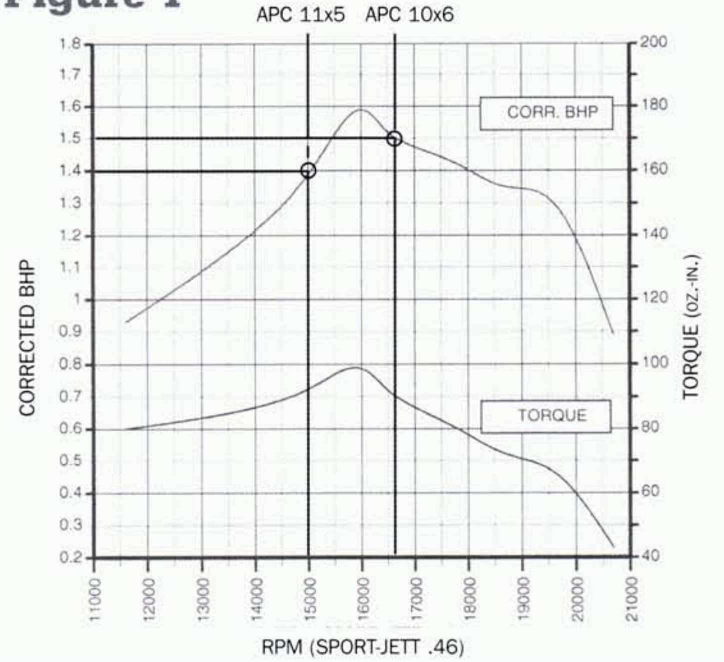
POWER FACTOR AND MANUFACTURER RATINGS

There are at least two good ways to use the power factor. As mentioned previously, one involves checking engine horsepower ratings from manufacturer ads.

An engine is advertised to produce 2hp at 15,300rpm. The manufacturer claims that it spins a 10x6 APC propeller at 15,300rpm. With this information in hand, let's use our newly acquired knowledge to determine if this ad has merit. Use the Sport-Jett .46 bhp graph (Figure 1) and the APC propeller rpm data from the Sport-Jett .46, listed below:

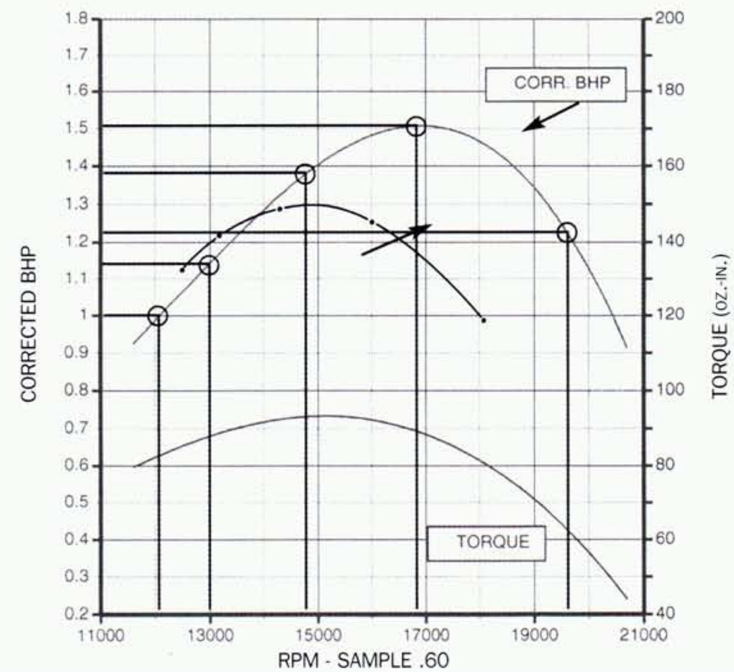
PROP	RPM
9x7	17,500
9.5x6.5	17,000
10x6	16,700
9.5x7.5	16,500
10x7	15,300
11x5	15,000
10x8	14,300
12x6	10,500

Figure 1



APC PROP	SAMPLE .60 RPM	BRAND X .60 RPM	SAMPLE .60 BHP CONSTANT	BRAND X HP @ RPM
9x6	19,500	18,000	1.25	0.99 @ 18,000
10x6	16,900	16,000	1.50	1.28 @ 16,000
11x6	14,800	14,500	1.38	1.30 @ 14,500
11x7	13,000	13,300	1.15	1.23 @ 13,300
11x8	12,100	12,600	1.00	1.13 @ 12,600

Figure 2



Note: the best propellers offering repeatable pitch and diameter specifications are made out of reinforced plastic in a mold. APC props are an excellent example and are often cited by manufacturers and engine columnists.

Again, if you know the rpm for each engine and the horsepower for one of them, you can find the horsepower of the other. From the rpm data chart, the Sport-Jett .46 turned an APC 10x6 at 16,700rpm. The advertised engine turned the same prop at 15,300rpm. From the Sport-Jett .46 bhp graph, the engine is found to produce 1.50bhp at 16,700rpm.

$$P_2 = bhp_1\ (rpm_2/rpm_1)^3$$
$$P_2 = 1.50\ (15{,}300/16{,}700)^3$$
$$P_2 = 1.50\ (0.9160)^3$$
$$P_2 = 1.50\ (0.769)$$
$$P_2 = 1.15hp\ @\ 15{,}300rpm$$

This is only 57.5 percent of the ad's claim of 2hp!

YOUR ENGINE'S HORSEPOWER

Determining the horsepower characteristics of one of your own engines is another good application of the power factor equation. This is accomplished by comparing the engine's rpm performance to that of a published review engine. The task is similar to earlier examples, with one exception: you must actually run your engine and collect rpm data with the same propeller sizes as were used on the review engine. To be meaningful, the review engine must have an honest bhp curve derived from a dynamometer torque test (see Figure 2).

I have compiled APC propeller rpm data for a make-believe engine we'll call "sample .60." The equally anonymous Brand X .60 review engine has been bench-tested for rpm with the same propellers; rpm data for these engines are listed in the chart to the right, along with the dynamometer-generated bhp data from the sample .60 graph.

As with previous examples incorporating the power factor equation, horsepower calculations for the Brand X .60 were generated for each propeller size. From this information, the Brand X horsepower curve was plotted (Figure 2), allowing its performance to be compared with the sample .60. An analysis of this comparison illustrates the techniques' usefulness: although the sample .60 develops more horsepower at higher rpm, the Brand X .60 peaks about 2,000rpm earlier and generates more horsepower below 14,000rpm. This allows the Brand X .60 to turn relatively large propellers with greater authority than the sample .60. The sample .60 is better suited to spinning smaller, low-load propellers at higher rpm, where it can make use of its peak bhp advantage.

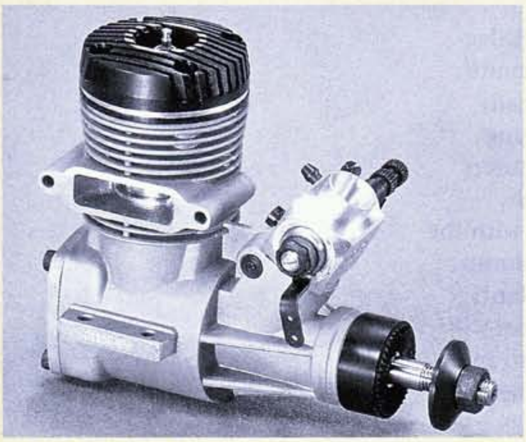
With newfound knowledge about the power factor, multitudes of modelers can finally demand truth in advertising from offending manufacturers and distributors of model engines. This, combined with the ability to analyze the performance of personal powerplants, should provide additional breadth and flexibility to individual modeling activities.

how to choose the right prop

BY DAVE GIERKE

For best flight performance of sport or scale model airplanes, the propeller diameter and pitch should match the characteristics of both the airplane and its engine. The fine engine reviews by Mike Billinton, Dave Gierke and the late Peter Chinn published in *Model Airplane News* provide complete details on engine performance. The MDS engine in Figure 1 is an example; it appeared in "The Right Combination" (August 2000 issue). The table "MDS .46 rpm on standard propellers" is self-explanatory, but it provides only half the performance picture; the bhp curve (upper) and the torque curve (lower) give the other half.

In my experience, few modelers understand the significance of these two curves, and even fewer use either in propeller selection. There is also some confusion about which curve to use—torque or bhp. I hope what follows will explain



MDS .46 rpm on standard propellers

PROP	OPEN EXHAUST	STANDARD SILENCER
15x6 Airflow	6,200	–
13x6 MK	9,260	–
12x6 Graupner	10,200	9,780
10x9 APC	11,200	10,710
10x6 MK	13,240	12,320
10x7 APC	13,690	13,010
10x4 Zinger	16,460	15,760

Figure 1.

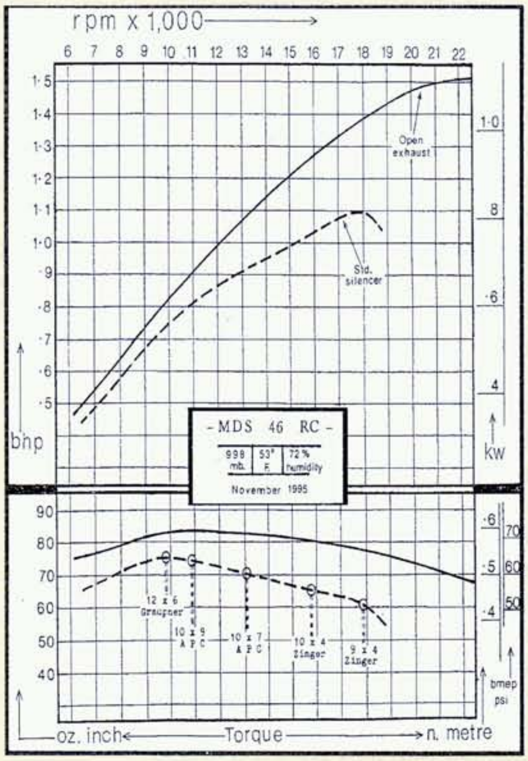


Figure 2.

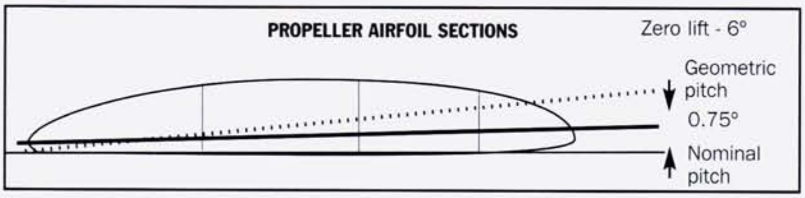
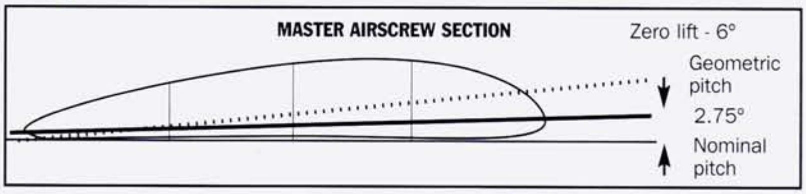


Figure 3.



both curves and which to use for prop selection.

Torque. Torque is the elemental force that rotates the prop. In Figure 1, the MDS .46 RC engine's maximum torque is 75 oz.-in. at 9,798rpm with a standard silencer, as measured on a dynamometer. The torque load imposed on the engine by various diameters, pitches and makes of propellers is marked on the torque curve. The 12x6 Graupner prop spins at 9,780rpm and demands the maximum torque. Larger props would overload the engine and cause a reduction in both torque and Bhp—as indicated by the steep downward slope of the torque curve to the left—and risk overheating the engine.

To the right, smaller prop sizes demand progressively less torque from the engine, permitting increased rpm. A 9x4 Zinger prop turns just under 18,000rpm; this corresponds to just over 60 oz.-in. of torque.

Brake horsepower (bhp). This calculated figure reflects force over time. Dave Gierke's bhp formula is:

Bhp = torque (oz.-in.) x rpm / 1,008,000

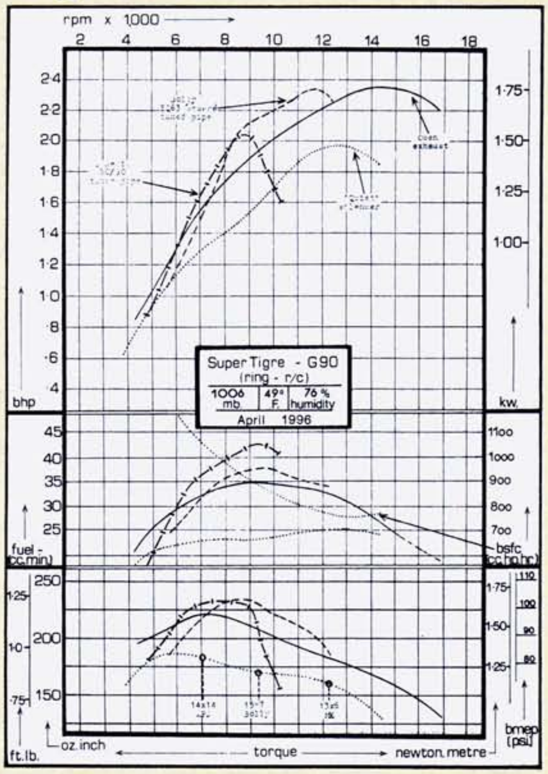
[Note: this is an approximation. The exact figure to divide by is actually 1,008,384; it has been rounded off for simplicity.]

As torque demand diminishes with the size of the prop, the engine can spin more rpm. As long as the rpm increase at a greater rate than the torque declines, the engine's bhp (as calculated above) will continue

RPM on standard propellers

OPEN EXHAUST	ST QUIET EXHAUST	GENESIS PIPE MUFFLER	BOLLY PIPE @ 510MM	@ 480MM
18x7 Mastro	6,160	5,605	–	–
14x14 APC	7,865	7,060	7,960	7,820
16x6 Merati	8,360	7,600	8,640	–
15x8 Graupner	9,060	8,360	–	–
16x6 Airflow	9,230	8,540	9,100	9,460
15x8 APC	9,440	8,640	–	–
16x5 Zinger	9,680	8,940	–	–
13x10.5 MK	9,900	9,080	–	–
15x7 Bolly	–	9,290	–	10,291
15x6 Airflow	10,140	9,370	9,600	–
14x7 Graupner	10,220	9,580	–	–
12x12 APC	10,550	9,790	9,740	10,930
13x6 MK	12,770	12,250	11,200	12,430
12x6 Mastro	13,140	12,550	–	–
10.5x8 Bolly	–	14,760	–	–
11x7 APC	14,960	14,180	–	–
10x6 MK	15,080	–	–	–

Figure 4.



to climb. At some point, this figure will peak—specifically, when the rate of torque decline begins to exceed the rate of rpm increase. The engine in Figure 1 peaks at 1.1 bhp and 18,000rpm, which is the speed at which it spins the 9x4 Zinger prop.

Thrust. An engine and propeller generate thrust by blasting a column of air backward to propel the airplane forward. It is a logical conclusion that the thrust thus generated is proportional to the volume of air per minute being blasted back. The greater that volume, the greater the thrust and vice versa. The volume per minute is easily estimated by multiplying the area of the prop disc (in square inches) by the static rpm and again by the nominal pitch. Disc area can be calculated with the following formula:

Disc area = prop diameter^2 x pi (3.1416) /4

Or, simply, prop diameter^2 x 0.7854. Thus, the formula for air volume per minute is:

Volume per minute = diameter^2 x .7854 x rpm x nominal pitch

For the APC 10x9 prop at 10,710rpm, the air volume is:

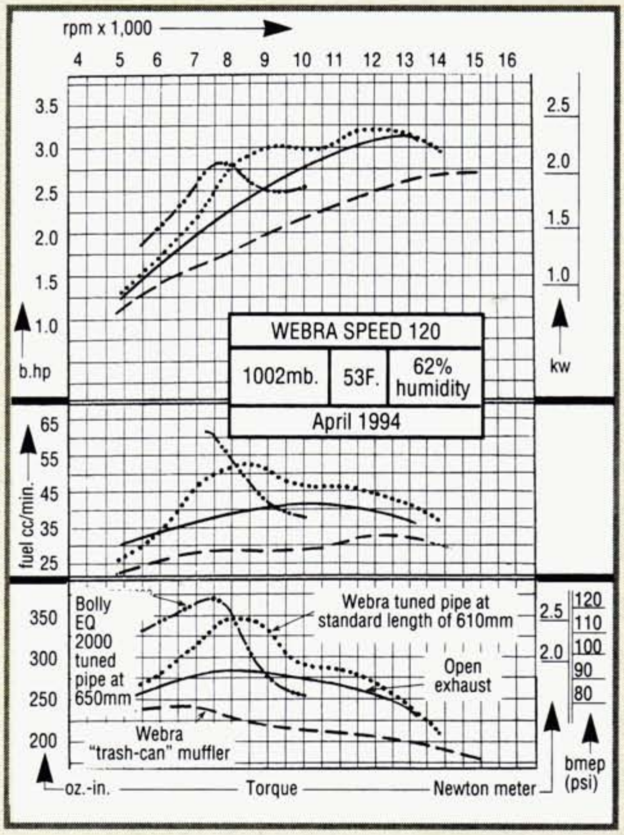
10^2 x .7854 x 10,710 x 9 = 7.57 million ci/min.

This air-volume-per-minute figure is conservative. In-flight rpm are higher than static rpm, and on some propellers, the true (or geometric) pitch is higher than the nominal pitch (see Figures 2 and 3).

Comparison of torque vs. bhp. From the many engines reviewed in *Model Airplane News*, I selected four that ranged from .46 to 1.5ci. In addition to the MDS unit in Figure 1, I chose the SuperTigre G90 (Figure 4, from the December 1996 issue), the Webra Speed 1.20 (Figure 5, from the October 1994 issue) and the Irvine 1.50 (Figure 6, from the January 1996 issue).

For each engine, the air volume per minute was calculated in two ways; for prop

Figure 5. RPM on standard propellers



PROP	OPEN EXHAUST	W/"TRASH CAN" MUFFLER	SLIMLINE MUFFLER	W/TUNED PIPE @ 610mm	BOLLY EQ 2000 T/PIPE @ 650mm
20x10 Mastro	4,748	4,576	4,710	4,875	5,407
24x8 Zinger	4,903	4,420	–	4,615	5,258
20x8 Top Flite	6,783	6,052	6,052	6,580	7,340
18x7 Mastro	7,040	6,563	–	7,627	7,758
18x8 Merati	7,251	6,497	–	7,489	7,754
20x6 Zinger	7,350	6,907	–	7,930	8,010
16x12 APC	8,012	7,474	7,474	8,680	8,370
14x14 APC	8,560	7,810	–	9,139	8,700
15x8 Graupner	10,150	9,261	–	10,484	9,866
15x8 APC	10,360	9,569	9,966	10,484	10,145

diameter/pitch at or close to the rpm where peak torque occurs, and for prop diameter/pitch at or close to the rpm where peak Bhp occurs. The results are shown in Table 1.

Obviously, "propping" the engine near its peak torque range produces the greater volume of air per minute, and, therefore, the greater thrust.

The model. In the table, the prop sizes listed opposite "torque" match the engine's performance characteristics, but more than likely, they will not match the model's performance characteristics. Models with lower wing loadings require props of larger diameter and lower pitch to match their lower flying speeds. Models with higher wing loadings fly faster and need smaller-diameter, higher-pitch props. For best results, however, both props should load the engine into its peak torque range.

This is where Dave Gierke's "propeller load factor" (PLF) formula is very useful. Note that his formula should be limited to families of props from specific manufacturers.

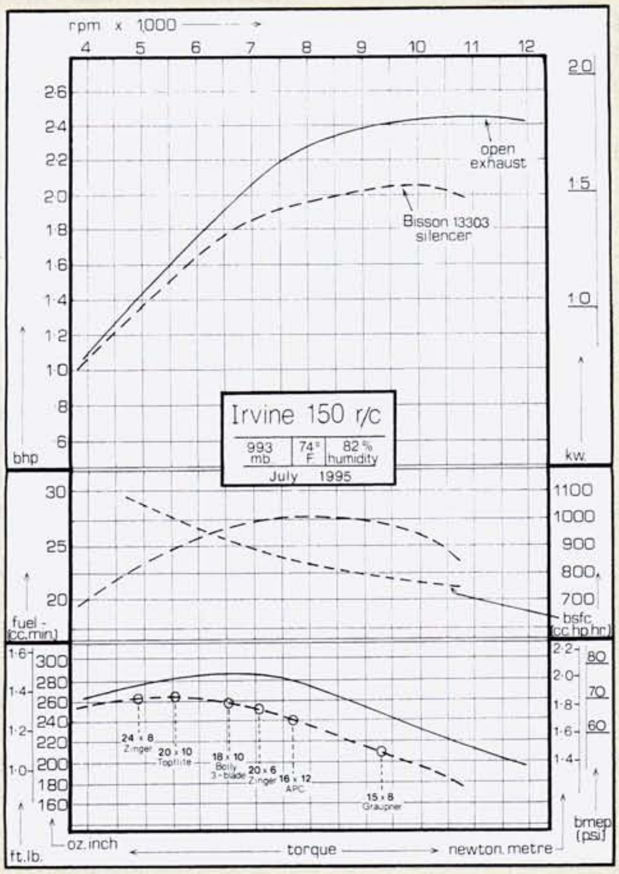
$$PLF = diameter^2 \times pitch$$

Its usefulness is best described by examining, as a practical example, the SuperTigre G90 engine with the ST Quiet Muffler (Figure 5). The APC 14x14 prop most closely matches the peak torque because it spins at 7,060rpm. By placing a straightedge on the points corresponding to pitch and rpm on the rpm/speed/pitch nomograph, the level flight speed is shown to be 115mph. For a model that has a moderate wing loading of 20 ounces per square foot and a level-flight speed of 80mph at the same 7,060rpm, the nomograph indicates a prop pitch of 10 inches and, obviously, a larger diameter.

Consulting the catalog for available APC 10-inch-pitch props, I found a 15x10 and a 16x10. I also found 16x8 and 16x12 sizes. Plugging these dimensions into Dave Gierke's PLF formula, along with those for the original 14x14 prop, we get the following values:

Figure 6. RPM on standard props

PROP	OPEN EXHAUST	BISSON 13303 MUFFLER
22x10 Menz	-	4,395
24x8 Zinger	4,840	4,710
20x10 Menz	-	5,290
20x10 Top Flite	-	5,540
18x12 Menz	-	5,920
20x8 Top Flite	6,650	6,510
18x10 Bolly (3-blade)	6,720	6,550
18x7 Mastro	-	6,760
20x6 Zinger	-	7,120
16x12 APC	7,720	7,535
15x8 Graupner	9,560	9,280



Torque vs. brake horsepower

ENGINE AND DISPLACEMENT	TORQUE VS. BHP	PROPELLER	DIAMETER	PITCH	RPM OF PEAK	AIR VOLUME IN MILLIONS OF CI/MIN.	PERCENTAGE OF PEAK VOLUME
Fig. 1: MDS .46 RC w/std. silencer	Torque	APC	10	9	10,710	7.57	100%
	bhp	Zinger	9	4	17,900	4.55	60%
Fig. 4: SuperTigre G90	Torque	APC	14	14	7,060	15.21	100%
	Bhp	APC	11	7	14,180	9.43	62%
Fig. 5: Webra Speed 120 w/610mm tuned pipe	Torque	APC	14	14	9,139	19.69	100%
	Bhp	APC	15	8	10,484	14.82	75%
Fig. 6: Irvine 1.50	Torque	Top Flite	20	10	5,290	16.61	100%
	Bhp	Graupner	15	8	9,280	13.11	79%

PROP	PLF
14x14	2744
15x10	2250
16x10	2560
16x8	2048
16x12	3072

The APC 16x10's PLF of 2,560 is closest to the 14x14's value of 2,744 and would be a good choice. However, consider also the APC 16x12. Since there is a direct relationship between PLF and rpm, it is easy to estimate the rpm that the new props will turn based on their calculated PLFs and the rpm of the original 14x14 prop. With a PLF of 3,072, the 16x12 would spin at an estimated 6,300rpm. Looking at the torque curve in Figure 4, you can see that 6,300 is just as close, if not closer, to the peak of the torque curve. Plotting 6,300rpm and the 12-inch pitch on the nomograph in Figure 7, level-flight speed would be 85mph. Using the formula from above, air volume would be 15.2 million cubic inches per minute versus 14.4 million cubic inches per minute for the APC 16x10 prop.

Propellers. All currently available prop makes are good, but some are "gooder" than others. I've had success with APC props on many models. Consider the props in Figure 1; the closest to the torque curve peak are a 12x6 Graupner (9,780rpm) and the APC 10x9 (10,710rpm). Calculated air volume for the Graupner is 6.63 million ci/minute; for the APC it is 7.57 million ci/minute.

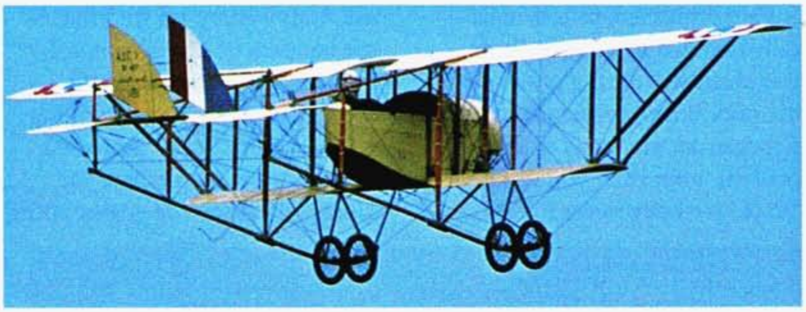
Tuned pipes. Tuned pipes dramatically improve both maximum torque and rpm by, as Dave Gierke succinctly puts it, "supercharging" the engine. This is illustrated in Figures 4 and 5. For models with marginal power, or if you are in need of greater speed, consider a tuned pipe.

Theoretical versus practical. I have been in contact with two local modelers who both fly models powered by the SuperTigre G90 with Quiet Muffler. Neither had read Mike Billinton's review of this engine in the December 1996 *Model Airplane News*, so they were unaware that the G90 developed its maximum torque of 186 oz.-in. at just under 6,000rpm to meet FAI noise standards. Both used props at or near 13 inches in diameter with 6-inch pitches, spinning at between 11,000 and 12,000rpm.

Modeler no. 1 flies a pattern ship and prefers relaxed flying at moderate speeds. He was surprised at the G90's low rpm at maximum torque; he tried 16x6 props and liked the results. Modeler no. 2 flies a scale P47D Thunderbolt with 713 square inches of wing area. He test-flew seven propellers and found that the 16x8 APC prop at 7,200rpm produced the best overall result. Takeoff runs were short; climb was much improved; the engine idled reliably at lower rpm, and the model was surprisingly quiet in flight.

Airframes & prop selection

BY CHRIS CHIANELLI & DAVE GIERKE



In previous columns, I have spoken about why peak horsepower figures alone were all but meaningless to us modelers, and why horsepower readings were only meaningful when taken at rpm levels where peak torque was being developed. This has provoked much interest and, to my delight, upbeat comment. I would like to take this opportunity to thank my main mentor: Dave "Dr. Dyno" Gierke. He supplied me with the Enya .60X dynamometer curve I used in the May 1999 "Air Power" and further consulted with me on the article. When I go out on a limb, it's thanks to guys like Dave, Andy Lennon, Mike Billinton and Clarence Lee that I've managed to keep my you-know-what out of a "technical sling" over the years.

The topic of propping an airframe, and not the engine, is so important—and so often misunderstood—that we thought the approaches of both Dave and me (his technical, mine practical) would be most beneficial.

So often, I'm asked a question to which, without more information, I'm unable to give a meaningful answer. That question is, "Chris, which prop should I run on my .25, .45 or .60-size brand-X engine?" The question that should be asked is, "Which prop is appropriate for my model's airframe?" This is why engine manufacturers often recommend a range of props of varying diameters and pitches in the instructions for a specific displacement engine in their lines.

Let's take, for example, a strong, twin ball-bearing sport .45 and consider it on three vastly different airframes with broadly disparate wing areas, wing loadings and drag factors. Let's look first at a very dirty, high-drag Fokker triplane with 750 square inches of wing area; then at a super-clean, low-drag Ultra Sport with retracts and 550 square inches of wing area; and falling in between these two, a medium-drag Space-walker with 650 square inches of wing area. To keep things simple, let's assume each weighs in at 5.5 pounds (88 ounces, for a total weight of 100 ounces when the approximate 12 ounces of a sport .45-size engine is added). This gives each airframe a power loading (power-to-weight ratio) of 222 ounces per cubic inch. The preceding is one of the factors designers consider when determining the correct engine displacement for a certain model to ensure it will be adequately powered. But this still tells us nothing about which prop will make best use of the engine's power when considering a specific airframe's unique drag and lift characteristics.

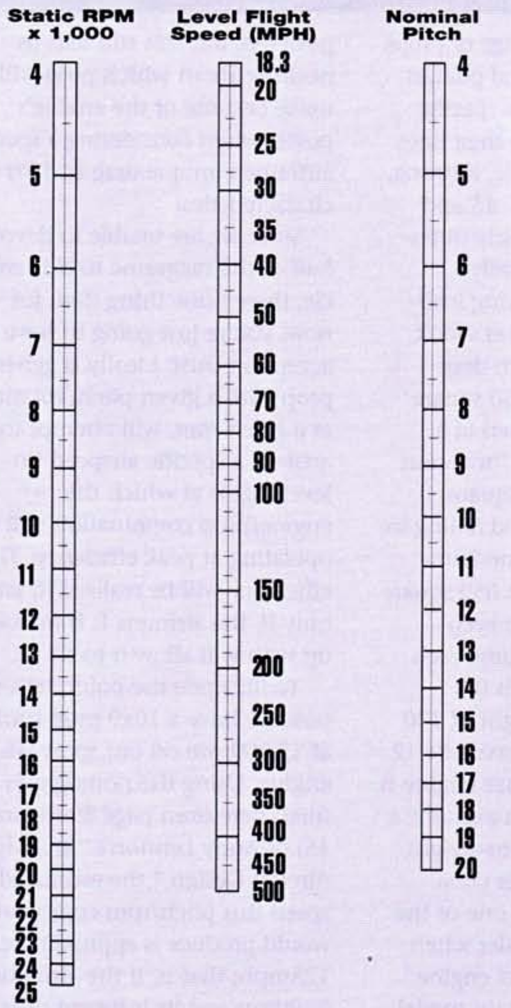
Since we are unable to devote half of the magazine to this article, there's one thing that, for now, you're just going to have to accept on trust: ideally, a generic prop with a given pitch, rotating at a given rpm, will attempt to achieve a specific airspeed (in level flight) at which the engine/prop combination will be operating at peak efficiency. This efficiency will be realized if, and only if, the airframe it is matched up with will allow it to do so.

To illustrate the point, let's suppose we have a 10x9 prop turning at 12,000rpm on our sport .45 engine. Using the nomograph pictured here from page 89 (figure 15) of Andy Lennon's "R/C Model Aircraft Design," the estimated speed this pitch/rpm combination would produce is approximately 125mph; that is, if the airframe in question and its inherent drag will allow.

Now let's move this spinning prop to the nose of the Fokker triplane. Obviously, with the drag presented by a .45-size model with three wings, a round cowl, fixed landing gear and cabane and interplane struts, it's never going to fly anywhere near 125mph. If you attempt to force the issue in a power-on dive, dangerous control surface flutter would surely result. If, by wizardry, the Fokker's engine displacement was magically doubled in the middle of this already daunting power-dive, the poor little triplane just might self-destruct in a mass of airborne confetti faster than you can say "VNE" (velocity never exceed).

The inherent drag of the Fokker will not permit it to reach sufficient speed, thereby not permitting the engine to unload to sufficiently high rpm levels that would put it in its optimum torque band range. Simply stated, the engine is too "loaded" under these conditions.

Conversely, let's assume the Fokker's airframe allows a top speed of only 60mph. Again, if we use Andy's chart, we find that in the ballpark of 12,000rpm, a 4-inch pitch would match this speed nicely. Since the pitch has now been drastically decreased, we must now manipulate the diameter to keep the engine turning in the 12,000rpm range. Moving from the original 10-inch diameter to a 12-inch diameter will probably do nicely. If the 12-inch diameter happens to reduce the rpm level to 11,500, for argument's sake, this would bring the speed to about 55mph which would still be correct for a .40-size model of this type. At the very least, a 12x4 prop would be an excellent starting point for the Fokker. Using the 10x9 prop, or anything close to it would be, in a sense, kind of like driving uphill in a pickup truck loaded with firewood in fourth gear.



Using a straightedge on this nomograph, line up the estimated top speed for a particular design (center) and the full throttle rpm (left) which places the engine on peak torque. At right, the straightedge will reveal what pitch will give the speed you're looking for. To maintain the rpm level within the engine's peak torque-producing band, you vary prop diameter.

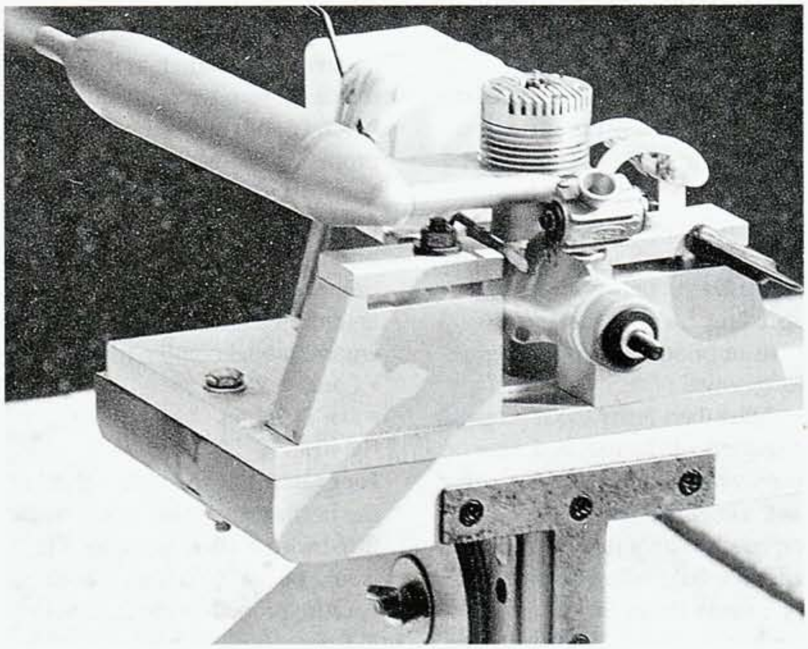
The other side of the picture, of course, would be to put the .45 engine/10x9 prop combination on a clean design like a .40- to .45-size Ultra Sport. With retracts, this airframe would have no problem whatsoever attaining 130mph. This would allow the engine to go ahead and unload at 12,000rpm. So a 10x9, or possibly an 11x8 would be a good match. In terms of lift, drag and top speed, the Spacewalker would fall somewhere in between the Ultra Sport and Fokker, making an 11x6 prop a good starting point for this design. At 12,000rpm, the 11x6 would be looking in the neighborhood of 80mph—a very comfortable neighborhood for a Spacewalker.

These are some practical examples that make use of Andy's ingenious nomograph, with some empirical thought added to the mix regarding the overall "dragginess" of your model. If you'd like more insight to nail your prop selection dead-on, "The Load Factor Formula" on the next page gives an easy-to-use arithmetic tool you'll find very useful during testing at the field. You'll truly be an expert, not just sound like one—like that guy in every club who wears a windsock beanie and mirrored sunglasses, walks the flightline and bestows advice, but never flies. —*Chris Chianelli*

THE LOAD FACTOR FORMULA

You're at the flying field trimming out a shiny new sport model when one of your more experienced flying buddies asks, "Are you at full throttle? The engine doesn't sound like it's turning fast enough. I think you're using too much prop ... maybe you should try one that doesn't load the engine as much."

Too much prop? Loading the engine too much? To many modelers, these terms are meaningless—something for the experts to fuss about. After all, engines are engines, right? Fasten a prop to the shaft, fuel it, fire it up and fly. What could be simpler?



It requires considerable tinkering to find the best compromise between engine, propeller and airplane. Here, a new K&B .40 ABC runs on the test stand with an APC 10x6 propeller (PLF 600) turning 14,500rpm.

Why is it important to match the propeller to the engine? If you read the instructions that accompany your engine, the manufacturer probably recommends a size, right? In many cases, this prop will put you in the ballpark for a trainer-type model. But what happens if your model is somewhat different from the hypothetical trainer? What if it's a biplane? It may be heavier, generate more air drag and fly slower, or it might require a propeller with more diameter and less pitch. A lightweight monoplane with a relatively thin wing, streamlined fuselage, wing fairings and a low-drag cowl will probably produce less drag, fly faster and demand a prop with less diameter and more pitch. How do you determine which prop to use?

A family of propellers (APC) to be flown with a given engine/airplane combination. These have PLF numbers ranging from 363 to 605.

WHICH PROP SHOULD I USE?

For a given engine displacement and horsepower, there are propellers that are either too big or too small to function properly. Some foul up the engine's operation; others are inadequate to fly the model; some are guilty of both. If the propeller is too large, it has too much diameter and/or pitch. Changes in diameter affect engine load the most. Oversize props force the engine to operate too slowly, and this limits the horsepower needed to fly the airplane and invites overheating—especially with 2-stroke cycle engines. Experience has shown that most 2-stroke engines abhor being operated below 10,000rpm at wide-open throttle without special modifications.

Engines outfitted with props that have excessive pitch and marginal low-speed thrust production may not be able to achieve minimum takeoff speed: they run out of runway! After taking off into the wind, propellers with insufficient pitch may not maintain the minimum flight speed required to avoid the dreaded stall spin. In general, undersize propellers allow overspeeding, increase fuel consumption and reduce engine longevity.

Most fliers learn about propeller requirements by trial and error or copy what their buddies are using, and sometimes, that's a good idea, especially with a new airplane. But after the bugs have been worked out, many desire improved performance: better climbing ability (vertical performance?), top speed, or takeoff acceleration. Sorry! Unless you increase the engine's horsepower, you probably can't realize these attributes simultaneously. Without changing the power, propeller selection becomes a compromise. A shorter ground run prior to takeoff is accomplished with a lower-pitch prop, resulting in improved acceleration ... at the expense of reduced top speed. Top speed can be improved dramatically with a higher-pitch prop at the expense of a much longer takeoff run and reduced vertical performance. Most sport fliers prefer a performance smorgasbord: a little of each, thank you!

UNDERSTAND THE NUMBERS

If you like to experiment, the following technique allows you to manipulate flight performance incrementally—not wildly, or from one extreme to another. This strategy allows you to change (or modify) the propeller in terms of its diameter, pitch, or both, while maintaining or selectively changing the load on the engine. Sounds complicated but you'll find it really isn't.

Propeller load and engine rpm are inversely related: as load increases, rpm decrease and vice-versa. Load is represented by the propeller; change propeller size, and load is changed. By using the propeller load factor (PLF) formula, $L_{prop} = D^2(P)$, incremental propeller load changes can be determined and applied to the engine/model combination.

- Lprop = PLF.
- D = diameter.
- P = pitch.

For example, if the sport model at the beginning of this article was fitted with a 10x8 propeller, PLF would be 800 (10x10x8 = 800). Because propeller rpm increase as PLF decreases, we need to find a prop with a number that's less than 800. I have compiled a list of APC sport propellers and calculated their PLF to illustrate the technique.

From the list, the next smallest PLF is 729 and is represented by the 9x9 propeller. This prop allows engine rpm to increase and would generate higher top speed at the expense of a longer, slower takeoff run. Climb performance would probably also suffer. The 11x6 propeller with a similar PLF (726) offers almost the same load as the 9x9 but provides better takeoff and climb performance while sacrificing some top speed. Another possibility would be the 10x7 (PLF 700). It allows the engine to speed up a bit more than the 9x9 and 11x6 while allowing an in-between top speed and takeoff potential.

Notice that I haven't included propellers from a variety of manufacturers on the PLF list. Because blade shape, area, airfoils and pitch generation all have an effect on load, you should limit PLF to families of propellers from specific manufacturers.

Although the PLF system doesn't provide an initial propeller size for your engine/model combination, it points you in the right direction based on your observations of engine rpm, takeoff distance, climb rate and flight speed (among others). You and your friends can now make objective evaluations of a model's performance based on how the engine and propeller function. You may not agree, but now you have a tool that tells you where you are and in which direction you should head. —*Dave Gierke*

LINEAR SIZES	REARRANGED BY LOAD	PLF
9x6	11x3	363
9x7	10x4	400
9x8	11x4	484
9x9	9x6	486
9x10	10x5	500
10x4	9x7	567
10x5	10x6	600
10x6	11x5	605
10x7	9x8	648
10x8	10x7	700
10x9	11x6	726
11x3	9x9	729
11x4	10x8	800
11x5	9x10	810
11x6	11x7	847
11x7	10x9	900
11x8	11x8	968

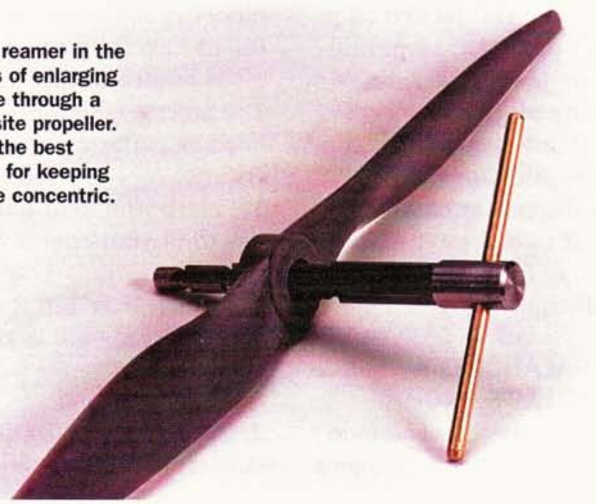
balancing props

BY DAVE GIERKE · ILLUSTRATIONS BY PAUL PERREAULT

A propeller converts the engine's torque into thrust. "Prop" is slang derived from the root word propeller, which means, "It breaks on landing." Seriously, though, it wasn't too long ago that propellers were primarily made of wood—a good choice, except that wood is vulnerable to breakage. Today, the hobby industry sells about 20 composite plastic props for every wooden one sold. This doesn't necessarily mean that wooden propellers are inferior; many fliers still consider wood to be superior in terms of strength and aesthetics.

A hand-held drill motor, twist drill and propeller. These units should be mutually exclusive; never enlarge a propeller hole with a hand drill!

Wood's high strength-to-weight ratio and ability to continually flex without fatigue are its main recommendations. Unfortunately, wood isn't the most stable material. Although manufacturers try to compensate for its inconsistencies (bending, twisting and warping), a wooden prop from a hobby shop still needs to be balanced before it's ready to fly. Composite plastic propellers are more stable in terms of maintaining their shape, but they can have problems caused by unsuspecting or careless modelers who drill them to fit the engine's shaft; an unbalanced propeller is often the result of faulty technique.



A hand reamer in the process of enlarging the hole through a composite propeller. This is the best method for keeping the hole concentric.

Balancing is the process of removing weight (material) in a systematic manner from specific surfaces of the propeller to bring it to a state of equilibrium while suspended from an accurate balancing instrument. Because propellers spin at high rpm, it's important to precisely balance them to avoid transferring damaging vibrations to the engine and airframe. Most propellers need to be balanced. Occasionally, you'll find one that doesn't require alteration, but you'll need a balancing instrument to determine this. Balancing techniques vary depending on whether the propeller is a 2-blade, 3-blade, or 4-blade unit. Here's how to balance each.

BALANCERS

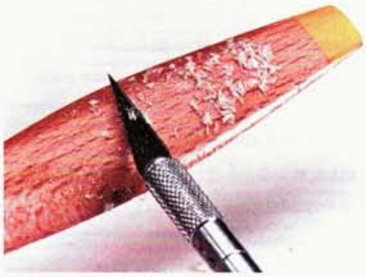
Several types of balancers are on the market today, but I'm partial to the Robart High Point unit, which has been used in the industry for decades. The

WHAT YOU'LL NEED

WOODEN PROPELLER
- Balancer
- Abrasive paper (100-grit, 220-grit garnet, 400-grit silicon carbide)
- Gap-filling CA and accelerator
- Plastic sandwich wrap

COMPOSITE PROPELLER
- Balancer
- Half-round woodworking file (coarse)
- Hobby knife with no. 11 blade
- Abrasive paper (100-grit, 220-grit garnet)

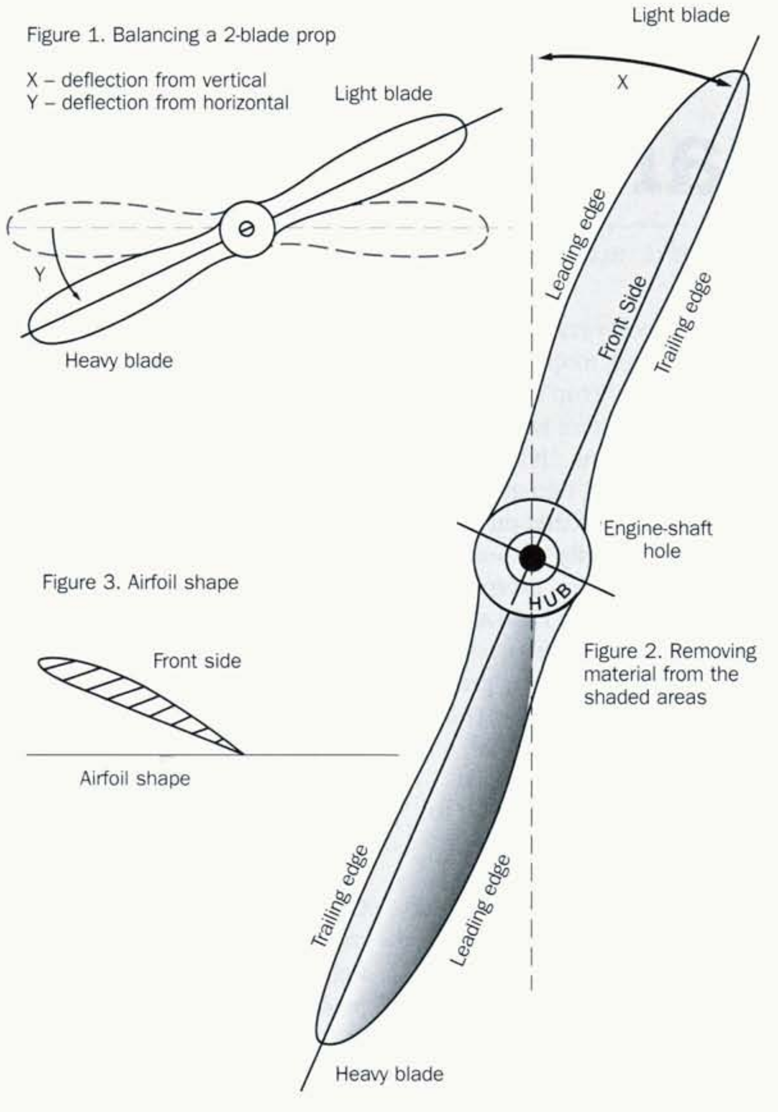
Materials needed to balance wooden and composite plastic propellers.



Use a hobby knife with a no. 11 blade to scrape the front side of the heavy blade to lighten it.

The High Point balancer with a 2-blade propeller. The heavy blade always hangs to the bottom.

2-blade propeller balancing



propeller balancing shaft is supported at each end by two large aluminum discs that pivot individually on Jewel-type axles. Capitalizing on the balancer's large mechanical advantage, no appreciable friction is transferred to the task at hand. The High Point unit doesn't need to be leveled to function flawlessly, either.

BALANCING A 2-BLADE PROP

Because balancing the common 2-blade propeller appears to be a straightforward matter, modelers sometimes take the process for granted; this often results in a botched job. The process is simple, but it must be performed correctly.

1. Enlarge the shaft hole size to fit your engine (see the sidebar, "Enlarging the prop-shaft hole"). If the hole is already too large, use another prop.

2. Place the propeller horizontally on the balancer to find the

heavy blade (see Figure 1).

3. Next, place the prop on the balancer exactly in the vertical position, with the heavy blade at the bottom. If it rotates to a new equilibrium point, it has a heavy edge (see Figure 2).

Two methods are commonly used to balance the propeller. The first involves lightening the heavy blade until the propeller balances in the horizontal position and then removing material from the heavy edge (at the hub) to balance the unit vertically. Unfortunately, removing material from the hub weakens it, so to be safe, don't remove material from the propeller hub.

4. The preferred method is to lighten the heavy blade and the heavy edge at the same time without altering the hub. To accomplish this, remove material from the shaded area of the propeller as in Figure 2.

When you remove material from the heavy blade, sand, scrape, or file it from the front side, not the back side (this would adversely alter the prop's pitch). When you remove material from the front side of the blade, be sure to maintain its airfoil shape (see Figure 3). Don't remove stock from the blade tip and trailing edge; these are already thin and shouldn't be reduced further.

5. When the propeller balances horizontally and hangs vertically with either blade in the down position, the balancing job is almost complete.

6. Wooden and composite plastic props should be final-sanded using a fine abrasive paper such as 220-grit or finer garnet. For wooden props, see the sidebar, "Finishing a wooden prop."

ENLARGING THE PROP-SHAFT HOLE

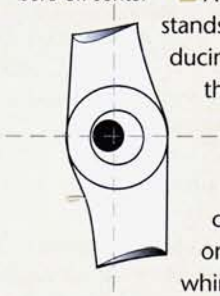
I don't have statistics, but it's my belief that more propellers are ruined when they're drilled out to fit the engine's shaft than are broken during landings. Sadly, many of these dangerously out-of-balance props get fastened to the engine's shaft anyway!

What could be simpler: find a twist drill; mount it in a drill motor, and drill the hole—right? Probably not! Here's just a partial list of things that can go wrong.

The drill press is set up to enlarge the hole through the propeller hub. Although a technically superior method compared with using the hand-held drill motor, the prop can easily get out of control while being held by only one hand—a very unsafe practice!

- Wrong drill-bit size.
If the hole is too big, the propeller will rattle around on the crankshaft and will be impossible to balance.

Twist drills can bore off-center



- A hand-held drill motor stands little chance of producing a straight hole through the hub.

- When you use a drill press, there's a chance that the propeller (which you're holding with one hand) will be yanked from your grip, producing a whirling weapon.

- If you're successful at producing a straight hole through the prop hub, chances are it isn't concentric with the manufacturer's pilot hole; twist drills have an aggravating tendency to bore off-center (see figure), sometimes making the propeller impossible to balance. The problem disappears if the prop is clamped to the drill press table, but this is often difficult because of the limited hub-clamping area—especially with smaller props.

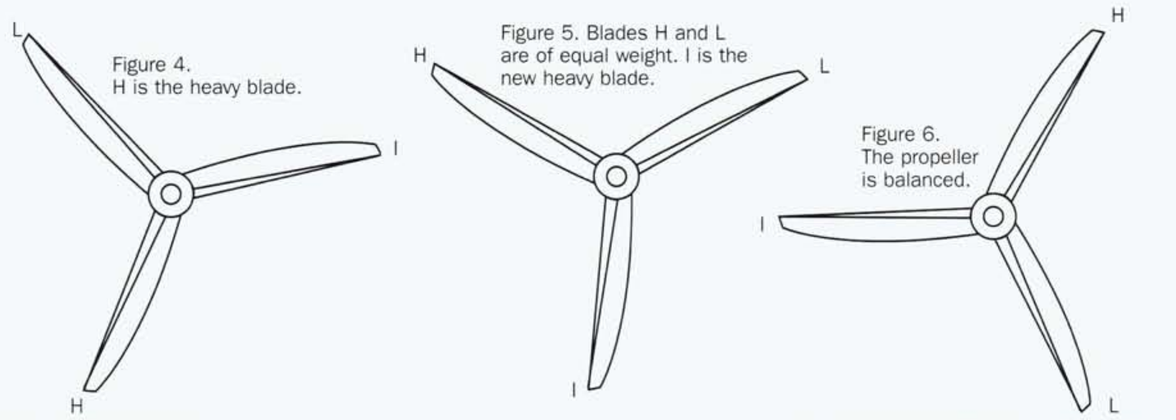
What's the answer? Manual prop reamers! These are multi-fluted cutting tools designed to enlarge cylindrical holes while maintaining concentricity. In simple terms, the reamer is designed to avoid the problems generated by the twist drill! Fox Mfg., Horizon and Great Planes all make T-handle prop reamers for .15- to .60-size engines; Dave Gierke Flying Models makes one for larger engines. These are intended only for manual operation. As with the machine-driven twist drill, safety is a concern; don't use a step reamer in a drill press or hand-held drill motor.

BALANCING A 3-BLADE PROPELLER

The method for balancing a 3-blade propeller is a bit unusual but is simple to do.

1. After you place the 3-blade prop on the balancer (see Figure 4), notice that one blade will probably hang low; this is the heavy blade, "H." The other two blades, "L" (light) and "I" (in between), will be positioned as shown in the diagram.

Three-blade propeller balancing



Balancing the 3-blade propeller on the High Point unit. As with the 2-blade prop, the heavy blade always hangs lowest (your starting point).

2. The next step is to lighten the front face of H until it allows blade I to hang straight down, becoming the new heavy blade (see Figure 5). The old heavy blade, H, is now equal in weight to the light blade, L.

3. The final step is to lighten the new heavy blade (I) until it sits horizontally (see Figure 6), thus becoming balanced with L and H.

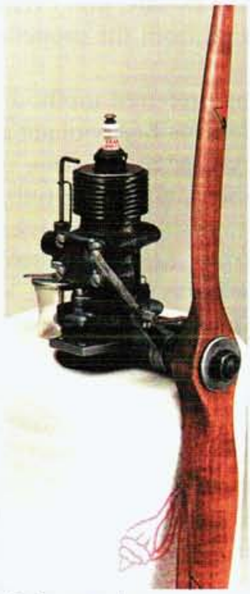
4. Finish-sand the 3-blade propeller as you did the 2-blade unit, and it's ready to run.

Smooth a vibrating engine with an unbalanced prop

Many antique model engines were notable for their tendency to vibrate. Heavy iron or steel pistons were usually the culprits, along with inadequate crankshaft counterbalancing. Here's a simple trick to smooth things out.

- Make sure that the piston is at top dead center.
- Place an unbalanced propeller on the offending engine's propeller shaft with the heavy end pointing straight down.
- Install the prop washer and tighten the prop nut.

The heavy blade adds to the counterbalance weight and results in smoother engine operation. This will only work with engines that have inadequate crankshaft counterbalance weight. The only other drawback concerns the poor position of the propeller for hand starting; however, this isn't a problem if you use an electric starter. This works especially well with many ignition engines, as well as with some early glow Fox, K&B Torpedo and McCoy engines.



Antique engines with heavy pistons can benefit from an unbalanced propeller.

BALANCING A 4-BLADE PROP

A 4-blade propeller is the easiest type to balance. Balance it as you would two, 2-blade props that are fastened (at the hub) 90 degrees to each other.

1. Lighten blade 1 until blades 1 and 2 are horizontal (see Figure 7).

100-grit garnet abrasive paper works well for wooden propellers.

4-blade propeller balancing

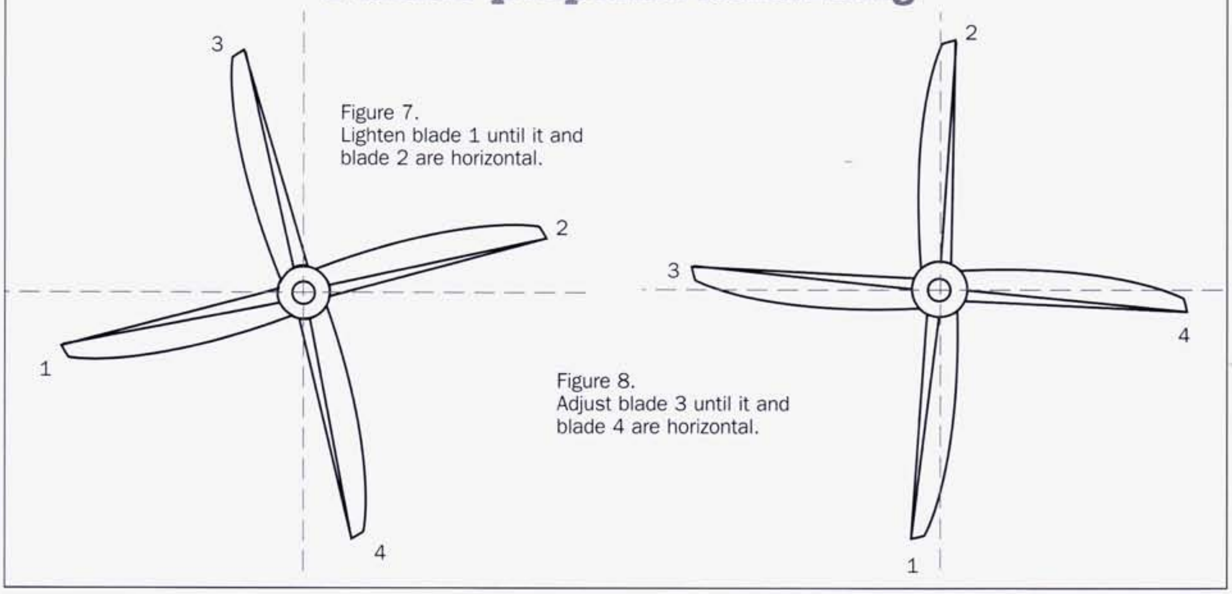


Figure 7.
Lighten blade 1 until it and blade 2 are horizontal.

Figure 8.
Adjust blade 3 until it and blade 4 are horizontal.

2. Rotate blades 3 and 4 to the horizontal position. If they move to a new equilibrium point (see Figure 8), remove material from the front of blade.

3. Make adjustments until blades 3 and 4 are balanced horizontally. Recheck blades 1 and 2, making minor adjustments until the propeller remains in any position around its rotation.

4. Finish-sand.

FINAL THOUGHTS

The time and effort it takes to balance your propellers is well worth the result; you'll be rewarded with a longer-lasting airframe and an engine that runs more smoothly. You spend so much time building your airplane and tuning your engine that they deserve a balanced propeller.

Finishing a wooden prop

Because the exposed wood grain is susceptible to absorbing water and oil, it must be recoated with a sealant. Try this quick and effective method.

1. Apply a liberal drop of CA to the balanced blade of the wooden propeller to seal it against water and oil.

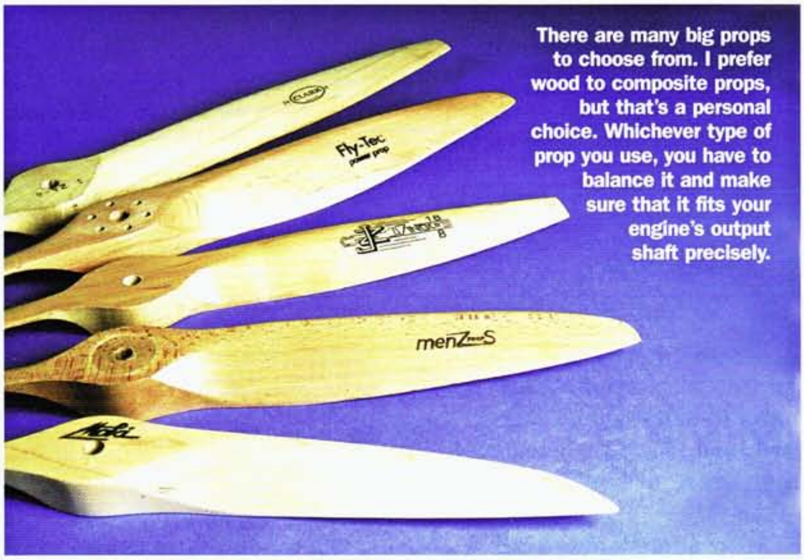
2. With plastic sandwich wrap protecting your finger, spread the CA over the raw wood portion of the balanced propeller blade.

3. To speed the sealing process, spray a bit of CA accelerator to the still liquid CA.

4. Lightly sand the hardened CA with 400-grit wet or dry silicon-carbide abrasive paper. Recheck the balance. If necessary, add a bit of CA to the opposite blade.

giant-scale propeller tips

BY CHRIS CHIANELLI & DAVE GIERKE



There are many big props to choose from. I prefer wood to composite props, but that's a personal choice. Whichever type of prop you use, you have to balance it and make sure that it fits your engine's output shaft precisely.

With so many propellers available from so many sources and with the seemingly countless variations of diameter and pitch values, there is virtually an unlimited supply of props to choose from. One of the most frequently asked questions I receive from readers is, "What prop should I use with my (fill in the brand name) engine?" This question seems pretty straightforward, but as we shall see, it's anything but! What should be asked instead is, "Which prop should I use for my model?" To answer that, let's dig a little deeper.

To select the appropriate propeller, you have to take into account both your engine's power and your airframe's weight and structure. The prop requirement for a 1/3-scale Sopwith Pup is not necessarily the same as for a 1/5-scale AT-6 Texan even though both models might be powered by the same engine—a Zenoah G-62, for example. The Pup, with its rigging wires and two wings, has more drag to deal with, and because of its relatively light wing loading, it can fly at low airspeeds. In comparison, the Texan has retractable landing gear, a single wing and a higher wing loading; it needs to be flown much faster than the Pup. It isn't likely that you would use the same prop for both planes.

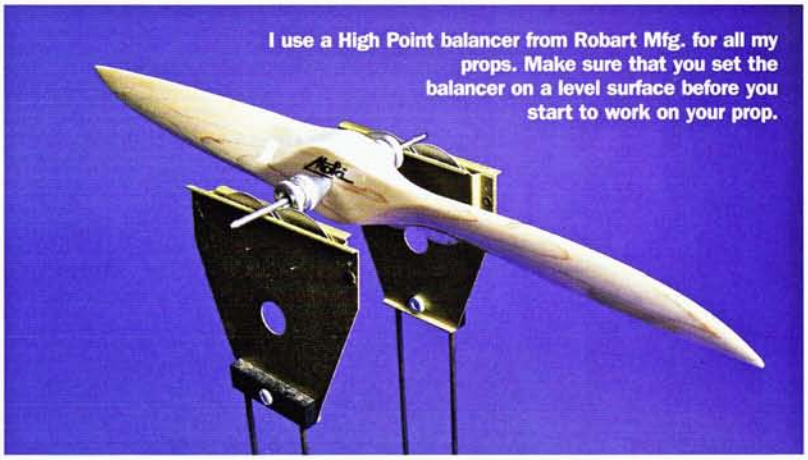
What you have to ask yourself is, "How do I want my model to perform?" With the Pup, you want good climb performance and a maximum airspeed of about 40 to 50mph. With the Texan, you want good climb performance, but you also want the model to fly somewhere in the 60 to 80mph range. Also, you want your prop to load the engine sufficiently for it to operate within its optimal power band. So the information needed to pick the correct

The first thing to do to your new prop is to ream the prop hole so it fits the output shaft. Use a metric or a standard reamer, depending on your engine.

prop boils down to the model's weight, wing loading and estimated airspeed and the engine's optimal rpm range.

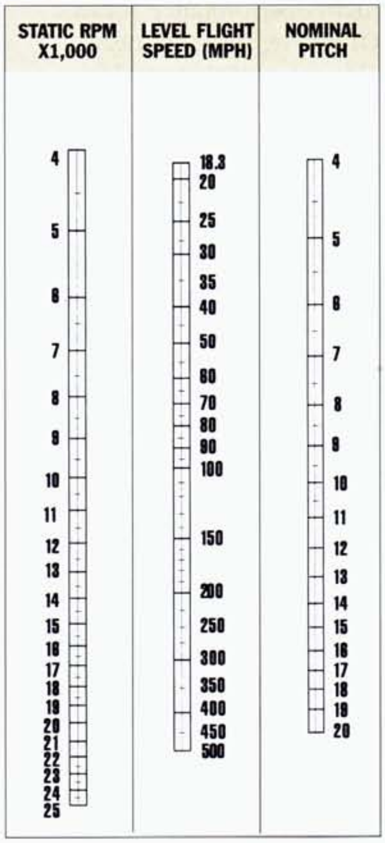
With calculations by model aerodynamics guru Andy Lennon, Figure 1 will help you to estimate your model's top speed given its engine's static rpm and the prop's nominal pitch value. Use a ruler to connect the rpm (left column) to the pitch value (right column). The level flight speed in mph is then found in the center column. In a nutshell, a prop with a lower pitch is good for a slow, draggy Pup, and a higher

For multi-bolt prop hubs such as on this ZDZ 40 engine, use a drill press to drill the bolt holes. Be sure to position the holes so that there is a clear path of wood from tip to tip.



I use a High Point balancer from Robart Mfg. for all my props. Make sure that you set the balancer on a level surface before you start to work on your prop.

Figure 1

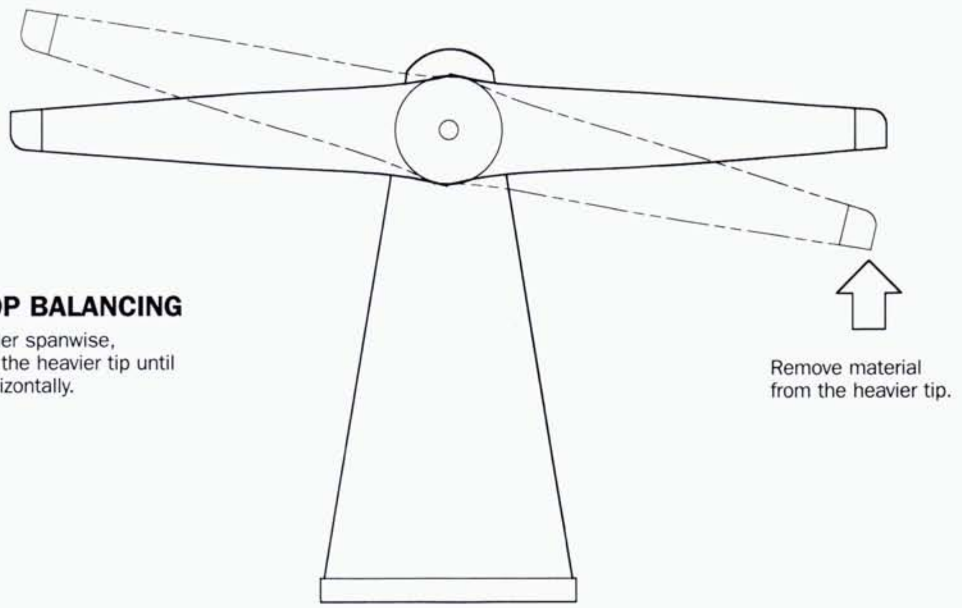


Use this nomograph to estimate your model's top airspeed. Use a straightedge, and align the engine rpm value with the pitch of the prop you plan to use. The level-flight speed (in mph) is shown where the straightedge intersects the center column.

Figure 2

SPANWISE PROP BALANCING

To balance the propeller spanwise, remove material from the heavier tip until the prop sits level horizontally.

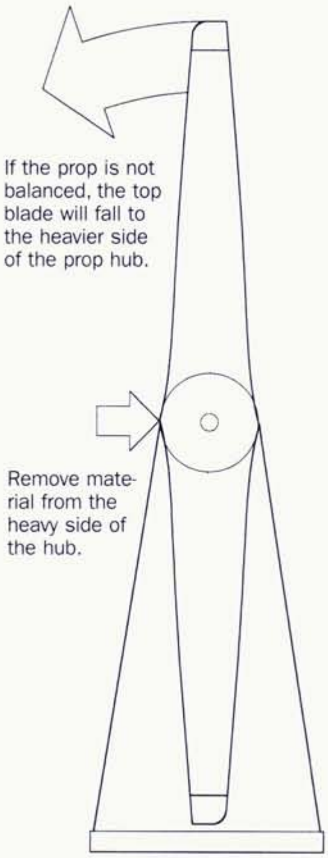


pitch is good for the faster, higher-performance Texan. Of course, these are two extreme model examples, so the best way to find the optimum prop/engine/airframe combination is to test-fly your prop choices.

THE BALANCING ACT

It is very important to properly balance your propellers, especially with giant-scale models. An unbalanced prop causes unwanted vibration that can, over time, damage both the engine and the model's airframe. Use a good-quality prop balancer that's suitable for the size of prop you are bal-

Figure 3
CHORDWISE PROP BALANCING



To properly balance the propeller, you have to balance it both spanwise and chordwise.

B.H. HANSON ZENOAH G-26

Famous for his hopped-up Zenoah RC marine engines, Bruce Hanson offers a hopped-up Zenoah G-26 model airplane engine. The B.H. Hanson 260 has an internally mounted electronic-ignition system from RC Ignitions. Bruce's 260 is lighter than the stock G-26, and the ignition conversion does away with the magneto flywheel and coil. The ignition is sealed in the back part of the engine case between the engine and the engine mount. The rear end of the crankshaft has also been cut off, and an aluminum plate seals the rear of the case. The modified engine weighs 2.8 pounds, not including the muffler.

The ignition system makes starting a breeze and requires only 200mA at any rpm to operate. That's roughly 2½ hours on a small 4.8V, 500mAh pack. The engine comes with a muffler, a spark plug and a wrench, and it includes a socket and a removable RCA jack (RadioShack audio cable) to connect your battery pack (not included) to the engine.

The engine is timed to fire at 28 degrees (BTDC) at any rpm above 4,000. I am told that the engine produces about 3hp and peak torque at about 9,000rpm (no muffler). That's about the rpm you get while turning a Mejzlik 18x6 prop. The stock muffler brings the revs down to about 8,100.

The B.H. Hanson 260 is a great value for the power and performance this little dynamo puts out!

The ignition system is installed in the aft portion of the engine case. Note the magnetic pickup installed in the prop-hub assembly.

The B.H. Hanson 260 is a modified Zenoah G-26 with an electronic ignition system.

Figure 4
A GOOD FIT

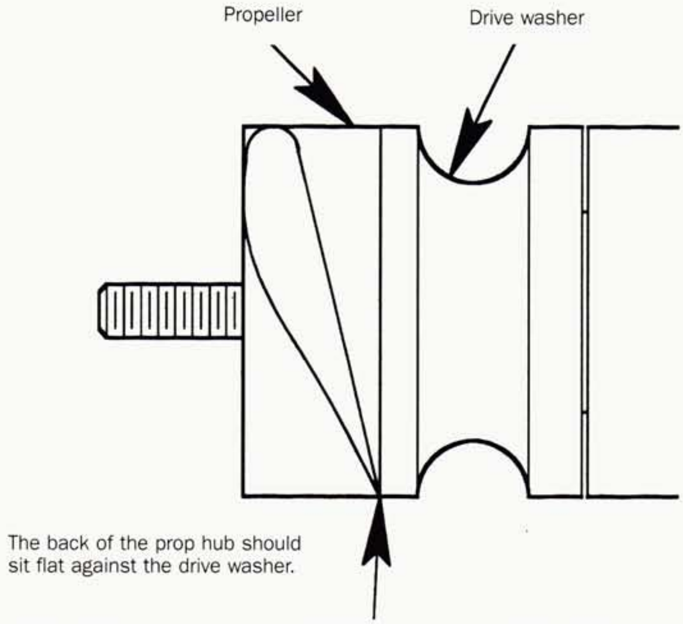
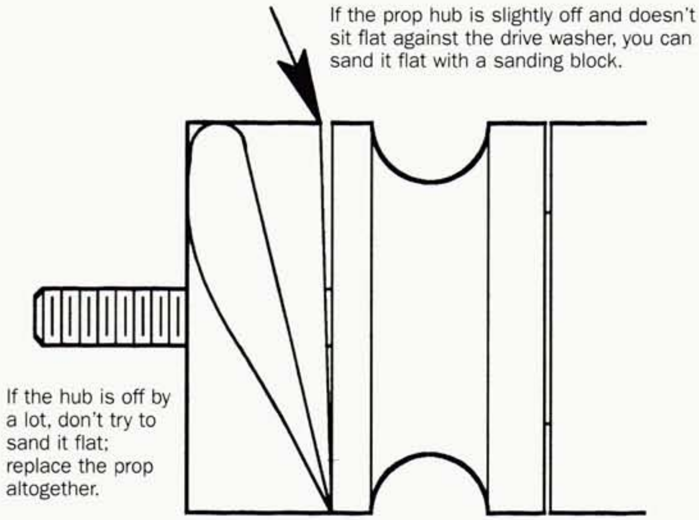


Figure 4
A BAD FIT



After reaming the prop hole to fit your engine shaft, check to make sure that the back of the hub sits flat against the drive washer.

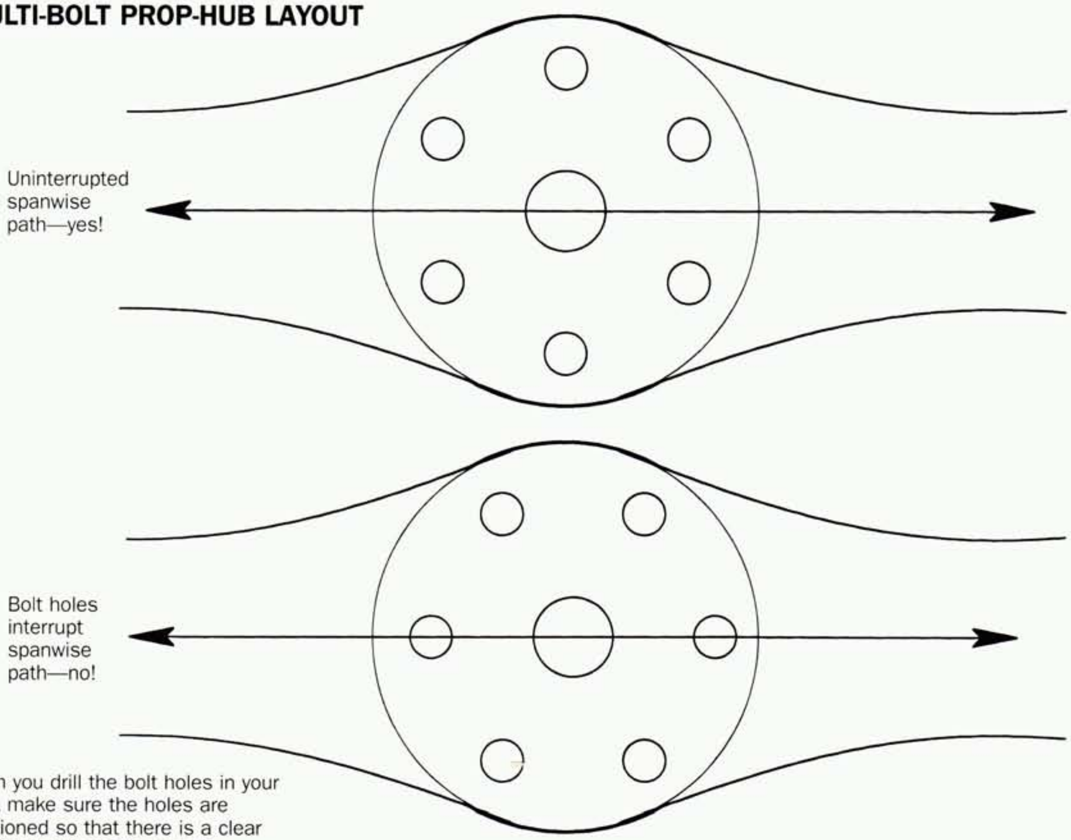
ancing. I have used a High-Point balancer from Robart Mfg. for many years. At the very least, you should always balance your props so that they sit horizontally on the balancer's spindle. But this is only 50 percent of the job: the prop is balanced spanwise (Figure 2). You should also balance it chordwise or across the hub face. Placing the prop in a vertical position will show whether it needs further attention. Whichever way the top blade falls, that's the side of the hub that is heavy (Figure 3). The propeller is perfectly balanced when it can be placed in any position and remains there without moving at all.

The first thing to do before balancing a prop is to ream the prop hole so it precisely fits your engine's output shaft. It makes little sense to balance the prop if the prop hole is too big or off-center. Don't use a drill bit to enlarge the hole; the bit could easily damage the prop. Use a prop reamer and do the job slowly by hand. Once the hole has been reamed to the proper size, slide the prop onto the output shaft and see how the aft prop hub face sits against the engine's drive washer. It should sit flat against it. If it is off slightly, sand the hub's surface with a sanding block. If it is off by a lot, replace the prop altogether (Figure 4).

There are many ways to balance props, but I believe in the "Keep it simple, stupid" method. I simply remove material from the very tip of the heavier blade or from the heavier side of the prop hub until the blades balance. Many modelers sand the blades' front or rear surfaces, but this can change the prop's airfoil cross-section. This method also removes a lot of the prop's protective finish and can allow moisture to be absorbed by the sanded blade area. By removing material only at the very tip, I need only a small amount of paint or clear varnish to seal the exposed wood. You can also paint your props to improve their scale appearance and to further protect them from moisture. And while you're at it, paint those tips with a bright color so they'll be more easily seen when the engineis running.

Once you have balanced your props, store them lying flat in a horizontal position. Don't hang them in such a way that one blade is lower than the other. Over time,

Figure 5
MULTI-BOLT PROP-HUB LAYOUT



When you drill the bolt holes in your prop, make sure the holes are positioned so that there is a clear path from prop tip to prop tip.

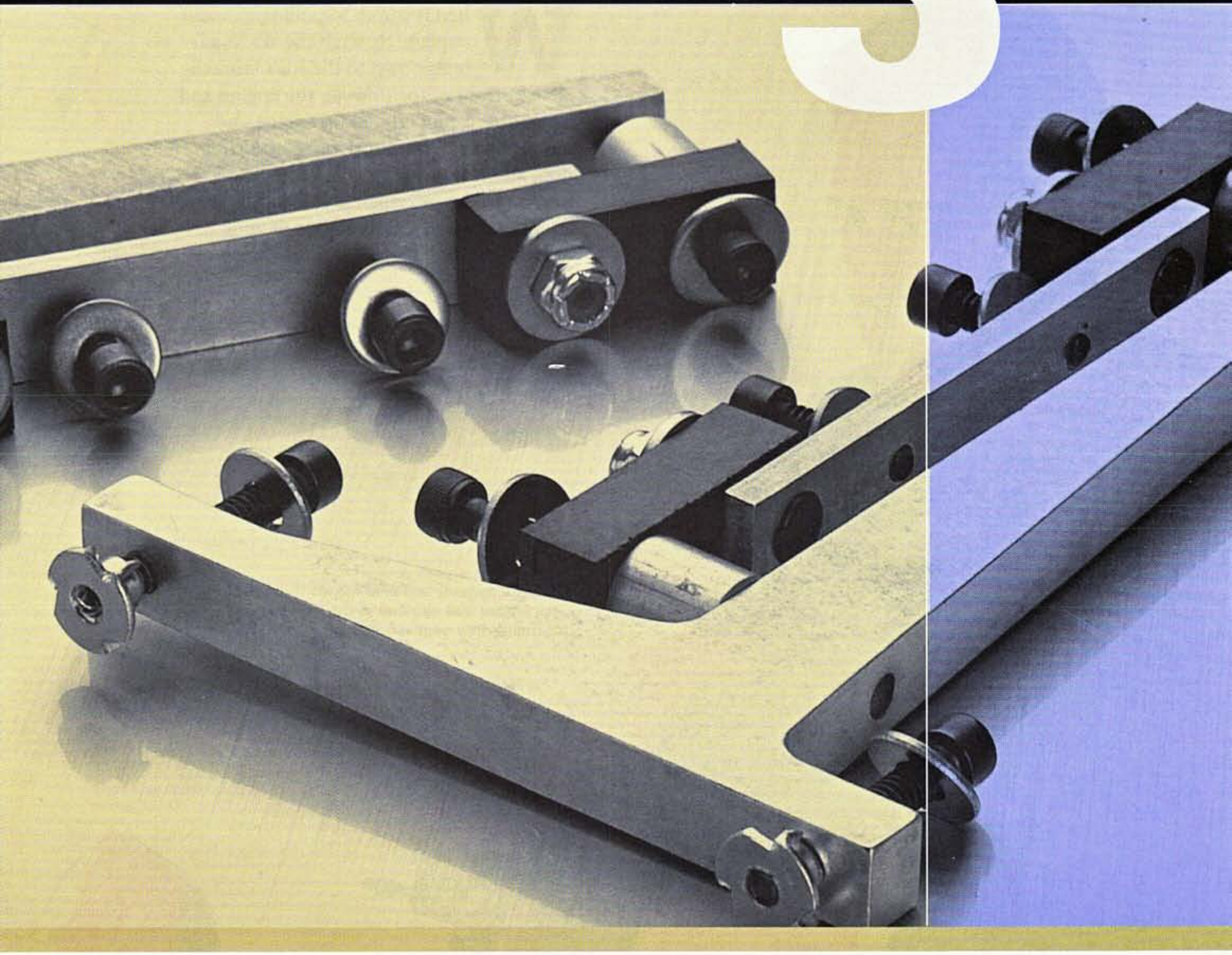
moisture will find its way to the lower prop and will ruin all your hard work.

MULTI-BOLT PROP HUBS

Several engines come with multi-bolt prop hubs in which there are six bolts around the central prop shaft. Don't try to drill these holes with a hand-held drill; use a drill press if you can, and use the prop washer as a guide while you drill the holes. The proper way to drill the bolt holes is to position them so that there is a clear path from prop tip to prop tip (Figure 5).

Once you have drilled the holes, check their alignment by placing the prop on the engine and installing the bolts by hand. They should all thread easily into the drive washer. If they don't, enlarge the misaligned holes slightly so that the bolts fit easily. When you're satisfied with their fit, remove the prop and balance it. To ensure that the prop is always attached in the same position on the shaft, make a pencil mark on the prop hub and the drive washer. Whether you use a single prop nut or a multi-bolt prop hub, always make sure the prop is securely attached to the engine. Make sure the prop bolts are tight, and always check the prop for damage before you go flying. When it comes to props, don't take any chances!

INSTALLATION 3



Please note: prices and sources subject to change.

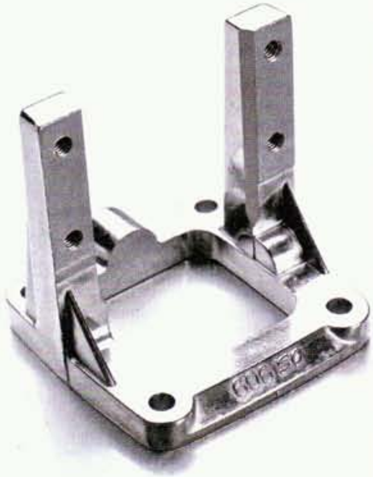
firewall forward: installing your engine

BY GERRY YARRISH · PHOTOGRAPY BY DERON NEBLETT

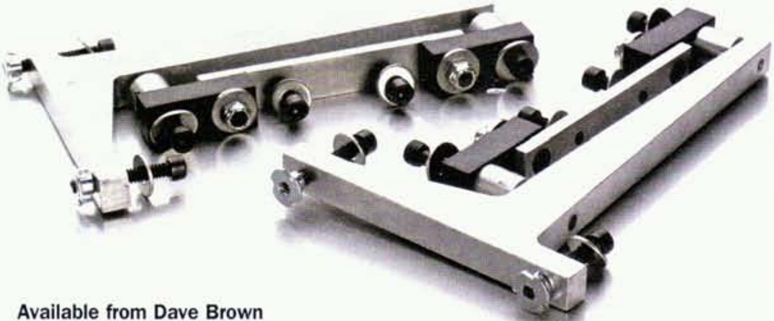
When it comes to pulling a model airplane through the sky, it all boils down to the stuff immediately in front of the firewall: the engine and its mount. A properly set up engine and mount helps to minimize noise and vibration, and it maximizes safety and power transfer to the propeller. If you plan to install an internal-combustion engine in your model, you have to do it right. Here's how!

Having a properly installed mount that fits your engine and airframe is the foundation for trouble-free engine operation.

Engine mounts are available molded of plastic (such as this one from Carl Goldberg Products) and made of aluminum. Both types are easy to use and install.



Custom mounts are also available; they're drilled and sized to fit a specific engines, and they save you some setup time.



Available from Dave Brown Products, these Vibra-Damp mounts are avalable for popular 4-stroke engines; they come drilled and tapped.

These Du-Bro Vibra mounts are very popular and come with replaceable rubber isolators.

Setup considerations

Before you bolt your engine to the firewall, consider the requirements of the engine type and configuration, the fuselage and firewall layout, engine cooling, the cowl construction, the horsepower output and the carb position; these are the factors that most affect the engine installation.

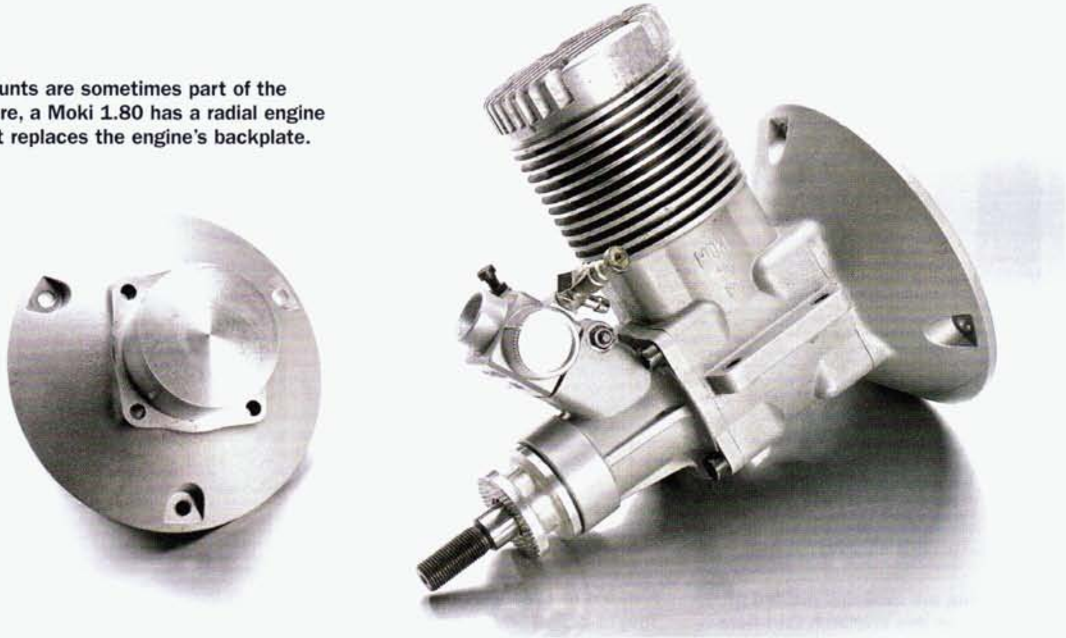
Engine mounts

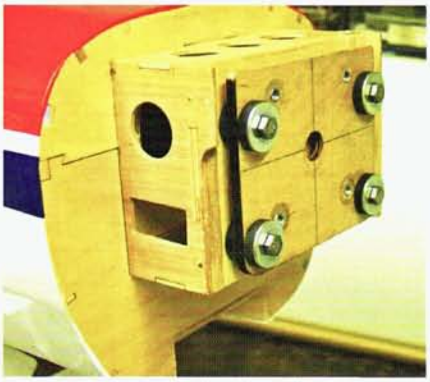
The hardware that supports the engine and attaches it to the rest of the airplane is the engine mount, and it comes in a variety of shapes and materials. One- and two-piece mounts are available, and they are made of metal (usually aluminum) or molded plastic. Some engines come with their own mounts, and some mounts are designed as part of the engine case. For large gasoline engines, a simple metal plate serves as the mount; it comes bolted to the back of the engine case. There are also cup-shaped engine mounts for gas engines; these increase the distance between the firewall and the propeller. They mounts also help draw heat away from the engine.

Several companies offer custom-designed, predrilled mounts that fit specific engines. Though they cost a bit more than the mounts you have to drill yourself, custom mounts save time and offer precise machining for strong support. Also available are adjustable mounts that fit a range of engine sizes.

Engine mounts come in two basic types: hard and soft. Hard mounts provide a solid frame that you bolt directly into place on the firewall. Soft mounts provide a firm but flexible engine installation that helps to isolate the rest of the model from engine vibration. Both types work well, but I prefer to use hard mounts on all of my airplanes except those with very light, delicate construction.

Engine mounts are sometimes part of the engine. Here, a Moki 1.80 has a radial engine mount that replaces the engine's backplate.





Great Planes offers a large, gas-engine isolation mount that's made of plywood and is installed between the engine and the firewall. Four rubber pads help absorb engine vibration.

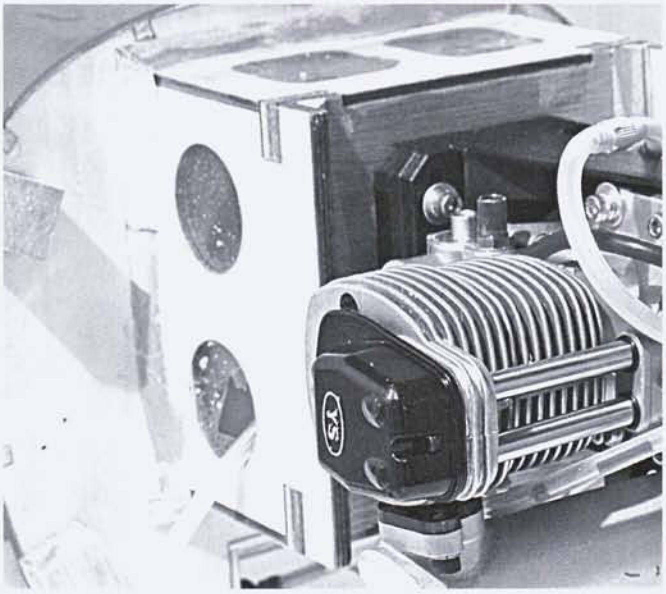
Available from Nick Ziroli Plans, these gasoline-engine soft mounts offer different levels of vibration damping according to the hardness of the mount you use. They are color-coded for different engine sizes.

For most gasoline engines, the engine mount is a flat, aluminum plate that is bolted to the back of the engine case. Here, a Fuji 50cc engine has been "hard mounted" to the engine-mount box structure in the front of a Great Planes Christen Eagle. Notice the offset throttle linkage using a 90-degree bellcrank.

Davis Model Products makes these Iso-mount inserts to isolate engine vibration from the rest of the model. They are easy to install, and you can adjust the amount of vibration damping by tightening and loosening the screws.

Nuts and bolts

There are two ways to bolt your engine to its mount: drill holes all the way through the mount beams and use washers and locknuts to secure the attachment bolts, or drill and tap the beams to match the holes in the engine's side lugs. Depending on the size of the engine, the attachment bolts range in size from 4-40 to 8-32. The size of the holes in the lugs typically dictates the bolt size. Since engine cases are made of aluminum, it is best to install flat washers under the heads of the attachment bolts and under the locknuts (if you use them). This will help to prevent the nuts and bolts from wearing the mounts' softer material.



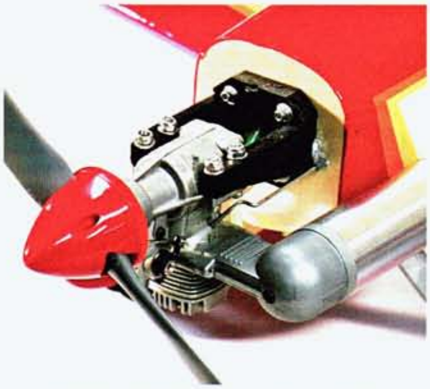
This YS 1.20 4-stroke engine is side-mounted (horizontally) and uses a Pitts-style muffler to guide the exhaust straight downward. The plastic engine mount has been drilled and tapped for the engine-mounting bolts.

Several adjustable mounts come molded out of durable plastic. These adjustable mounts from Carl Goldberg Products have slotted bolt holes so they can be made wider or narrower to suit the engine.

Adjustable mounts

To provide a one-size-fits-all arrangement, several manufacturers offer adjustable engine mounts. These include mounts with slotted attachment rails and those with clamping plates that fit over the engine-attachment lugs. Two-piece mounts are adjustable by design, as engine width affects how far apart they will be bolted to the firewall. Whenever you use adjustable mounts, be sure to follow the instructions closely for proper engine support.

Here is an adjustable engine mount bolted to a Hangar 9 Corsair. The two mounting brackets are made of aluminum, and the attachment holes are slotted to accept a wide range of engine sizes.



This engine installation is typical of most .40-size sport models. The engine is inverted and uses a one-piece, molded-plastic mount. Notice the locknuts used to secure the attachment bolts.

Firewall configuration

Typically made out of strong, multi-layer plywood, the model's firewall design must be considered before you install your engine and engine mount. In most models, the firewall is a flat, vertical structure in which you need only drill holes for the bolts (Figure 1). You then install blind nuts or locknuts to secure the installation. Most trainer and sport models use this arrangement, and so do many scratch-built scale models. It is simple and very strong.

Found in scale and aerobatic models, the engine mount-box structure is becoming very popular (Figure 2). Basically, this is a plywood box that's built into the fuselage to tie the firewall into the first and second formers. The box helps distribute stress loads and is a strong, relatively light structure. In many kit-built airplanes, this box can be slid into and out of the fuselage to accommodate various engine lengths.

A recessed firewall (Figure 3) is used when an engine is too long for the cowl. Used primarily in scale airplanes, this is an inverted box structure that protrudes into the fuselage.

An old-time—but still very acceptable—way to attach the engine to the model is to build two long, hardwood rails (usually made of maple) into the firewall. This arrangement distributes stress loads over a number of formers for a very secure engine installation. The rails are usually drilled and tapped for the engine-attachment bolts.

Firewalls

FIGURE 1. BASIC ENGINE MOUNT

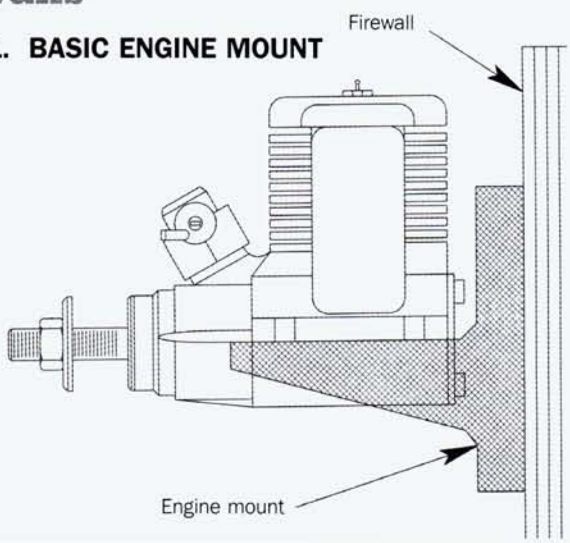


FIGURE 2. BOX STRUCTURE

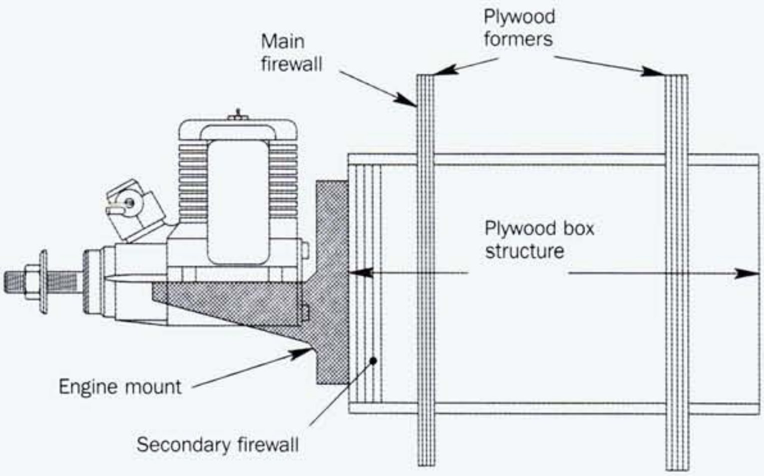
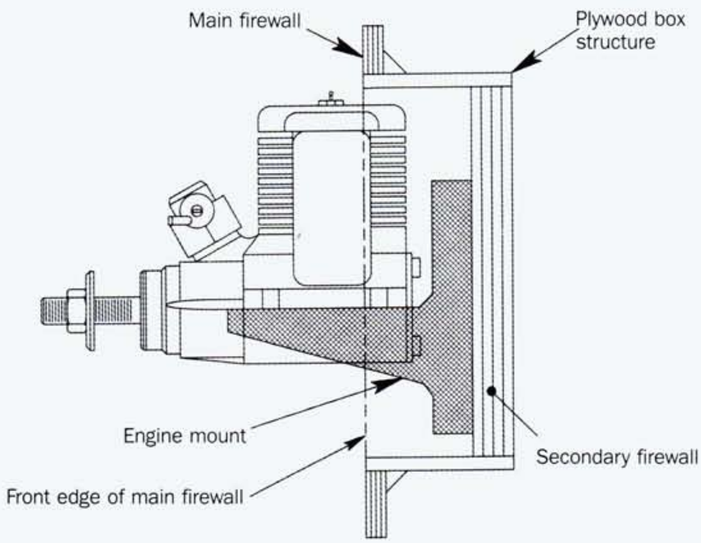


FIGURE 3. RECESSED FIREWALL

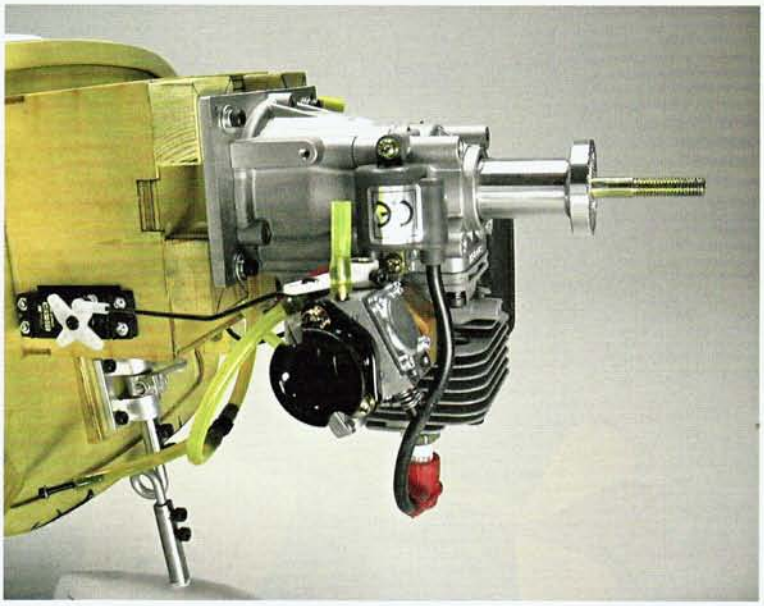


Throttle linkage

For reliable engine operation, make sure that the pushrod or throttle cable that operates the carburetor is installed properly. Once the engine and mount have been installed, mark the location of the throttle-linkage exit so that the throttle linkage will operate smoothly. Make the exit hole large enough to allow slight side play as the throttle arm moves from full throttle to full idle. Several connectors are available to attach the linkage to the throttle arm, including clevises, ball links and EZ connectors. Avoid using a Z-bend with an aluminum throttle arm, as this produces metal-to-metal contact that can cause radio interference. Z-bends work fine with plastic arms.

Fuel tank location

It is also important that you install your fuel system properly. To maintain a proper fuel flow, install the fuel tank so that its centerline is at or just slightly below the carburetor's centerline. With large gasoline engines, tank position is much less critical; they are equipped with pumper carbs that can draw fuel regardless of where the tank is placed. When you drill holes through the firewall for the fuel and vent lines, make them large enough for the lines to pass through easily; a tight fit will chafe the lines and eventually cause them to leak. I prefer to drill a single large hole and then pass all the fuel lines through it. This also makes installing and removing the tank easier than when you try to feed three lines through three different holes.



Many modelers now install the throttle servo in front of the firewall and run a short pushrod to the throttle arm. Be sure to avoid metal-to-metal contact by replacing the steel throttle arm with a plastic one.

A cool engine is a happy engine

ENGINE COOLING

Regardless of which engine mount you use, cooling is critical to any engine installation. When you use an engine cowl to improve aerodynamics or appearance, make sure that there is an adequate airflow to draw unwanted engine heat away. The basic rule is to provide twice as much exit area as inlet area. If you have 2 square inches of air inlet, the exit should be at least 4 square inches. With large, roomy engine cowls in which there is abundant dead-air space around the engine, you may have to install sheet plywood or aluminum baffles to direct the airflow around the engine head. You can't get maximum engine performance without proper cooling

Tight engine cowls such as the one on this Great Planes Shoestring Racer require proper engine cooling to prevent the engine from overheating.

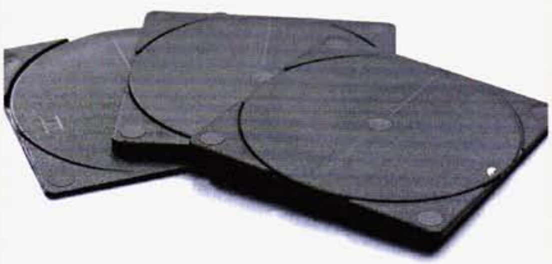
It's all about flying! Without properly installed engines, our models would just sit there and look good.

ANGLED ENGINES

ENGINE-THRUST OFFSET

Depending on the type of model airplane you have, a few degrees of engine-thrust offset (usually right and down) is required for it to fly properly.

To add offset, adjust the engine on its engine-mount rails or angle the entire engine-mount assembly. The mount can be angled by adding a wedge-shaped spacer or by installing a few washers under one side of the mount. The thrust angle can also be built into the firewall, where it is glued into place at the desired angle. The engine mount is then simply bolted to it. When you add right thrust, you should offset the engine-mount placement slightly to the left of the firewall's vertical centerline. Typically, 1⁄8 to 3⁄16 inch is enough for 2 degrees of right thrust. Offsetting the engine keeps the prop shaft centered at the cowl nose.



These engine-thrust plates from Ernst are used to adjust the engine's right and down angle. They are installed between the firewall and the engine mount.

CONCLUSION

All that's left is to check the details and make sure that everything is tight and properly secured. Having a well-thought-out, properly equipped engine installation is the foundation for trouble-free engine operation. Keep everything simple and well organized.

easy, accurate engine mounting

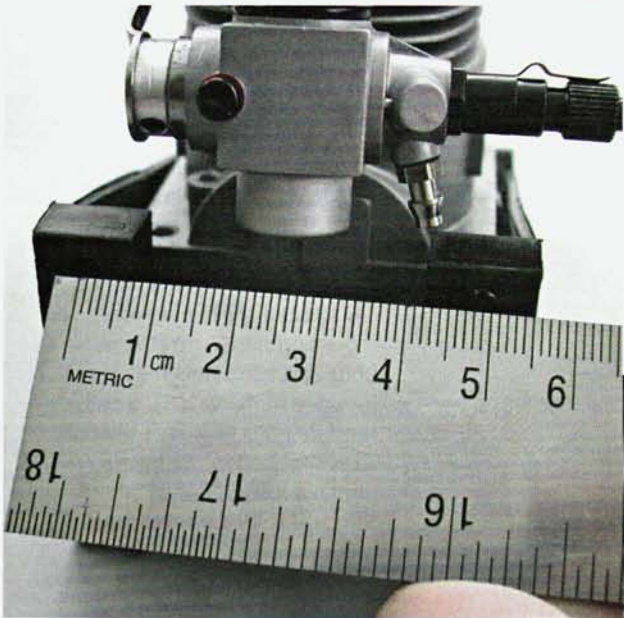
BY ERICK ROYER · PHOTOGRAPHY BY ERICK ROYER

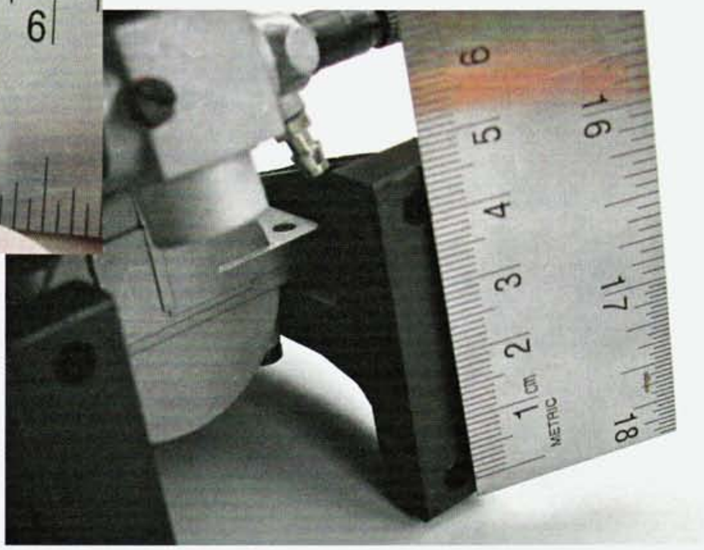
Correctly installing an RC engine mount and engine is one of the most important steps when you assemble a model plane, whether it's almost ready to fly (ARF) or scratch-built. Most ARF model kits come with engine mounts, and though some models come with the mounting holes already drilled in the firewall and with blind nuts installed for the engine mount, others require that you mark and then drill the holes in the firewall and the mounting rails. This critical process is actually very simple when you take it step by step; here, I show how I installed an RCV .58 4-stroke in a Model Tech Magic ARF. The steps to follow will be the same for a 2-stroke.

1 First, you'll need an engine, suitable tools, a mount, mounting hardware (the nuts, bolts and blind nuts that are included in many kits), a drill (and drill bits to match the bolt sizes specified in the instructions), a ruler, a pen or pencil, thin and thick CA and a triangle. I also suggest that you secure the bolts with thread-lock compound to prevent them from vibrating loose.

I use a Great Planes Dead Center Engine Mount Locator to determine and mark the correct positions for the engine-mounting holes. This simple tool makes it easy to mark the holes' positions correctly every time.

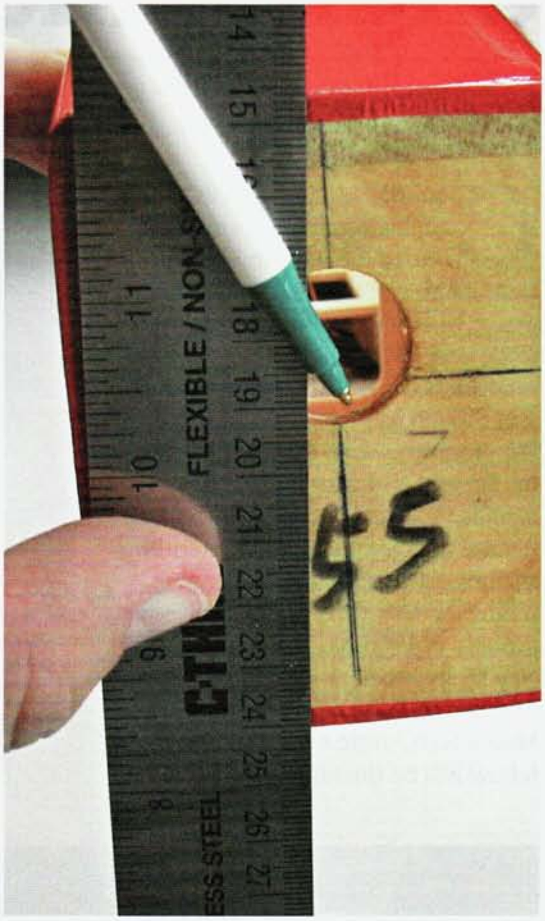
2 First, temporarily attach the engine to the mounting rails with a few drops of thin CA. Engines come in a variety of widths, and it's easier to measure the distances between the holes when the engine is temporarily secured to the rails.



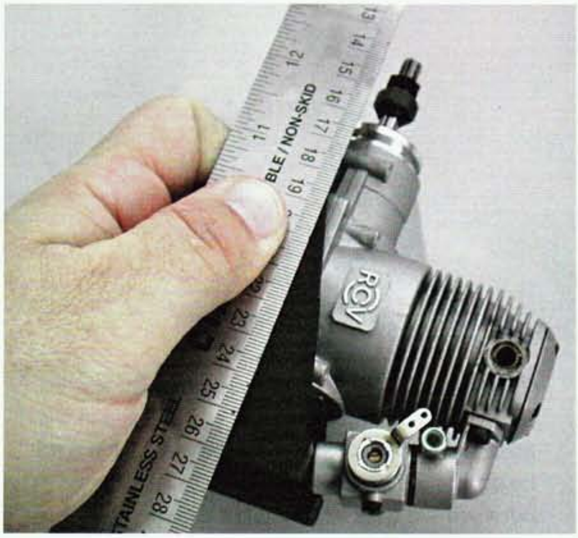


3 Measure the distance between the holes in the left and right mounting rails, and then measure the distance between the holes on each end of each mounting rail. Note these measurements, and then lightly tap the engine to break it free of the mounting rails.

4 Refer to your instructions for the positions of the firewall's vertical and horizontal reference lines. In some ARFs, right thrust has been built into the firewall, so the vertical reference line should be offset slightly to one side to account for this.



5 Depending on your plane, you may have to mount the engine upright, inverted, sideways, or at a 45-degree angle. Refer to the instructions to find which way is best for your model. For a cleaner appearance, I decided to mount my RCV engine inverted. Divide the distance between the left and right mounting rails by two. Here, the distance was 52mm , so I made a mark 26mm to the left and right of the vertical reference line on the firewall. Do this above and below the horizontal centerline, and use a straightedge and a pencil to connect the marks.

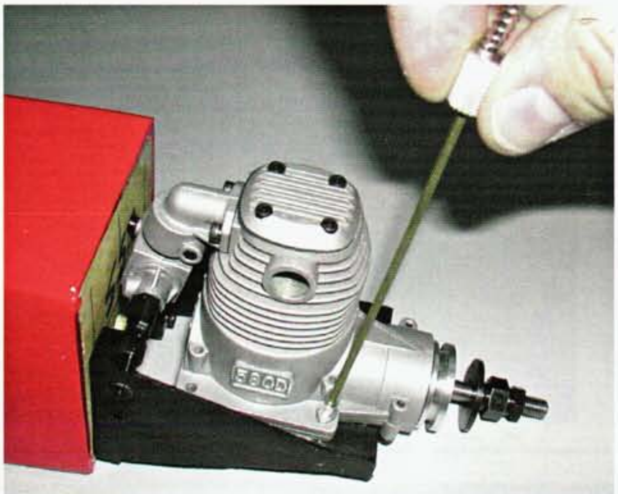


6 On planes such as the Magic, you'll need to center the crankshaft on the horizontal centerline. Using a ruler, I marked the back of each mounting rail to indicate the center of the prop shaft.

7 To correctly position the engine, I had to offset the mount toward the top of the firewall. The distance between the holes in each mounting rail was 38mm. I determined that the top holes should be 26mm above and the bottom holes 12mm below the horizontal centerline. Draw a line between the upper marks and the lower marks to make two new horizontal reference lines.

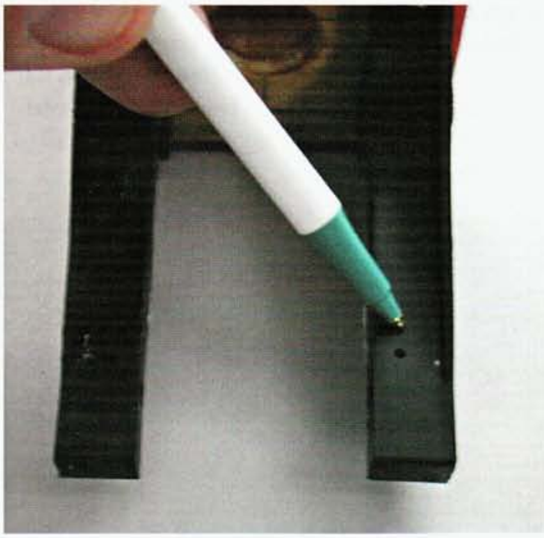
8 Using a drill bit of the proper size, drill holes (a total of four) where the lines intersect, and then attach the mount to the firewall with your bolts. Install the blind nuts on the rear of the firewall, using the mounting bolts to seat them. Add a few drops of thick CA to the inside face of each blind nut to ensure that it will remain in place if you ever need to remove the engine mount.

9 Place the engine on the mount at the correct distance from the firewall, as indicated in the model's instructions. For models that have a cowl, be sure to leave at least an 1/8-inch clearance between the spinner backplate and the cowl. For planes such as the Magic, which doesn't have a cowl, you can position the engine to balance the model (without adding weight). I balanced the model before I marked the mounting holes, and I determined that I'd have to mount the engine as far aft on the rails as possible.

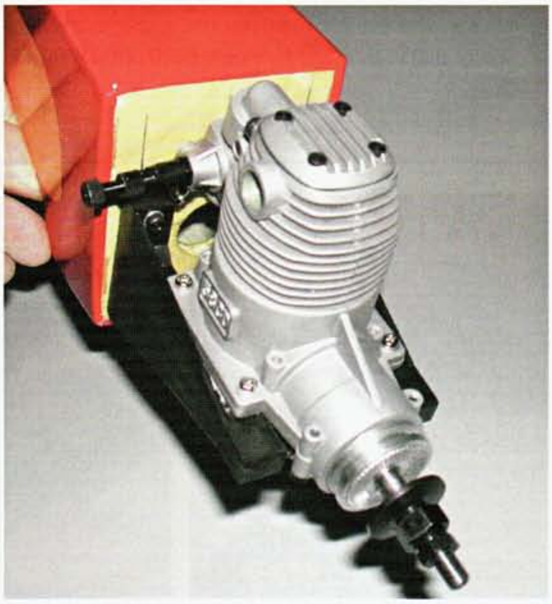


10 I placed the Great Planes mount locater in each hole of the engine mount's lugs and gave the locater a twist. The tool has a little 1/16-inch drill bit that marks pilot holes on the mount rails.

11 Having marked the pilot-holes' positions, I drilled the mounting holes with the correct drill bit and then installed the engine with the recommended hardware (put a drop of thread-lock on every nut).



12 Here, the engine is securely mounted on the Magic's firewall. There are many ways to mount engines, but these steps are useful for most installations. With the proper tools and accurate measurements (measure twice and drill once!), you'll quickly and easily have a perfectly mounted engine.



rc fuel systems

BY GERRY YARRISH

Flying RC model airplanes that are powered by glow and gasoline engines means that you'll have to install a fuel tank and other necessary fuel-system components. This is easy for experienced builders, but newcomers often find it challenging to choose, assemble and install a proper fuel-delivery system. This article shows the basic makeup of typical fuel systems and how to properly install and maintain them. Whether you want to pilot ½A sport models, speedy pylon racers, or giant-scale warbirds, you have to keep the fuel flowing to the engine. These tips will make all that plumbing more understandable.

THE BASICS

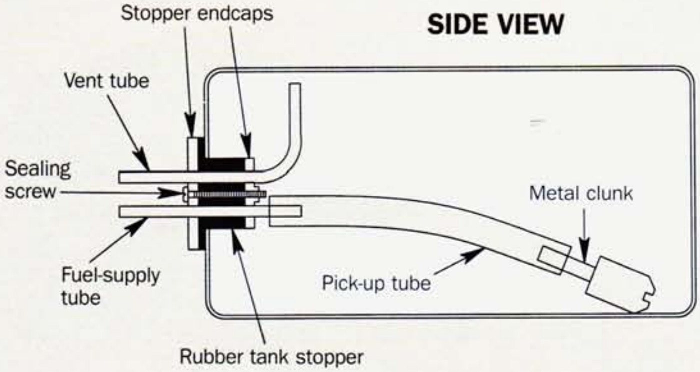
The fuel tank holds the engine's supply of fuel. The tank is connected to the carburetor with flexible fuel line (fuel tubing), and a rubber stopper seals it. For a tank to operate properly, it must have a vent line that allows air to enter the tank as fuel is drawn out. The vent relieves the vacuum left in the tank. Model airplanes don't always fly straight and level; they climb and dive and often fly inverted. To allow the fuel to flow at different attitudes, the tank has a flexible internal pick-up tube. A heavy fitting (called a "clunk") at the end of the pick-up tube keeps the end of the tube at the lowest part of the tank for a continuous supply of fuel. Lengths of brass tube pass through the tank's stopper, and the flexible fuel lines that carry the fuel to the engine simply slip over the brass tubes. The rest of the fittings and accessories help the fuel system work properly and make it easier to maintain and operate.

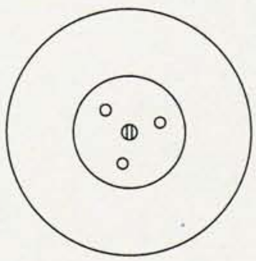
Once you've chosen the correct tank, fuel lines and accessories for your model, you'll be well on your way to having an engine that runs reliably.

Fuel-tank setup

Different types of airplanes have different fuel-system requirements. Most trainers' engines are exposed, and this makes for easy access to the fuel line. A simple two-line setup works well with this arrangement. In scale models where the engine is completely enclosed by a cowl, a three-line system is the way to go. You can avoid many problems if you follow a few simple guidelines :

- For glow engines, always use silicone tubing of the proper inside diameter. Medium tubing works well with .15- to .75-size engines. Use narrow fuel tubing for ½A engines; wider tubing is best for engines larger than .75ci.
- For gasoline engines, use neoprene plastic or special "Tygon"-brand tubing.
- Set up the internal fuel link properly inside the tank. The vent tube must point upward and be as close as possible to the top of the tank. Many tanks have a "bubble" molded at the top; the end of the vent tube should fit into it. The vent tube should extend about ¾ inch into the tank and then bend 90 degrees upward in a smooth radius without any kinks. A Du-Bro tubing bender works well.
- The vent line can either be exposed (uncapped) or attached to a fitting on the muffler to pressurize the tank.
- The fuel pick-up line inside the tank must move freely and should be just long enough to prevent the clunk from touching the back of the tank.
- Always check for leaks or pinholes in the fuel lines; many fuel-system problems arise when air gets into the lines.
- Whenever possible, install the tank so that its centerline is about ⅜ to ½ inch below the carburetor's spray bar. If the tank is too high, fuel will be siphoned into the engine and will flood it. If the tank is too low, the engine will run leaner as the tank empties.
- Wrap the tank in foam rubber to isolate it from vibration. Vibration can cause the fuel to foam and the engine to run lean. If the neck of the tank is inserted into a hole in the fire wall, apply silicone around the neck to protect it from vibration.





Fuel-tank shapes & sizes

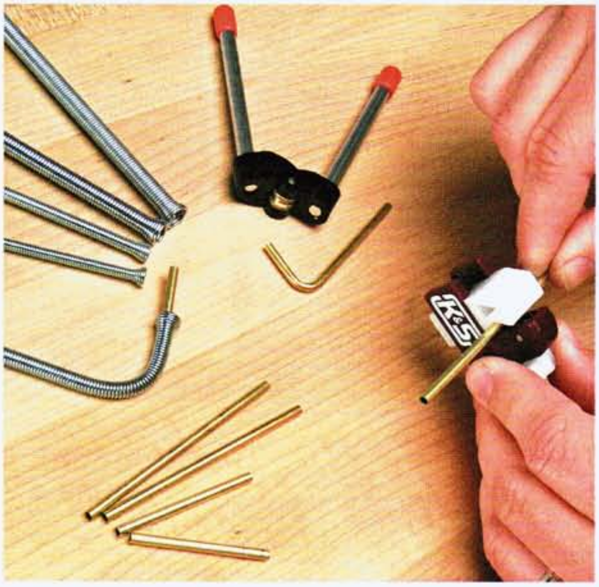
Fuel tanks come in various shapes, sizes and styles. Capacities range from 1 to 32 ounces, and shapes include slanted, round, rectangular and oval. Tanks are generally molded of polyethylene because it isn't affected by glow fuel or gasoline. Some tanks, such as Sullivan's Flextanks, can be heated and reshaped to fit into tight spaces. Be sure to use the proper stopper in your tank for the type of fuel you're using. A stopper meant for glow fuel will deteriorate very quickly when it contacts gasoline. If the neck of your tank doesn't fit into a hole in the firewall, use a slanted tank or one that has a "chin" on the front of it. The chin prevents the fuel line from being pinched between the tank and the firewall.

Fuel tanks come in many sizes and shapes. Note the slanted- and chin-style tanks on the end; they prevent the fuel lines from being pinched by the firewall.

How many lines?

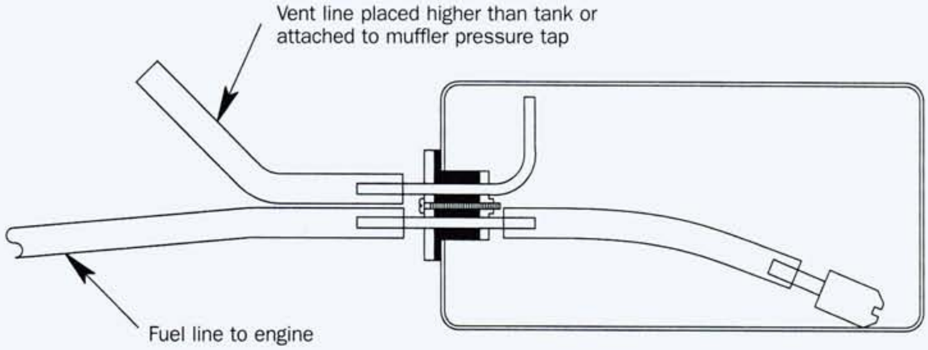
■ Two-line setup. A two-line fuel system is very simple and almost foolproof. To set up the tank, you need only two pieces of brass tube, a clunk, a rubber stopper and a short length of silicone tubing. Bend one tube 90 degrees to form the vent and insert it through the stopper. It lets outside air in as the fuel is drained out, and it acts as an overflow indicator when you fill the tank. The second tube is the fuel-supply tube; the pick-up tube and clunk are attached to it. This line is attached to the carburetor and is also used to fill the tank.

■ Three-line setup. In a three-line tank, you assemble the tank just as you do a two-line system, but the third line is used to fill the tank. It can be made from a short length of brass tube and doesn't need a pick-up line in the tank; you can also make it like the vent tube, except it is pointed downward. Before you start the engine, you must plug the third line to prevent fuel from leaking out.



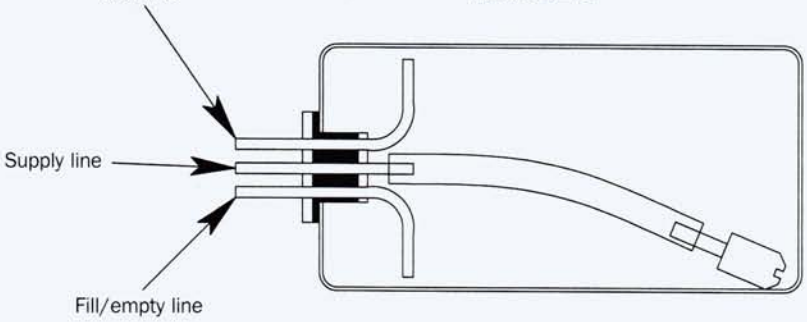
To properly size and fit the brass tubes required in a fuel system, it's handy to have a tube cutter such as this one from K&S Engineering. It's designed to cut soft metals such as brass and aluminum. With the Du-Bro and K&S benders, you can safely make 90-degree bends without kinks or breaks.

Basic two-line fuel tank
FIGURE 2



With a two-line fuel-tank installation, the vent line is attached to the muffler pressure tap or left to vent to the outside air pressure. If left as is, the end of the vent line should be above the fuel tank so fuel will not run out.

Three-line fuel-tank setup
FIGURE 3



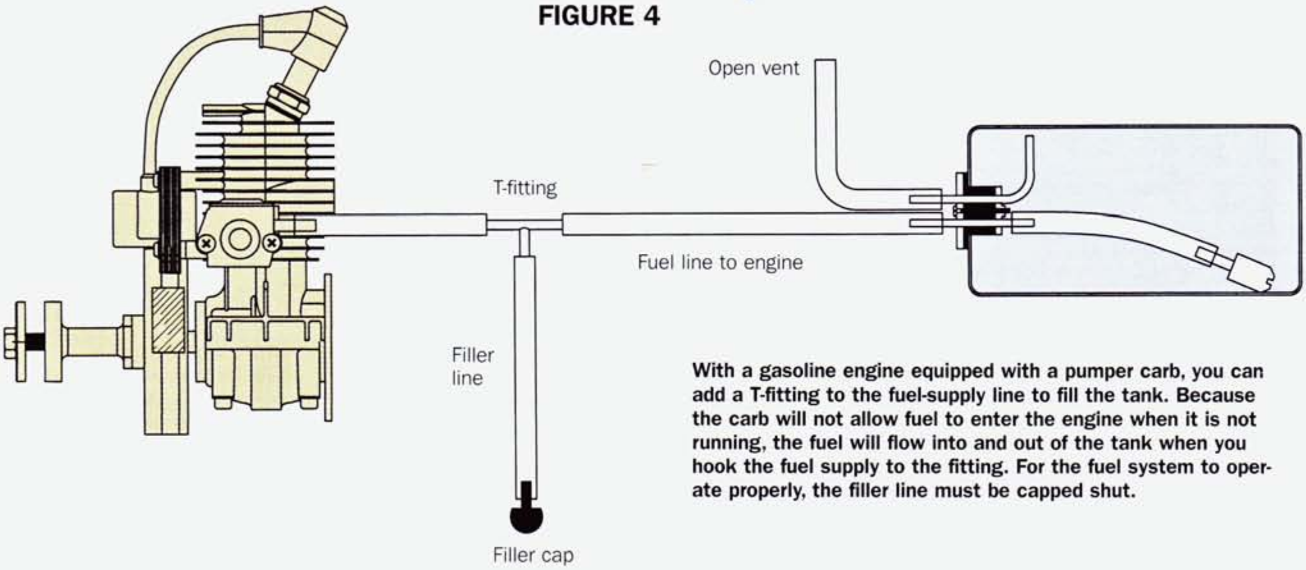
A three-line tank installation has an additional fuel line that is used to fill and empty the tank. Both the vent and supply lines are the same, but for the tank to operate properly, the third line has to be capped before you start the engine.

Gasoline fuel systems

Perhaps the simplest fuel systems are those for gasoline-powered engines. Unlike glow engines, which use a venturi vacuum to draw the fuel into the carb, most gas engines have a pumper carb to draw fuel out of the tank. For this reason, the placement of the gas tank is not nearly as critical as it is for the glow engine. A gas engine can draw the fuel through several inches of tubing without any ill effects. Also, because the gasoline carb has a diaphragm pump, it won't allow fuel to flow into the engine unless it is running.

An easy way to fill and empty the tank is to install a T-fitting in the supply line and add a length of tubing. When you pump fuel into this line, it will flow only into the tank and won't flood the engine. When the tank is full, you can use a plug to seal the fill line, and the engine will draw the fuel from the tank. By adding a long fill line and using a fuel dot fitting, you can place your filler cap anywhere you like—great for scale models.

Gasoline-tank setup
FIGURE 4



With a gasoline engine equipped with a pumper carb, you can add a T-fitting to the fuel-supply line to fill the tank. Because the carb will not allow fuel to enter the engine when it is not running, the fuel will flow into and out of the tank when you hook the fuel supply to the fitting. For the fuel system to operate properly, the filler line must be capped shut.

When your stopper wears out, buy a replacement at your local hobby shop. Be sure to get a stopper that is compatible with the fuel you use. The brown one in the middle is for use with gasoline engines.

FUEL-SYSTEM ACCESSORIES

A fuel-filler valve makes it easier to fuel your model; several are available. Used with two-line setups, they allow you to fill or empty the tank without disconnecting the fuel lines. They're easy to install and are simply connected to your supply line like a T-fitting. Most fuel valves consist of a simple check ball design and can be installed on the model wherever it's convenient. Don't attach the filler valve to a removable engine cowl; attach it to a convenient spot on the firewall so you can get to it through a hole in the cowl. Attach the feed line from the tank to the valve, and then to the carburetor.

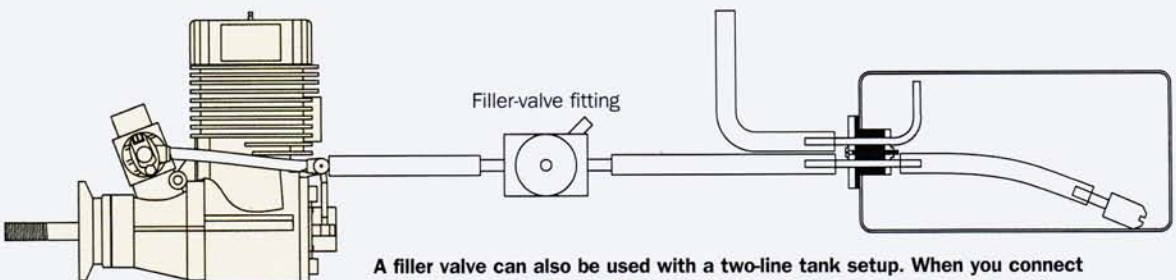
The large Du-Bro filter (left) is used on the bigger glow and gas engines. The sintered bronze filter from Du-Bro (center) can be used in the tank or in a fuel jug. The smaller Great Planes filter is perfect to use between the tank and the carburetor; it can be taken apart and cleaned.

If you use a three-line system, a fuel dot is a good choice for a tank filler. The dot is attached to the third line; you simply pull it from its retainer, remove the plug and fill your tank. To hold a fuel line securely in place and to ensure that it doesn't accidentally become disconnected during flight, use retainer clips, a zip-tie, or an ⅛-inch-wide piece of fuel line slipped over the main line.

If you want your engine to run reliably, a fuel filter is an absolute necessity. Some filters can be used either in the tank as a clunk or in your fuel jug. A small filter can be placed in the feed line between the tank and carburetor. Some filters can be disassembled and cleaned.

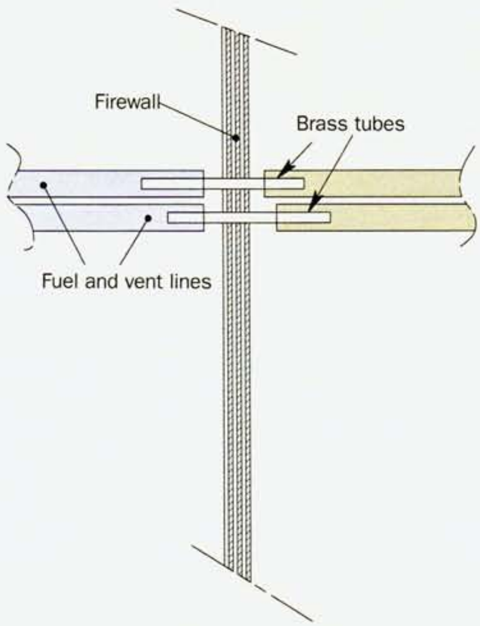
Above left: valves such as these from Sullivan (top) and Du-Bro (bottom) can be installed on the firewall. The R/C City fuel dot (center) is used in a 3-line fuel system, and it's foolproof. Above right: the Du-Bro spring clips come in sizes to accommodate small-, medium- and large-diameter fuel lines. Aerotrend makes neat little clamps that work well on Tygon fuel line. Trinity's nylon zip-ties are a quick and easy way to secure fuel lines.

Two-line fuel tanks with filler-valve fittings
FIGURE 5



A filler valve can also be used with a two-line tank setup. When you connect your fuel supply to the valve, it shuts off flow to the engine so the tank is filled or emptied. When the fuel supply is disconnected, the valve permits fuel flow from the tank to the engine.

Figure 6
FIREWALL PASSAGES



Troubleshooting your fuel system

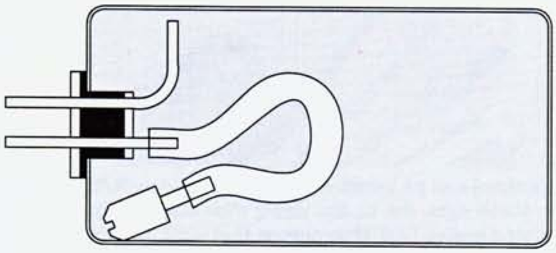
Properly installed, your fuel system will last a very long time and may never need to be changed. During a hard landing, however, some of its parts may be dislodged and stop working. Here are some common fuel-flow problems and fixes.

- If your engine begins to run lean, check for small pinholes in the fuel-supply line. Check closely wherever there are tight bends in the line, or where it comes into contact with your model. Leaks commonly occur where the lines pass through the firewall. A better method of installation is to drill small holes in the firewall and use lengths of brass tubes in the holes. You can then slip the fuel lines over the brass tubes to complete the system (see Figure 6).

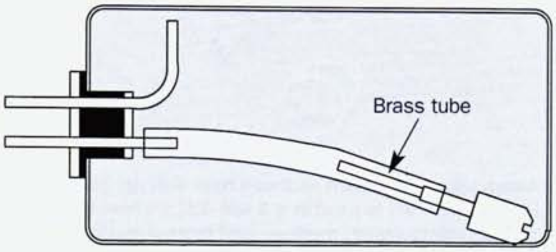
- After a hard landing, the flexible pick-up tube and clunk inside the fuel tank may be forced all the way forward. This often goes unnoticed until the next flight, when the tank stops delivering fuel to the engine in a nose-high attitude. To prevent this, solder a short piece of brass tube to your clunk. This decreases the pick-up tube's flexibility but still allows it to draw fuel in normal flying attitudes (see Figure 7).

- If your engine begins to run erratically, chances are that debris has gotten into the fuel system and is blocking the carb. It usually finds its way into the fuel tank from your fuel jug, and if it blocks the fuel flow, your engine will die. The easiest way to prevent this is with an in-line fuel filter. Install it just before the carb in the supply line. You can also install a filter in your fuel-pump line so that you'll fill the tank only with filtered fuel. Add a combination fuel clunk/filter, and you'll have a triple defense against dead-sticks.

Figure 7
PREVENT YOUR PICK-UP TUBE FROM BENDING

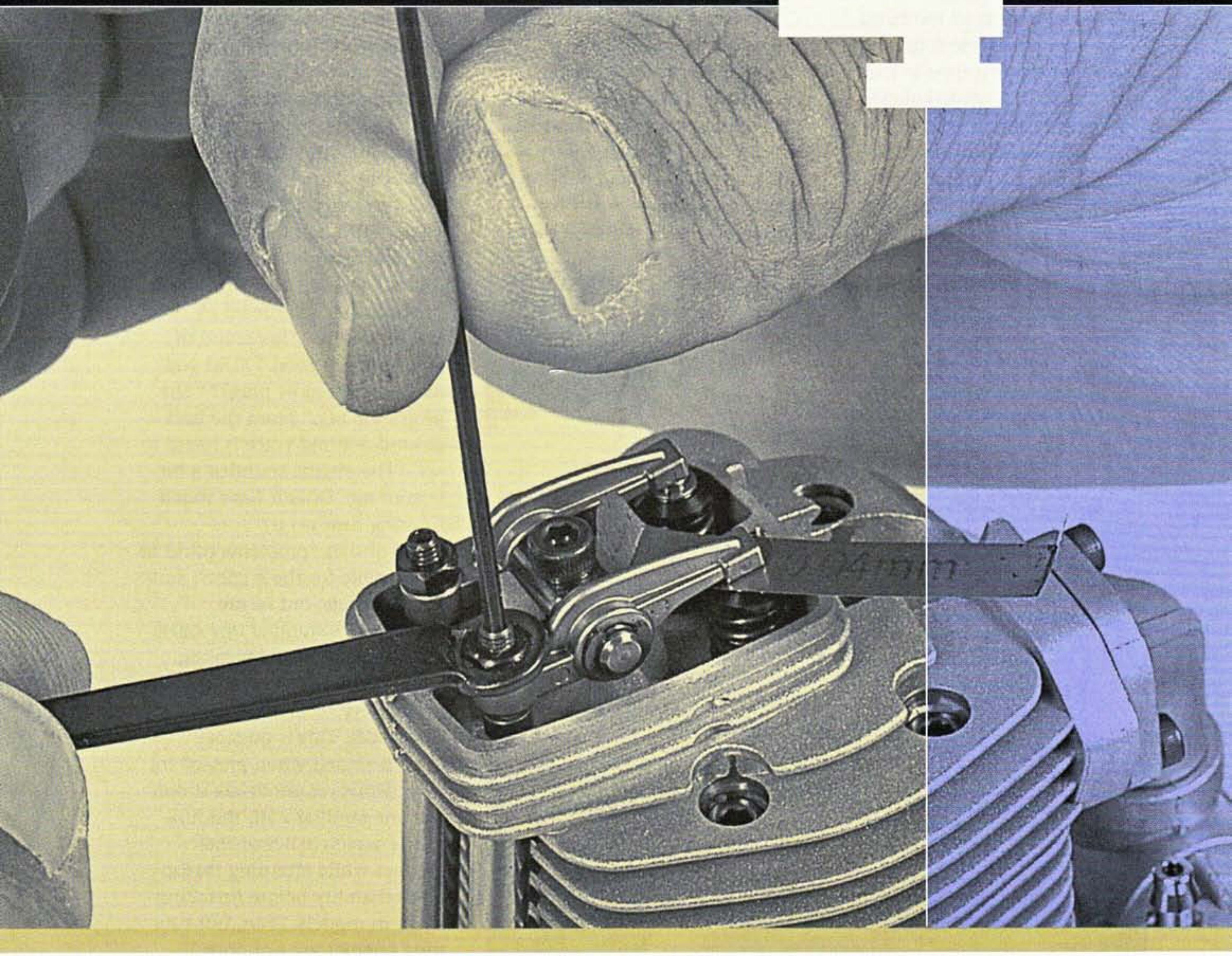


In a sudden stop or a hard landing, the fuel pick-up tube and clunk can be driven forward; this can prevent the tank from delivering all the fuel in the tank.



By soldering a short length of brass tube into the end of the clunk, you can stiffen the pick-up line. This helps prevent the line and clunk from being forced to the front of the tank.

BREAK-IN & MAINTENANCE 4



Please note: prices and sources subject to change.

break-in secrets for longevity & reliability

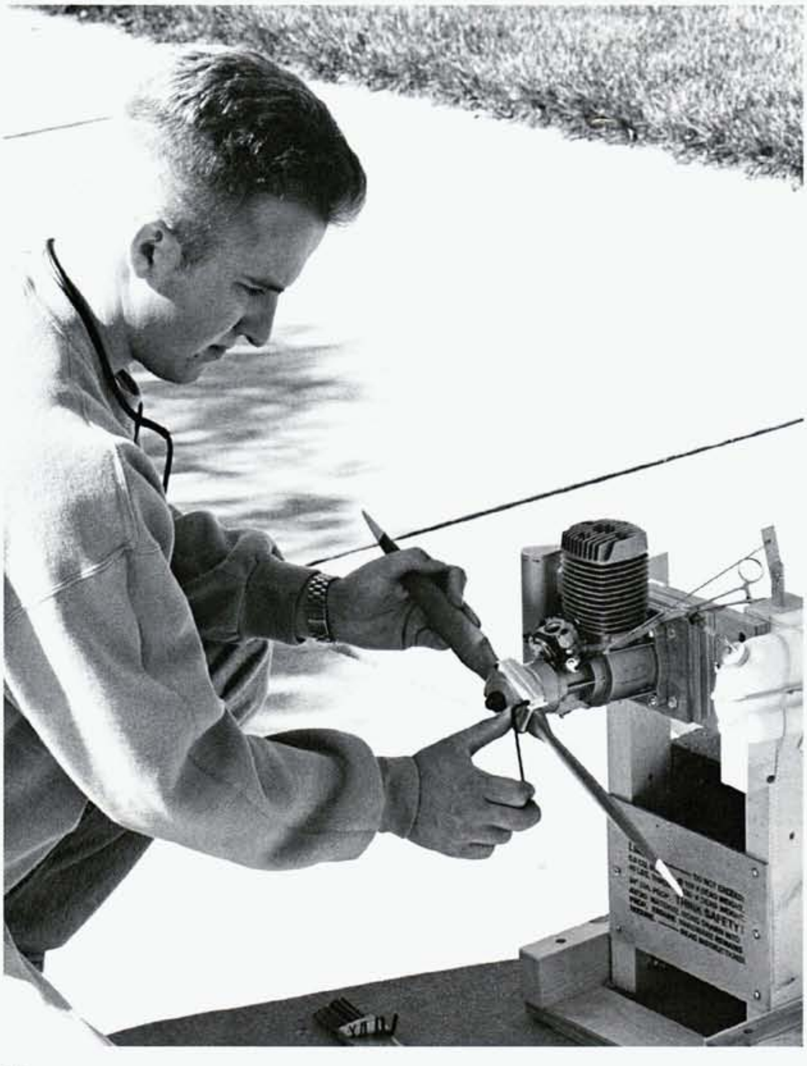
BY DAVE GIERKE

The scene is all too familiar: an engine is fired up for the first time at the flying field; that white-knuckle first flight is almost at hand. The anxious modeler surveys his shiny new model and reflects on the time and money required to get to this moment.

The engine, if it's lucky, has had a few tanks of fuel run through it before the pilot advances the throttle for takeoff. As the model breaks ground and climbs for altitude, he may have his hands full with an out-of-trim machine when the worst happens: the engine quits!—a nasty thing to occur so close to the ground with a nose-high attitude and low airspeed. If down-elevator isn't applied immediately, the model will likely experience a stall or stall spin; the consequences are usually catastrophic.

If fortunate, the model lands safely. Although the engine is still smoking and too hot to touch, opinions on its troubled performance are offered by several modelers: "This brand of fuel isn't any good." "Did you use the right glow plug?" "The prop's too big." From the background, a timid voice is heard to say, "The engine sounded a bit lean to me. Does it have much running time on it?"

All of these problems could be responsible for the engine's sudden stoppage, but in my opinion, the number one cause is the lack of proper break-in. Some say they always achieve satisfactory break-in while flying the model. This is possible; I've done it myself when pressed for time. However, modelers should become familiar with the running characteristics of their engines while attaining reasonable reliability before installing them in models. Lean, hot-running engines are not only unreliable but also often damag-



Preparing to start the large OPS 30cc 2-stroke engine for break-in on the large American Hobby Products test Stand, Gary Caruso tightens the hub on the two-piece APC break-in propeller.

ing to internal components, affecting both performance and longevity.

The following discussion is designed to convince those of you who have no opinion about the necessity and benefits of test stand break-in. For the others who routinely do it in the air: good luck!

WHAT IS BREAK-IN?

The late Peter G.F. Chinn, long-time engine review columnist for *Model Airplane News*, defined engine break-in as: "... the process involved in aiding an engine's transition from a newly assembled conglomeration of assorted metal parts to an efficient working whole." He elaborated, "It means running the engine under carefully controlled conditions at the beginning of its life in order to avoid the risk of immediate damage ... and to help working surfaces to become properly smoothed and aligned for maximum mechanical efficiency and performance." This statement, made almost 40 years ago, still holds true.

CONSEQUENCES

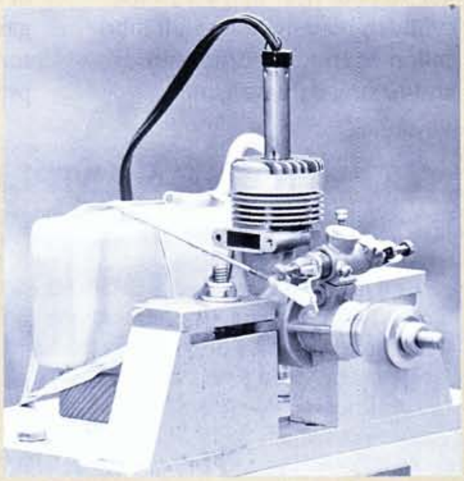
If you don't take the time, or if you don't perform the break-in correctly, your expensive new engine could be damaged almost immediately. Here's a partial list of deficiencies that will limit the engine's effectiveness:

• Difficulty in setting the high-speed needle valve (narrow range);
• Reduced peak power (at what rpm the engine will turn a given propeller);
• Difficulty in setting the idle needle valve (narrow range);
• Difficulty maintaining an acceptable idle (unreliable);
• Poor throttle-up characteristics (poor mixture control through the mid-range); and

Non-ABC Engine Sample Break-In

- **LOG.** Keep notes during break-in: include run time, rpm and any special details for each run.
- **FUEL.** Use low nitromethane content for non-ABC-type engines (5 to 10 percent nitro and between 24 and 28 percent lubricant).
- **MUFFLER.** The engine will run cooler if the muffler is removed for break-in; however, you'll lose the solid needle-setting muffler-pressure advantage, and the neighbors won't appreciate the additional racket, so leave it on.
- **PROPELLER.** Use one that is smaller than the recommended flight size, e.g., 12x6 for flight; 12x5 for break-in. Air-cooled 2-stroke engines run cooler when the load is reduced.
- **PROCEDURE:**

1. Set the needle valve for a rich start (see engine owner's manual).
2. Start the engine (leave the glow heat on).
3. Adjust the needle valve for 4-cycling operation.
4. Run for approximately 1 minute.
5. Perform step 4 four to six times with cooling-off periods in between. When you can hold the cylinder head without getting burned, the engine is ready for the next run.



The Fox .40 with an iron piston and a lapped-steel cylinder sleeve runs for the first time—very rich and 4-cycling. Until it loosens up, a new engine may require glow heat for the first few runs.

6. Run the engine for 3-minute periods, rich 4-cycling as before. Cool completely between runs. Perform eight to 12 times. Remove the glow heat if the engine will continue to run; if it doesn't, leave it connected.
7. Start the engine. Lean the needle valve until the engine breaks into a rich 2-cycling operation. Listen carefully to the engine and track the rpm with a tachometer. If the engine begins to slow down, quickly richen the needle valve. In such a case, the engine is still too tight and needs to be run more. Revert to step 6 until the engine will hold a setting at the leaner setting.
8. At this point, lean the mixture (needle valve) to a fast 2-cycling setting. Momentarily pinch the fuel line between your thumb and forefinger while tracking the rpm with your tachometer. The rpm should increase by at least 200 to 300 for this needle-valve setting to be correct. Adjust the needle valve to achieve this.
9. The engine should hold its setting for at least 30 seconds without losing speed. If it still doesn't maintain rpm, richen the mixture and run through step 7 again. Remember that the break-in process requires relatively short engine runs during which cyclic heating and cooling relieve internal stresses within engine components.

• Hot running, cranky operation, similar to a varnished engine with a piston and cylinder that need to be cleaned.

These problems are directly related to the condition of the piston and cylinder fit. Excessive piston to cylinder clearance produces:
• Combustion gas blowby (wasted power, high piston temperatures due to poor heat transfer to the cylinder, poor cylinder-wall lubrication retention, piston skirt and/or ring damage); and
• Poor crankcase compression (2-stroke idle and throttle transition problems).

INSIDE THE RUNNING ENGINE

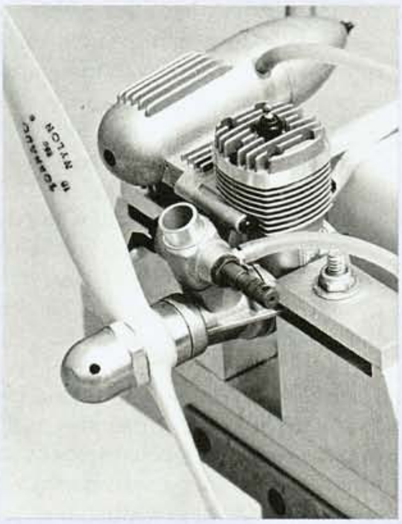
When the engine is running, we can't see what's happening inside, but here is what researchers tell us probably occurs:
• Cool air and fuel mixture enter the cylinder on one or more sides of the piston while hot exhaust gases exit the other; unequal piston expansion and distortion is probable in a 2-stroke engine.
• Cylinder temperatures are greater above the ports where combustion occurs; therefore, the cylinder expands more at the top than at the bottom, affecting the wear pattern of the piston in a 2-stroke engine.
• In 2- and 4-stroke engines, as the piston is being pushed away from the cylinder head by expanding, high-pressure gases, the connecting rod forms an angle with the axial centerline of the cylinder. This produces a side thrust (vector force) that generates a distorting load for the piston

ABC ENGINE SAMPLE BREAK-IN

- **LOG.** Keep notes during break-in; include run time, rpm and any special details for each run.
- **FUEL.** Use the highest nitromethane content recommended by the engine's manufacturer—usually between 5 and 15 percent nitro. Lubrication content should be 20 percent. Use some castor oil.
- **MUFFLER.** The engine will run cooler if the muffler is removed for break-in; however, you'll lose the solid needle-setting muffler-pressure advantage, and the neighbors won't appreciate the additional racket, so leave it on.
- **PROPELLER.** Use one that is smaller than the recommended flight size, e.g., 12x6 for flight; 12x5 for break-in. Air-cooled 2-stroke engines run cooler when the load is reduced.
- **PROCEDURE**

1. Set the needle valve for a 2-cycling start (see engine owner's manual).
2. Start the engine; if necessary, leave the glow heat turned on to keep the engine running.
3. Adjust the needle valve for a rich, 2-cycling operation.
4. Run for approximately 1 minute.
5. Perform step 4 four to six times with cooling-off periods in between.
6. Run the engine for 3-minute periods, rich 2-cycling as before. Cool completely between runs. Perform five to eight times.
7. Start the engine. Allow it to warm for at least 20 seconds. Lean the high-speed needle valve until the engine peaks (attains maximum speed) as deter mined by a tachometer. Back off (richen) 200 to 300rpm. Check this setting by pinching the fuel line while you watch the tachometer; rpm should increase by 200 to 300 and then return to the original rpm. Listen to the engine closely and watch the tachometer. If the engine begins to slow, quickly richen the needle valve to the rich 2-cycling position of step 6, as the engine needs more running time.
8. The engine should hold its semi-peak setting for at least 30 seconds without losing speed. If the engine still doesn't maintain rpm, richen the mixture and run through step 6 again.

Remember that the break-in process requires relatively short engine runs during which cyclic heating and cooling relieves stresses within engine components. ABC-type engines usually take 30 to 45 minutes to break in.



Pro-Magnum .36 ready for break-in. You should run an ABC engine on the test stand for at least 45 minutes, 2 to 3 minutes at a time, with adequate cooling periods between runs.

against the cylinder. This load isn't nearly as great on the opposite wall for the return stroke because the force is minimal.
• In 2- and 4-stroke engines, if air cooling to the cylinder is uneven, the aluminum-alloy jacket (crankcase) may distort the cylinder which adversely affects the running fit of the piston.

The extent to which each of these factors affects an engine's performance is the subject of debate among experts. One thing is certain: you can't force these changes to occur unless the engine is actually run, brought up to temperature and then allowed to cool, time after time.

HEAT CYCLING

Some argue that the accuracy of modern machining technology eliminates the need for break-in. Others (including me), believe that molecular instabilities within the parts due to manufacturing processes need final stress relief; this is accomplished by the repeated heating and cooling cycles within the engine itself. Known as "heat cycling," the process consists of short engine runs and complete cooling repeated multiple times.

ENGINE CATEGORIES

Since design and metallurgy differ from engine to engine, so does the break-in procedure somewhat. The type of piston and cylinder combination determines which of two general categories the engine falls into; there are only two break-in procedures (one for each category).

• Non ABC-type (2- and 4-stroke)
—Lapped iron or steel pistons (no compression ring) running in iron or steel cylinders. Examples: several modern Fox and Enya engines; many nostalgia period engines including K&B (green head), Veco, Johnson, Fox, O.S., etc.
—Ringed aluminum-alloy piston running in steel, iron, or brass cylinders and known as "ABCD" (aluminum piston, brass cylinder, chrome-plated with Dykes ring). Examples: most modern, large-displacement engines, e.g., Moki, MVVS, Aviastar and GMS; Saito, Enya and O.S. 4-strokes; and many antique and nostalgia engines including McCoy, Super-Tigre, K&B, Enya and Webra.

• ABC-type (2-stroke)
—ABC. Lapped aluminum alloy piston (no compression ring) running in chrome-plated brass cylinder.
—AAC. Lapped aluminum alloy piston running in chrome-plated aluminum cylinder.
—ABN. Lapped aluminum alloy piston running in nickel-plated aluminum alloy cylinder.

NON-ABC ENGINE BREAK-IN

To break in a non-ABC engine, the running temperature must be reduced and its internal components flooded with lubricant. Let's take a closer look at these concepts:

• Temperature. When a 2-stroke-cycle engine is operated very fuel-rich, it begins to 4-cycle, or fire on alternate crankshaft revolutions. Without exploring the reason for this at this time, it may be stated that reducing combustion events by 50 percent over a period of time reduces the operating temperature—a very desirable condition for breaking in non-ABC-type engines.

There's a pronounced difference in sound between 2-cycling and 4-cycling. The human ear senses this as a change in exhaust frequency. As a 2-cycling engine is progressively richened by the primary needle valve, a point is reached on the speed range at which a sudden loss in rpm is experienced, along with a change in exhaust note. This is 4-cycling. Get to know it; it's the sound of a cool running engine.

• Lubrication. Four-cycling also enhances lubrication. Coupled with oil volumes of between 24 and 28 percent, break-in requirements are adequately satisfied. After break-in has been achieved, these percentages may be reduced to the engine manufacturer's recommendation.

Castor oil should always be included as part of the lubrication package. It offers unsurpassed protection from hot, lean runs that would otherwise damage engine components if only synthetic oils were used. I suggest using castor for at least one third of the oil package, e.g., if the total oil volume is 24 percent, the minimum amount of castor should be 8 percent.

• How long does break-in take? As you might expect, break-in time varies for each engine type, also from manufacturer to manufacturer. During the 1930s through the 1950s, engine companies recommended 3 to 5 hours on the bench before all-out operation of their lapped iron and steel piston and cylinder engines.

Back in the old-old days ('30s and '40s), many modelers attempted to shorten the lapped piston break-in period by "motoring" the engine. This consisted of mounting the engine on a drill press or metalworking lathe, where it was turned over for a number of hours using lots of lubricating oil, which also acted as a coolant. This procedure didn't help the piston and cylinder fit because combustion temperatures and pressures were absent, but the connecting rod and wrist-pin holes usually polished up.

In the old days ('50s and '60s) some enthusiasts ran their new engines continuously on a large supply of fuel. The rich needle-valve setting kept them cool, and they assumed that after several hours, the break-in job was complete. Tests have shown that little, if any, break-in occurs unless the engine is heated to normal operating temperatures and then allowed to cool. As mentioned earlier, heat cycling does the job.

Ringed-piston engines require less break-in time than lapped versions, but patience is still necessary. The Moki 2.10 engine that I tested in the October 2001 issue wasn't fully broken in until after completing 3 hours of careful running. Now, it's a tremendous engine, exhibiting great compression and high torque and brake horsepower. The K&B .40 low-tension-ring RC engine (no longer in production) is another good example. K&B recommended a 1-hour break-in. My experience with this engine suggested that 2 to 3 hours were required for a top-performing long-lasting unit. Fox recommends running its .40 RC "... rich for the first few tanks of fuel." Mine still isn't fully broken in after 4 hours!

• **When is it broken in?** Time alone isn't an indicator of when break-in is complete. Break-in requires short running periods during which the needle valve is occasionally leaned to a point where the engine comes up to speed and temperature, then is immediately richened to cool it down.

A general rule suggests that lapped and ringed non-ABC-type engines are broken in when they'll hold a peak rpm setting without sagging (slowing down) for at least 30 seconds. For ringed engines, there is a visible sign that break-in is probably complete: when the machine marks have disappeared from the visible edge of the compression ring (as viewed through the open exhaust). Lapped engines are more difficult to assess through observation, although some experts are guided by the color and uniformity of wear on the piston. Also, if the piston doesn't leak a little compression at top dead center (TDC), it probably needs to be run more.

ABC ENGINE BREAK-IN

The newer ABC-type engines require less time for break-in than the lapped or ringed iron and steel combinations described earlier. For an ABC engine to attain and maintain maximum performance levels, however, an entirely new set of break-in procedures is required.

As mentioned earlier, ABC-type engines include ABC, AAC, and ABN piston and cylinder combinations in the lapped configuration (ringless). They rely on a very close fit between the piston and cylinder to prevent combustion gas blowby at operational temperatures and speeds. The primary advantage of the ABC concept is the ability of the piston and cylinder to expand from ambient to operational temperatures at almost equal rates, thus avoiding the damaging seizures occasionally experienced by non-ABC types. Complications arise because the portion of the cylinder above the transfer and exhaust ports operates at a much higher temperature than below the ports, allowing the upper cylinder to expand more than the bottom. To compensate for this, the cylinder bore is machined with a taper, producing a smaller bore at the top than at the bottom.

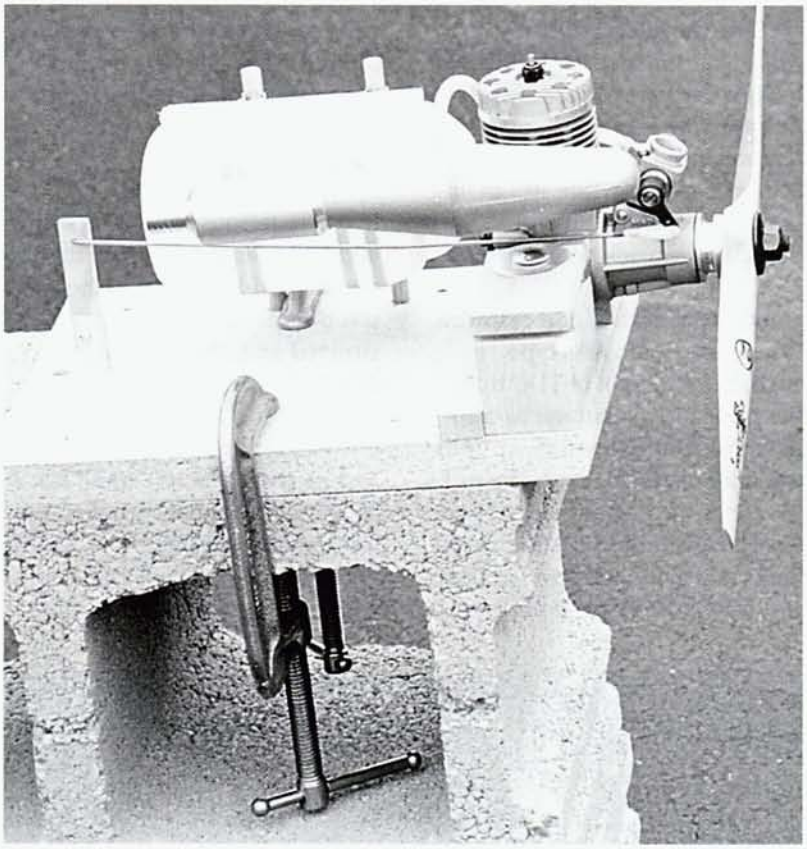
Trial-and-error experimentation in the 1970s discovered that ABC engines performed best when the piston actually interfered with the cylinder (zero clearance) at TDC (ambient temperature). This is a squeak that may be heard and the resistance felt when turning these engines over without the glow plug installed. Since the high-silicon-content aluminum alloys used for the piston allow the plated brass cylinder to expand slightly more at running temperatures, a free-running assembly is achieved while maintaining a gas-tight, blowby-free combustion chamber.

The problem with this system centers on a narrow band at the top of the piston's head, just below the crown, where it contacts the cylinder at TDC. Typically measuring only about 0.060 to 0.125 inch in height, depending on the size (displacement) of the engine, it controls the operational fit of the piston within the tapered cylinder. Wear it slightly (smaller diameter), and the delicate balance shifts; a great running engine is now only adequate. Wear it a bit more and the engine is worn out. Unfortunately, all of this can happen during the first few runs of a new ABC-type engine, perpetrated by an unsuspecting operator.

The objective of ABC-type engine break-in is to maintain the delicate top-of-the-piston fit while allowing the internal components to heat-cycle for the purpose of stress relief. Sound simple? Let's look at the requirements:

• **Fuel.** From the outset, use the highest factory recommended nitromethane fuel content. If the instructions say to use 5 to 15 percent nitro, then use the higher 15 percent. This generates the highest combustion temperature, resulting in the greatest expansion and therefore the most clearance between the piston and cylinder (when they're the tightest they'll ever be). After break-in, this same fuel must be carried over to the flying phase of the engine's operational life.

After running the engine for a season or two, you'll probably notice that performance begins to diminish (nothing lasts forever!). Performance can be determined by comparing tachometer readings on a standard propeller from when the engine was new to the time of comparison. If rpm drop by several hundred or more, the piston and cylinder clearance is probably excessive, so you should reduce the nitro content to 5 percent. Less nitro means lower combustion temperatures and less component expansion; this results in a tighter piston and cylinder fit with less blowby and lost power. Experience has shown that reduced nitromethane content is compensated for by the improved piston and cylinder fit at running temperatures. That's why some "worn-out" sport pylon racing engines make very acceptable fun-flying engines: less nitro!



This all-wood, American Hobby Products test stand is designed to be clamped to a bench top or cinder block (as shown). It incorporates a novel throttle-lever assembly that allows the operator to make minute carburetor adjustments. Moderately priced, it's suited to occasional to moderate use.

• **Lubrication.** For break-in, use 20 percent lubrication by volume. This is the standard oil content I use throughout an ABC-type engine's life—break-in and flying. One-third of this volume is castor oil, the greatest insurance policy you can buy against engine damage due to a hot, lean run.

Competition racers sometimes experiment with oil percentages of less than 20 (percentages of 18, 16, 14 and less have been used). Reducing the mass of lubricants in the air and fuel mixture may improve flame propagation (burning) in the combustion zone, which ultimately affects power output. These are minor performance gains and best left to the experimenter. Similar reductions in oil content have been tried with questionable results by individuals attempting to improve an engine's idle and throttle-ability.

• **Two- vs. 4-cycling operation.** If it were possible to completely eliminate 4-cycling within an ABC-type engine, it would be a great day for its longevity. Four-cycling operation is cool operation, which leads to premature wear. Never purposely run an ABC-type engine 4-cycling rich; the relatively cool temperatures generated by firing every other revolution of the crankshaft accelerate piston wear and the onset of reduced performance.

Because ABC-type engines were originally designed as wide-open throttle racing engines, their pistons and cylinders operated happily. Today, ABC engines are also expected to idle and throttle reliably. Unfortunately, this allows them to cool excessively, especially below ½ throttle, where poor cylinder scavenging causes them to 4-cycle, rubbing away at the critical piston and cylinder fit.

Because throttling is a necessary component of RC flying, you can't simply eliminate it from your routine; however, never throttle the engine during break-in. Afterward, when engine components have been stress-relieved through heat-cycling, the effects of throttling will be minimized. These effects may be further reduced by setting the idle needle valve on a fuel-metering carburetor to its leanest position while still maintaining a reliable idle and transition to wide open throttle.

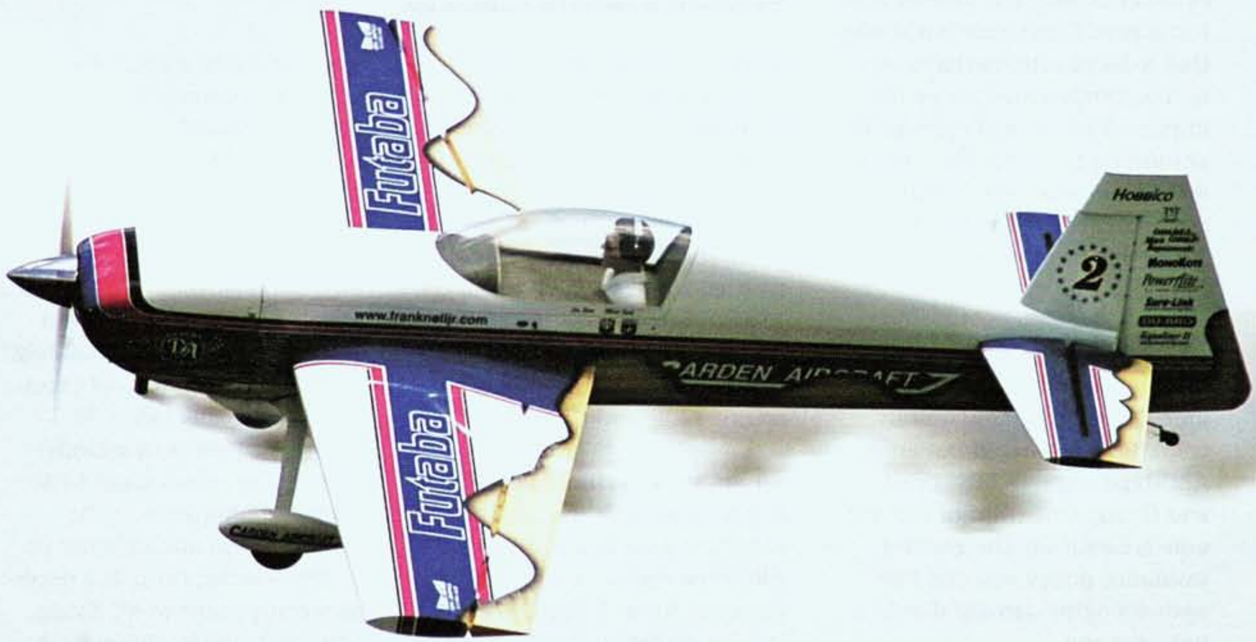
• **Tight ABC piston and cylinder.** When new, some ABC-type engines are so tight at TDC that the possibility of damage to components (connecting rod, wristpin, crankpin or piston) exists the first few times the engines are cranked over. To avoid this situation, warm the cylinder and head with a heat gun before the first few starts; this will cause the cylinder to expand, pulling away from the piston, permitting you to easily crank over the engine.

TEST STAND

If you're serious about preparing your engines for that first flight, a test stand is essential. The test stand must be sturdily constructed and able to hold the engine securely with a minimum of vibration. It actually consists of two parts: the test stand itself and its base. The test stand can be of superior quality, but if it's mounted on a flimsy base, such as a wooden box, the assembly will probably vibrate and could become a safety hazard by moving forward or tipping over.

Provisions must be made for mounting the fuel tank at the proper level in relation to the horizontal centerline of the carburetor metering jet (spraybar), and some method of throttle control is needed. American Hobby Products manufactures several different sizes of well-designed wooden test stands that meet all of the criteria, at very reasonable prices.

Wear your hearing protectors, get out a lawn chair and a nice cool soda, and drive your neighbors nuts—just kidding!



extend 2-stroke engine life

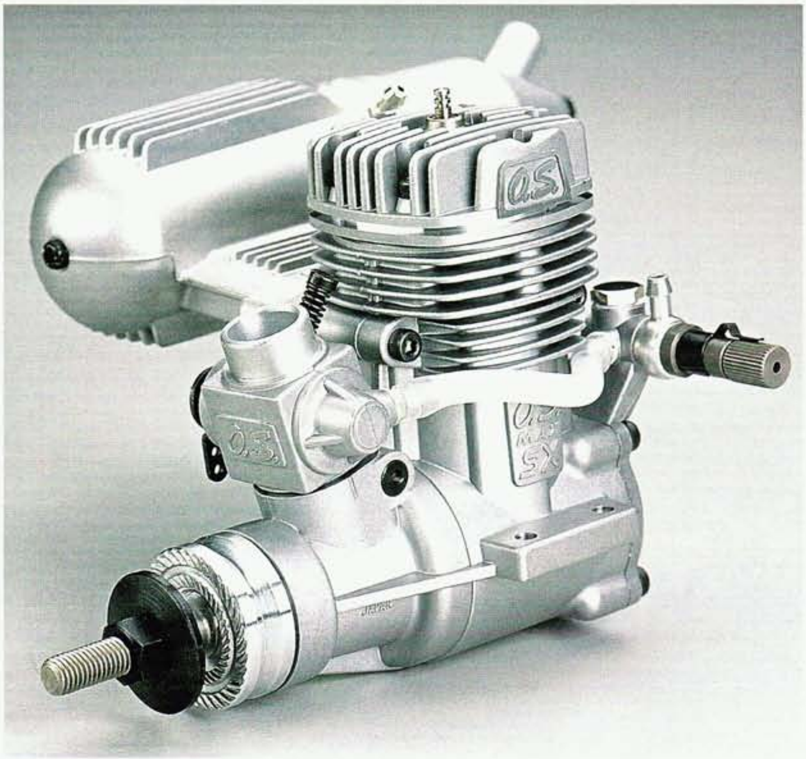
BY THE STAFF OF *MODEL AIRPLANE NEWS*

Always make engine adjustments from behind the prop.

Today's 2-stroke glow engines are technological marvels; they're powerful, lightweight, easy to use and, with proper use and care, will last for many years. Next to the radio system, the engine is one of the most expensive investments we make in RC. Over the years, we've learned a lot about the care and feeding of engines, and we know there aren't any secrets to operating a model airplane engine correctly. From adjusting the fuel mixture and choosing the best glow plug to proper maintenance and using common sense to improve reliability, this article is full of helpful hints and information to help you have a happy relationship with your 2-stroke glow engine.

EASY STARTING

Nothing is more frustrating than owning an engine that's difficult to start. Our frustration often leads to a flight that ends with a dead-stick landing or a crash. When you start any engine, there are three things to remember. For combustion to occur, your engine needs air, fuel and fire (heat). If your engine won't start, check the carb to make sure that air and fuel are available, and check your glow plug to ensure that it provides enough heat to ignite the air/fuel mixture. Remove the glow plug and attach the glow driver; its element should glow brightly. If it doesn't, replace it; if it does, reinstall it. Close the needle valve and then open it three full turns. Place your thumb over the carb, and flip the prop several times until fuel is drawn through the fuel line and into the carb. If you remove any one of these three elements from the equation, your engine will not start.



SECURE FUEL LINES

Proper fuel-line installation is very important. If your fuel line is too big, it may leak air or even slip off in flight. Fuel lines come in several diameters, so use the size that best fits the carburetor's fuel fittings. Air bubbles in the fuel line may cause the engine to run lean, and

The fun we have flying our glow-powered models is directly proportional to how well our engines run. Proper care of and knowledge about how they run are the keys to engine performance success.

if the line slips off, the engine will die. Be sure that there is adequate slack in the line, and secure it to the fuel fitting with a wire clip or a small length of fuel line slipped over the end of the main line.

Make sure the carburetor is securely fastened to the engine. There is an O-ring at its base, and if this is damaged, air may leak into the crankcase and cause the engine to run lean.

TIGHT SEALS

If your engine begins to run erratically, and the mixture leans out even after you've adjusted the needle valve, you may have an air leak in the carb. Make sure that the carb is firmly and properly attached to the crankcase. If the intake is sealed with an O-ring, check it for cracks or breaks and make sure that it's seated properly, lies flat and isn't distorted when the carb-attachment screw is tightened. Make sure that all the adjustment screws and the needle-valve assembly are properly sealed and work correctly.

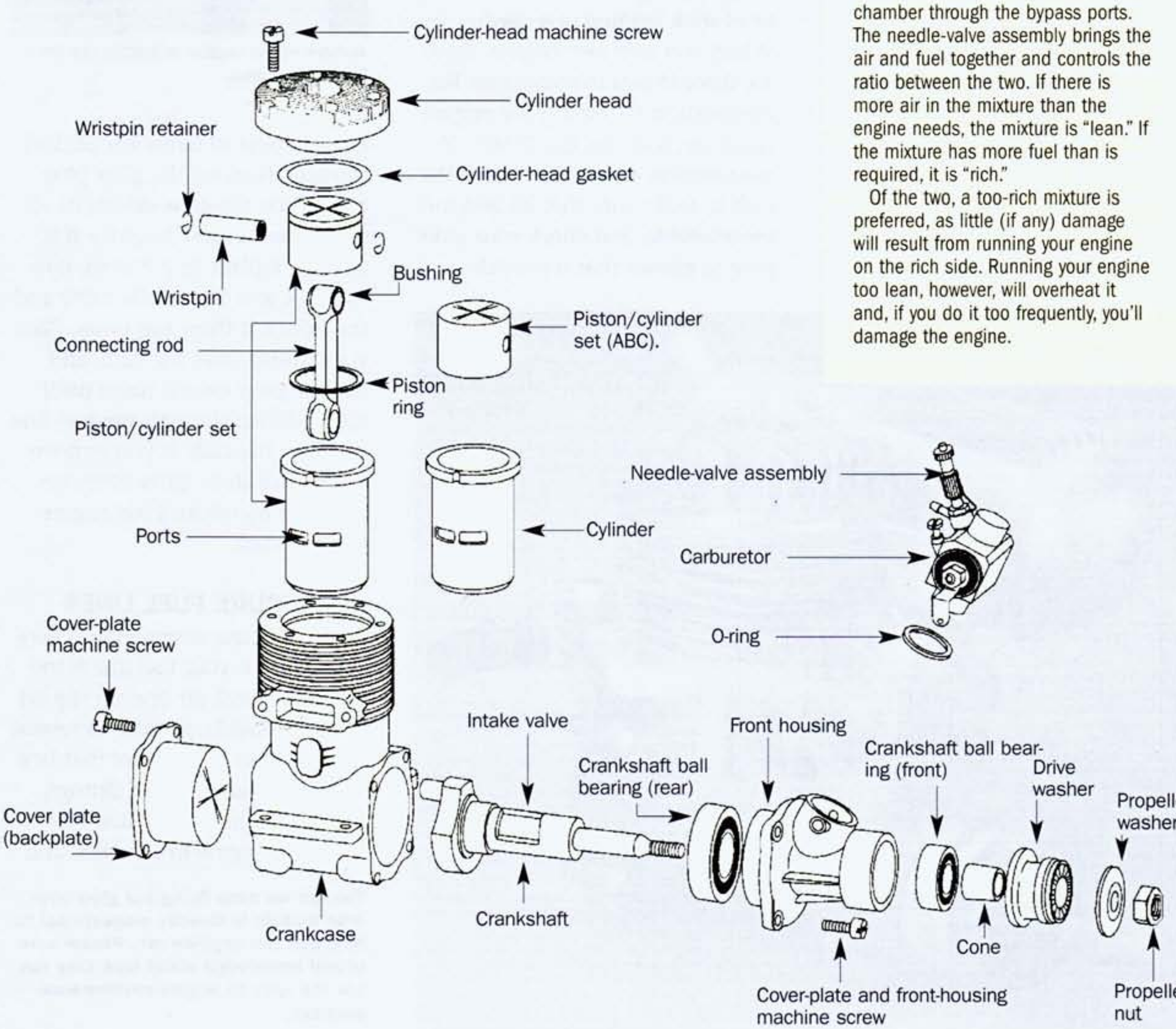
Last, check that the fuel-intake fitting is tightly screwed into place and that it isn't damaged or cracked. The fuel tank and fuel lines must be properly and securely installed. If you

A good mix

When you hear someone talking about adjusting an engine, you'll often hear them refer to "the mixture." This is the mixture of air and fuel that is combined in the carburetor. Fuel and air enter the venturi, become atomized and enter the engine through the intake port. The atomized mixture then enters the crankcase and is transferred to the combustion chamber through the bypass ports. The needle-valve assembly brings the air and fuel together and controls the ratio between the two. If there is more air in the mixture than the engine needs, the mixture is "lean." If the mixture has more fuel than is required, it is "rich."

Of the two, a too-rich mixture is preferred, as little (if any) damage will result from running your engine on the rich side. Running your engine too lean, however, will overheat it and, if you do it too frequently, you'll damage the engine.

EXPLODED VIEW: ENGINE PARTS DESCRIPTION.



A reliable idle is very important, especially during landings. A carburetor can have either a low-end needle-valve adjustment (above) or an air-bleed hole in the front of the carb housing (below). Adjust the high-end needle valve before you adjust the idle.

have previously nosed the model over or made a hard landing, the fuel pick-up clunk may have shifted forward in the tank; this can pinch off the fuel supply. The clunk and pick-up line should move freely, and you should be able to hear the clunk rattle in the tank.

FUEL FLOW

If your engine always runs rich or floods easily, check the position of the fuel tank. The tank should

Why use a tachometer?

A tachometer (tach) is one flightline accessory that I can't do without! I started using one to adjust my engine's needle valve a few years ago, and now I find that using one ensures that my engines run consistently. A tach shows minute changes in engine rpm that you cannot detect by ear. Having the engine set a couple of hundred revs below maximum rpm is ideal. Using a tach to count the prop revs is also much safer than pinching the fuel line to check the mixture setting. Note that the engine should be well broken in; a tight, new engine will rarely hold a good needle-valve setting.

A tachometer is a very important accessory to ensure proper engine operation. Use one whenever you adjust the engine's air/fuel mixture to check the change in rpm.

Here are some tips to help you properly adjust your engine.

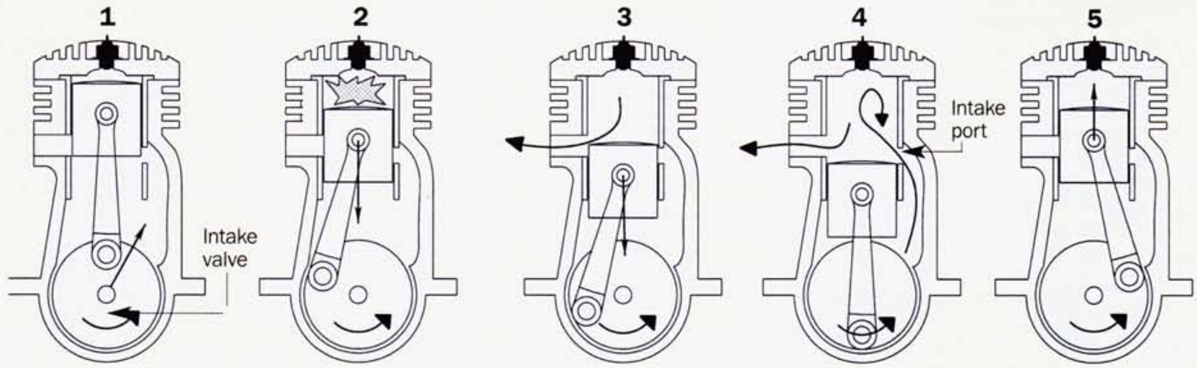
- Set the high-speed (main) needle valve to the recommended factory setting, and start the engine. The engine should run somewhat rich.
- While using the tach, gradually lean the mixture (turn the needle-valve adjustment screw in, or clockwise) until there is no longer an increase in rpm. Adjust the mixture slowly, and allow the engine speed to stabilize.
- Once you've achieved peak rpm, richen the mixture slightly (again, using the tach) to reduce the rpm by 200 to 300.

Once you've set the high end, check the idle setting. After you have properly adjusted the engine, avoid the temptation to tweak the needle valve whenever you restart your engine. If atmospheric conditions (humidity, air temperature, etc.) change, however, then a click or two of the needle valve may be necessary. Again, use the tach to check rpm while making these adjustments. —Rick Bell

Above: fuel lines come in several sizes and materials. It's important to match the line to your engine and fuel. Right: make sure the fuel line fits the fuel fittings tightly. Clamp the line, or slip a short length of tubing over the end of the main line to secure it.

Two-stroke engine operation

A 2-stroke engine is relatively simple in operation. The crankshaft makes one complete revolution for every power cycle. During the piston's upstroke, the fuel/air mixture above the piston is compressed for combustion. At the same time, a fresh mixture is drawn into the crankcase below the piston. After combustion, the piston is forced downward, and the spent fuel charge is expelled through the exhaust port. At the same time, a fresh fuel/air mixture is drawn through the carb and into the crankcase. The intake valve is sealed, and the mixture is forced through the transfer ports and into the cylinder above the piston to start a new power cycle.



1. As the piston reaches top dead center (TDC), a fresh air/fuel mixture charge is drawn into the crankcase because of the low pressure created as the piston travels upward.

2. The piston then compresses the mixture in the combustion chamber, and it is heated and ignited by the glow plug; this forces the piston down.

3. As the piston comes down, it opens the exhaust port, and the spent fuel begins to exit the combustion chamber. At the same time, the piston compresses the new fuel/air mixture in the crankcase.

4. At bottom dead center (BDC), the piston opens the bypass port, and the new air/fuel mixture charge flows from the crankcase into the combustion chamber as the last of the spent charge leaves.

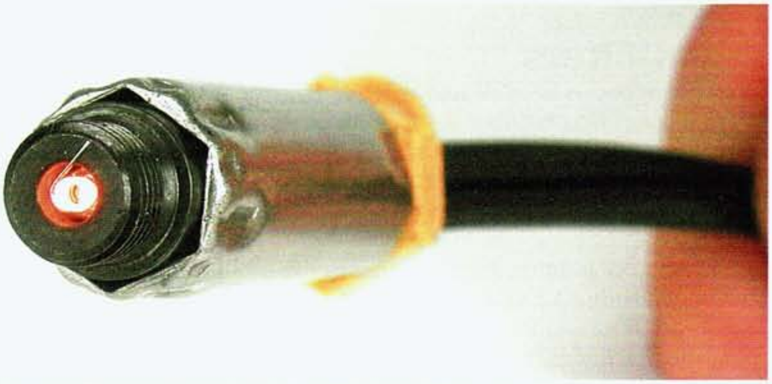
5. The piston comes back up and seals the exhaust and bypass ports, and the entire process begins again.

be installed in the fuselage so its centerline is at or slightly below the carburetor's spray bar. Use scraps of foam to position it securely so it can't move around in the tank compartment. If the tank is too high in the fuselage, fuel will tend to be siphoned out and run freely into the carb. Conversely, if the tank is too low or too far away from the carb, the engine may have difficulty drawing fuel into the carb, and it will run lean. To improve fuel draw, attach a line from the pressure fitting on your muffler to the tank's vent line. If you use a third filler line with your tank close it off to allow the muffler pressure to enhance fuel draw.

Glow plugs come in several sizes and types; here, you see (left to right) a short-reach plug, a standard (or long-reach plug) and a standard plug with an idle bar. Use the type of plug recommended by your engine's manufacturer.

IDLE RELIABILITY

An engine that idles poorly can be frustrating. The last thing you want is for your engine to quit during a landing. Proper fuel mixture, too much fuel line between the tank and the engine and the type of fuel and glow plug you use can all affect an engine's ability to idle reliably. The most common problem is a too-rich mixture. Adjust the high-speed needle for a slightly rich mixture and then adjust the idle. Start the engine and adjust the throttle for an idle of 2,100 to 3,000rpm. After several seconds, advance the throttle to full open. If the engine sputters and spits raw fuel out of the carb, the idle mixture is too rich. Stop the engine, and turn the idle adjustment clockwise (in) about ¼ turn to lean the mixture. Repeat this procedure until the engine transitions smoothly from low to high speed. If you have an air-bleed carburetor with a small hole at the front of the carb body and an adjustment screw control idle, turn the idle screw in to richen the mixture.



Make sure that your glow plug is in good shape before you use it. It should glow brightly when energized by the glow driver.

HAPPY GLOW PLUGS

The glow plug is a critical part of the engine's overall performance; you can choose from several types, but always refer to your engine's instructions for the recommended plug. Glow plugs come with long and short thread parts, with or without an idle bar and are rated for hot or cold operating temperatures, but they don't last forever. The first sign that a plug is on its way out is a drop in rpm when you remove the glow-plug driver; also, when an engine that normally idles well suddenly doesn't run well at low rpm, you have a problem. If you use a plug that is too hot for your engine, the engine may suffer from detonation and pre-ignition and might overheat and run lean. Using a plug that is too cold will result in lower top-end rpm and poor idling. Small engines (.15 and smaller) should use short-reach plugs; a plug that's too long may hit the top of the piston and damage the engine.

STAYING COOL

A cool engine is a happy engine. One of the worst things you can do to an engine is to run it lean. This increases its temperature and can drastically shorten its life. Always use a tachometer to adjust peak rpm and then richen the mixture slightly for a 200 to 300rpm drop from the peak reading. If your engine is inside a cowl (such as in a scale model), make sure you provide adequate ventilation. Ideally, the air-exit area should be at least twice the size of the air-entry area. Don't block the air outlet with the engine's muffler, or you'll greatly increase the engine's operating temperature.

PROPER COMPRESSION

Compression is important to a glow engine. As well as affecting the density of the fuel mixture, compression is also necessary for the glow plug to fire. If your

Troubleshooting

SYMPTOM: Engine doesn't start

CAUSE	CURE
Low voltage on glow-driver battery	Replace/recharge battery
Bad glow plug	Replace glow plug
Insufficient fuel prime	Repeat priming procedure
Flooded owing to excessive priming	Remove plug, and rotate prop to clear cylinder of fuel
Pressure lines and fuel lines are reversed	Remove fuel lines and reinstall them correctly
Needle valve not set properly	Set adjustment needles to factory settings for starting

SYMPTOM: Engine starts and then quits

CAUSE	CURE
Idle set too low	Reset idle for higher rpm
Low-speed needle is set too rich	Lean out low-speed mixture
Low-speed needle is set too lean	Richen low-speed mixture
Glow plug is loose	Tighten glow plug
Glow plug is bad	Replace glow plug
Mixture is too rich	Lean out main needle valve ½ turn

SYMPTOM: Engine bogs when full throttle is applied

CAUSE	CURE
Low-speed needle is set too rich	Lean out low-speed mixture
Low-speed needle is set too lean	Richen low-speed mixture
Glow plug is too cold	Install hotter glow plug
Mixture is too rich	Lean out main needle valve
Mixture is too lean	Richen main needle valve

SYMPTOM: Engine idles erratically

CAUSE	CURE
Air leak (hole) in pressure or fuel lines	Replace lines
Low-speed needle set too lean	Richen low-speed mixture
Bad glow plug	Replace glow plug

SYMPTOM: Engine doesn't reach full power

CAUSE	CURE
Mixture is too rich	Lean out main needle valve
Mixture is too lean	Richen main needle valve

Fuel filters

There has always been debate about whether or not to use a fuel filter between the model's tank and the engine's needle valve. For years, I've run my engines without an in-line filter, and I have never had a problem with fuel blockage. This is because I filter the fuel three times before it gets to the tank.

First, I use a sintered-bronze filter as the pick-up clunk in my main fuel jug. It prevents any large particles from leaving the jug.

After the fuel exits the fuel pump, it passes through a Sullivan Crap Trap, which removes any fine particles the first filter may have missed. The Sullivan filter has a transparent body and a fine mesh screen at both ends; you can see whether there is anything in the fuel.

The last filter I use is a Du-Bro Final Filter. It has two micromesh screens to remove the tiniest particles from the fuel. I use this filter between the fuel-pump line to the model's filler line. The filters are progressively finer, and this keeps out any contaminants that might be in the fuel.

To minimize the chances of your fuel becoming contaminated, change the pick-up lines in your jug twice a year. The nitromethane in the fuel can degrade the lines, and they are inexpensive to replace.
—Rick Bell

Filtering your fuel greatly decreases the chances of having contaminants clogging a fuel line or getting into your engine.

engine becomes difficult (or impossible) to start, compression may be low. To fix this, check the glow-plug and engine-head bolts to make sure they are tightly fastened. You should also check the backplate attachment bolts. If the cylinder-head bolts are loose, air can leak into the combustion chamber, and this will affect performance. If you have been running your engine too lean, the piston and sleeve fit can be worn out, and this will prevent your having a tight seal. If this is the case, you'll have to replace the worn components.

KEEP YOUR ENGINE CLEAN

If you fly off grass, there's always a chance that your airplane will nose over or overshoot the runway on landing. The odds are pretty good that debris will get onto and inside your engine. Always clean your engine after a mishap, and never turn the prop shaft until you're sure the engine's inside is clean. If they aren't removed, dirt and grit can impede engine cooling; even worse, ingested debris can ruin the interior of the engine. Clean the engine by plugging the muffler's outlet and the carburetor's venturi with small wads of paper towel. Stand the plane on its nose, and spray a mixture of dishwashing liquid and water onto the engine. Scrub the engine with a toothbrush, and use a toothpick to remove debris from between the cooling fins. Wipe the engine clean and let dry.

ENGINE CORROSION

Corrosion is the main enemy of our engines. It forms on the bearings and other ferrous components. The alcohol contained in glow fuel is hygroscopic (it attracts moisture). To prevent corrosion, at the end of the flying day, always run your engine until it is dry of fuel and use after-run oil. When you've finished flying for the day, empty the fuel tank, start the engine and let it run until it quits. This will ensure that there isn't any fuel residue left in the engine. Squirt after-run oil into the carburetor and the glow-plug opening, and turn the prop manually several times to fully coat the inside of the engine with the protective oil. Before storing an engine for an extended period, remove it from your model, oil it well, wrap it in a cloth and place it in a sealable plastic bag for safekeeping.

How much fun we have when we fly our models is directly proportional to how well our engines behave. Taking proper care of them is the best way to keep them happy. It's time well spent and an investment that keeps paying us back.

4-stroke valve adjustment made easy

BY JOHN REID

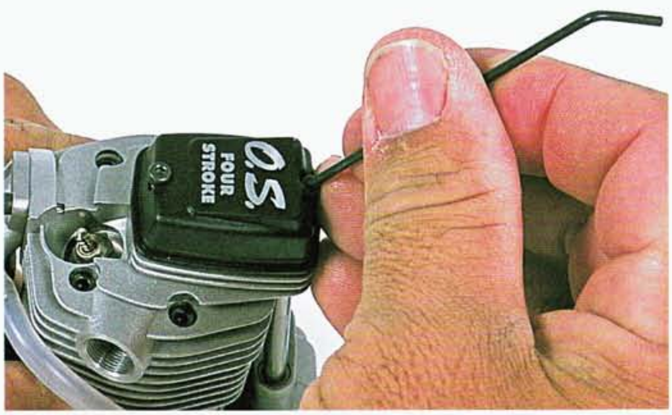
Four-stroke engines are marvels of miniature mechanical engineering. They're small enough to fit in the palm of your hand, and they produce up to 2hp. Even though they have twice as many moving parts as 2-stroke engines, 4-strokes provide hours of reliable service with very little maintenance. With so many moving parts, it is easy to see that timing is critical to smooth operation. Over time, a 4-stroke's moving parts wear, and this increases the gaps between them. Among the more crucial gaps are those between the rocker arms and the intake- and exhaust-valve stems. These gaps control valve timing, which in turn affects an engine's power output. If a gap is too large or small, it can greatly affect how an engine runs.

WHEN IS VALVE ADJUSTMENT REQUIRED?

Engine-valve clearances are usually correctly set at the factory. You may never need to adjust your engine's valves; it depends on how much you use it. There are certain symptoms, however, that indicate a need to check and adjust the valve clearances.

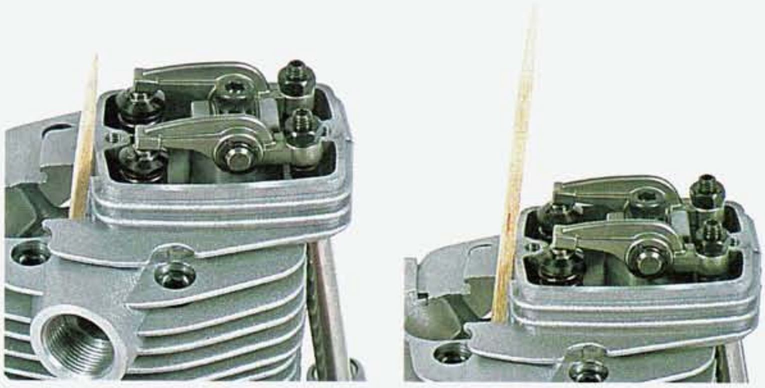
Check the valve clearance if there is a noticeable loss of power and after you've disassembled and reassembled you engine. Here's how to do it.

1 **To adjust the valves on an O.S. 4-stroke engine, you'll need a thin (0.04mm) and a thick (0.10mm) feeler gauge, a 1.5mm Allen wrench and a 5mm wrench. Engines by other manufacturers may require tools of different sizes.**



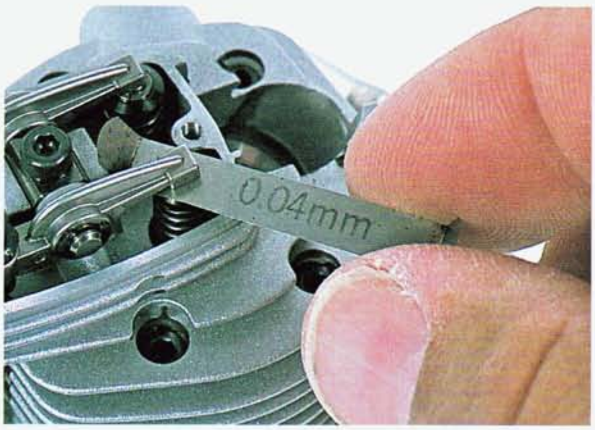
2 **Begin by removing the valve cover to expose the rocker arms. Check and reset the valve clearances only when the engine is cold. If you check when it's hot, the metal will have expanded, and the clearances will be smaller than when the engine is cool.**

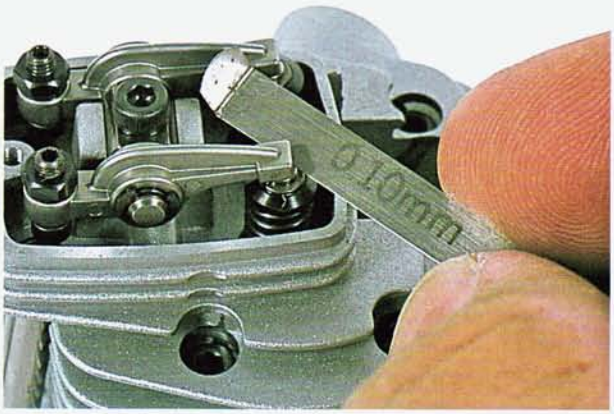
3 Before you adjust the valves, make sure that both rocker pushrods are at their lowest positions, i.e., the piston is at top dead center (TDC) between the compression and power strokes. There is also a TDC position between the exhaust and intake strokes. To find the TDC of either stroke, remove the glow plug and watch the piston while you turn the prop shaft. When the piston reaches its highest point in the cylinder, it has reached TDC. Insert a toothpick in the glow-plug hole and watch as it rises; stop turning the prop just before the toothpick starts to drop back into the cylinder. On the prop washer/hub, scribe a thin line that lines up with a line on the crankcase. (The O.S. 4-stroke shown already has a TDC mark on its prop hub.)



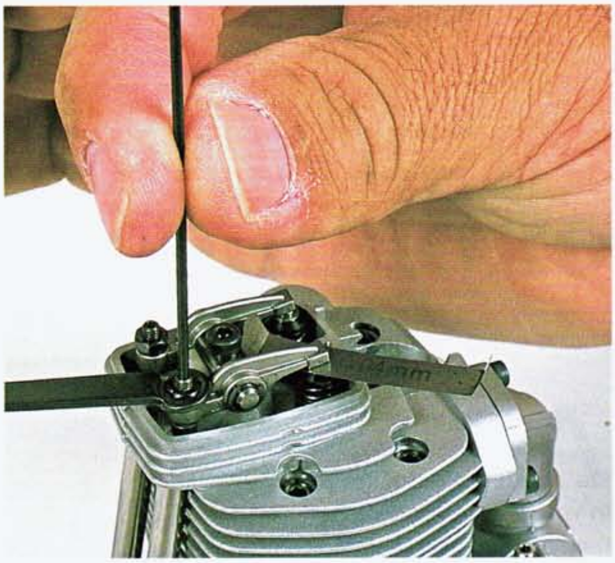
4 Next, find the correct valve and pushrod orientation between the compression and power strokes. Install the prop and glow plug, then turn the prop counterclockwise until you feel compression. Turn the prop ¼ revolution more until the mark on the prop washer/hub is lined up with the one on the crankcase. If you rotate the prop shaft back and forth about ⅛ inch and the rocker arms move, this is the wrong TDC position; the engine is between the exhaust and intake strokes. Rotate the prop one full turn counterclockwise until the marks are again lined up. This is the TDC between the compression and power strokes; rotating the prop shaft back and forth will not make the rocker arms move.

5 To check the rocker-arm valve clearance, insert the thin (0.04mm) feeler gauge; it should slide easily into the gap. Now try to insert the thick (0.10mm) feeler gauge; it should not fit into the gap. Be careful here; it doesn't take much force to depress the valve and allow the thick gauge to slide into the gap. The valves need to be adjusted if the thick gauge slides easily into place or if the thin feeler gauge doesn't fit.



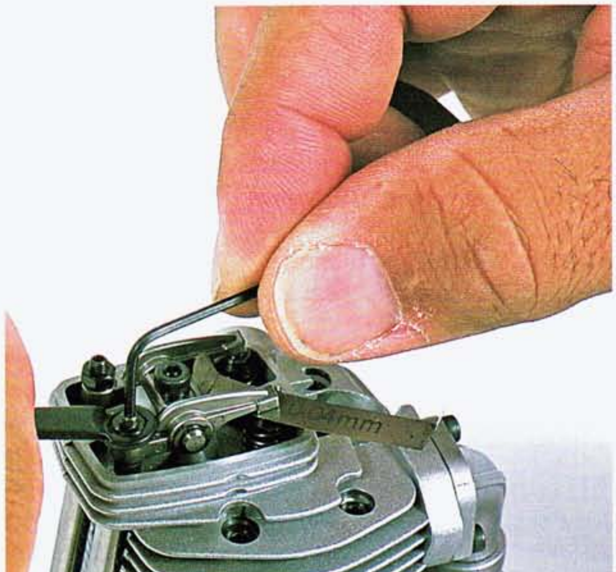


6 To adjust the gap, carefully use a wrench to loosen the locknut on the rocker arm about ½ turn. Then use the Allen wrench to back the adjustment screw out about one turn (usually counterclockwise).



7 Insert the thin feeler gauge between the valve stem and the rocker arm, and gently tighten the adjusting screw until the rocker arm and the valve stem lightly touch the gauge. The adjusting screw can make a big difference, so use a light touch when making this adjustment. Grasp the Allen wrench using only your thumb and index finger as shown.

8 Retighten the locknut while you hold the adjustment screw firmly with the Allen wrench. Remove the wrenches and the feeler gauge, rotate the prop a couple of revolutions, and recheck the gap. If the clearance is correct, repeat these steps for the other rocker arm and valve assembly. After you have properly adjusted and checked everything, replace the valve cover. That's it!



When you set the gap for valve adjustments, it's important to remember that it is better to have too much play in the valve assembly than too little. With a wide gap, the valves won't stay open as long as they should. This doesn't really hurt anything and incurs only a small loss of power, but having a very small gap or no gap at all can burn and erode the valves and valve seats. You can always avoid this by making sure that the thin gauge slides easily between the rocker arm and the valve stem.

Periodic valve adjustment will ensure that your engine runs smoothly and will help provide hours of reliable 4-stroke engine service.

engine cooling tips explained

BY DAVE GIERKE

All engines, whether they're in your RC airplane or the car parked in your garage, produce heat as they run and operate best at a certain temperature; but too high a temperature is detrimental to performance and, if left unchecked, can lead to engine failure. Many factors affect cooling in ABC engines (and with it, engine performance), and you can adjust or change them. We'll consider most of them here, but let's first look at what happens when cooling isn't controlled.

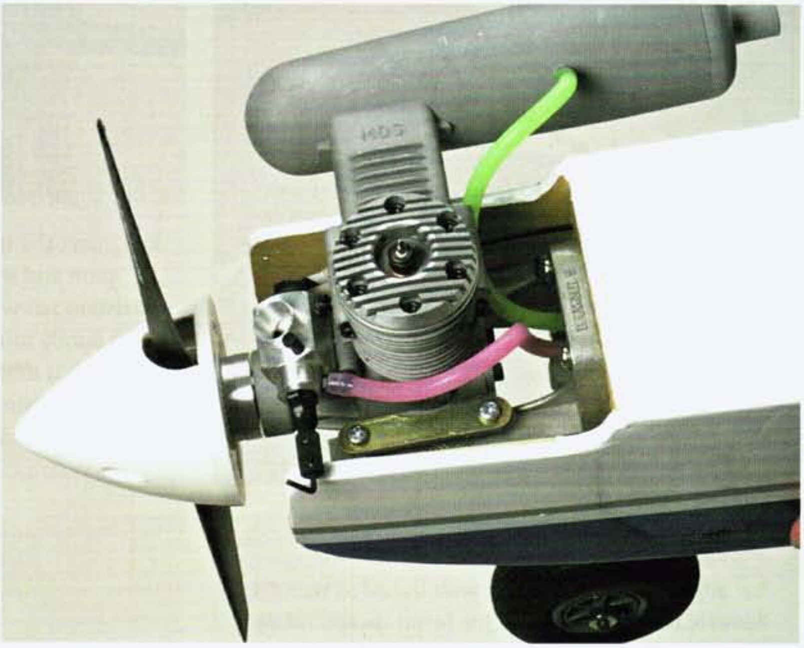
HOW FUEL COOLS

A 2-stroke RC engine is partially liquid-cooled by its fuel. Lubricating oil also helps cool the engine. Here's how:

• **Methyl alcohol (methanol):** the methanol in the fuel enters the crankcase in liquid droplet form and is heated by conduction. Conduction takes place when materials (solid, liquid, or gas) that have different temperatures are in contact with one another. Heat always flows from the hotter material (the engine parts) to the cooler substance (the liquid fuel). As the methanol reaches its boiling point (147 degrees F), it vaporizes and mixes thoroughly with inducted air molecules. This change-of-state process, called "latent heat of vaporization," consumes great quantities of heat and is especially effective in cooling the piston, wristpin and upper connecting-rod bushing. As the air/fuel mixture is transported through the bypass channels and cylinder transfer ports, additional evaporative cooling takes place.

• **Fuel oil:** all RC fuel mixtures contain oil to lubricate and cool the engine. To be successful, the lubricant must effectively wet moving surfaces while resisting surface boiling and vaporization. Two types of oil are typically used: castor and synthetic.

• **Castor oil:** this lubricates and cools well beyond the temperatures at which most synthetics can function. As temperature increases, castor oil becomes thermally unstable and rapidly polymerizes (a chemical reaction in which two or more small molecules combine to form larger molecules), becoming a better lubricant while consistently carry-



To maximize its performance, your engine should be run at between 350 and 375 degrees, and temperature is most accurately measured on the glow plug or near the glow-plug opening at the top center of the head.

Nitro facts

Nitromethane produces more energy per cycle, combustion-chamber pressure and crankshaft torque than any other common fuel component. Combusting nitro also adds excess heat.

Nitro isn't without its problems: burning it produces sharply elevated combustion temperatures that encourage detonation—especially with higher percentages of nitro mixed in the fuel. If you raise the nitro level, you should also consider shimming the head to reduce the compression ratio.

If your engine runs too hot, the piston might burn through. The piston on the left has a small depression while the one on the right has been burnt right through its center.

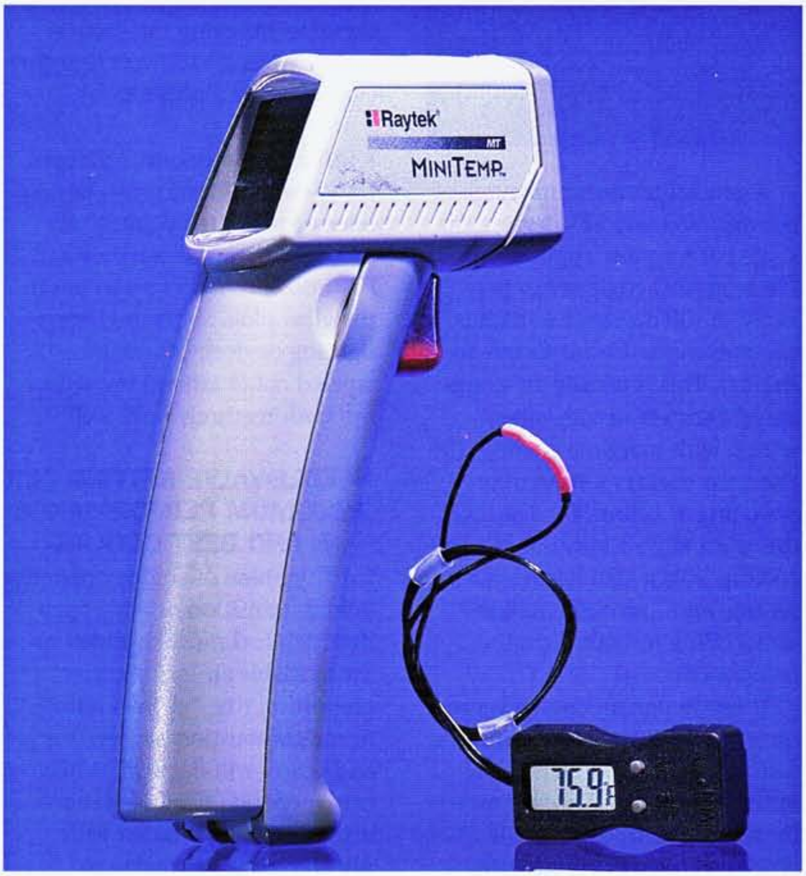
ing away waste engine heat through the exhaust system. Some enthusiasts consider castor oil a nuisance, since it decomposes into a soft varnish that must be removed from internal and external engine components from time to time.

• **Synthetic oil:** synthetic lubes are excellent but can also have limitations in the presence of overheating. Most can burn in the combustion chamber if the needle valve is set too lean; they can also boil on the cylinder walls, piston skirt and wristpin areas. Under extreme temperatures, they can degrade into the materials from which they were formulated, and these are generally less suitable lubricants.

SOME (DON'T) LIKE IT HOT

When excess combustion heat doesn't dissipate fast enough, engine temperature soars. Today's ABC components (aluminum piston, brass cylinder, chrome-plating) have closely matched expansion rates; this allows them to operate at temperatures well in excess of any other combination of metals without seizing. The piston is in direct contact with hot combustion gases, however, and it has no efficient heat-dissipation path, so its cooling is dependent on other events and circumstances. In extreme cases, the best silicon aluminum-alloy pistons will melt if temperature is allowed to climb unabated. Known by racers as "burning a piston," the phenomenon may be more accurately described as a blowhole through the crown.

The piston isn't the only component that suffers; the wristpin and the upper portion of the con-



There are two ways to measure an engine's temperature accurately: with an onboard temp gauge (see the small, light MIP gauge on the right of the photo) and with an infrared sensor (the Raytek "gun" on the left).

HOT ADVICE

CAUSES OF OVERHEATING

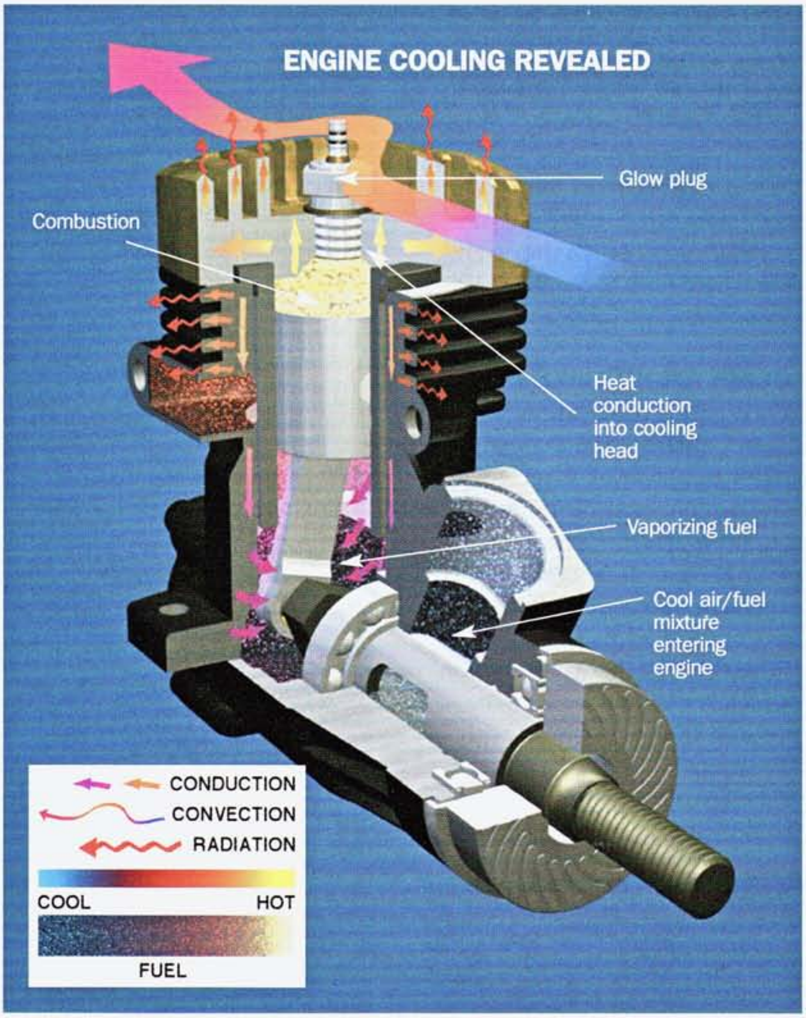
- The engine is being operated leaner than the "peak power air/fuel ratio" for a given fuel.
- The propeller is mismatched and does not allow the engine to rev up to an appropriate rpm.
- The piston/sleeve combination is worn out.

TO AVOID HEATING PROBLEMS . . .

- Set the engine slighly rich when you achieve maximum power.
- Use 18 to 22 percent lubricant and add castor oil to the mix.
- Don't change the nitro percentage.

SOLUTIONS TO HEATING PROBLEMS

- Detonation, caused by an overheated, over-compressed air/fuel mixture, can be fought by shimming the head to reduce compression and/or by switching from a hot to a cold glow plug.
- If head temperatures rise above 400 degrees, increase the airflow over the head, and reduce compression by shimming.



necting rod that operates within these furnace-like conditions are prime candidates for temperature-related failure. Many 2-stroke engines fail because the rod bushing seizes on the crankpin as a result of overheating. That takes care of the "worst-case" scenario; now let's look at how we can avoid it!

HEAD TEMPERATURE & ENGINE COOLING

The most accurate place to measure an engine's temperature is on the cylinder head near the glow-plug opening, or better, on the glow plug itself. The temperature reading at this location is a good indicator of engine cooling but a poor gauge of a correct or optimal air/fuel mixture.

A general temperature range of between 350 and 375 degrees F is a safe bet for most applications. I've seen ABC engines run perfectly at 400 degrees F (which is about as hot as I want to run an engine). This is usually an example of a correct needle-valve setting with marginal cooling. I've also seen engines self-destruct operating at below 300 degrees F; this is usually an instance of overcooling with a lean needle-valve setting, and that combination limits oiling to critical engine components.

Even though an engine is running "cool," it isn't necessarily running right. If extracting the optimal torque and horsepower from a particular setup is the objective, higher cylinder-head temperatures are desired from a slightly rich primary-needle-valve setting. But keep in mind that every combination of engine design, fuel, compression ratio, glow plug, propeller, forced convective cooling and other considerations will modify the ideal temperature.

HOW TO MEASURE HEAD TEMPERATURE

There are two common ways to accurately measure cylinder-head temperature: use an onboard sensor or an infrared temperature gauge.

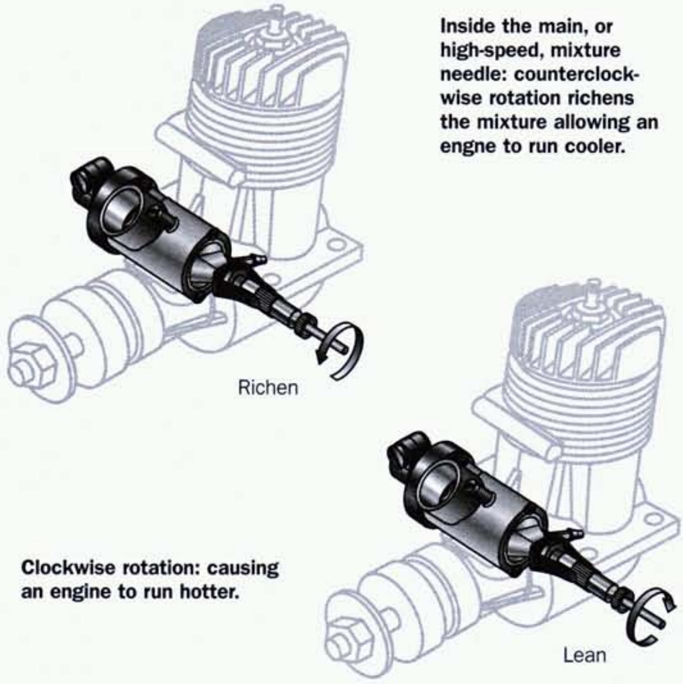
- **Onboard systems.** The units offered by MIP and Traxxas, two prominent RC car manufacturers, are very convenient and affordable, and they sense engine temperature via bi-metallic thermocouple sensor wires. Onboard units work well for relative temperature comparisons but do not measure actual temperature very accurately because the thermocouple wires are difficult to secure closely to the glow plug.

- **Infrared temperature gauges.** Hand-held infrared units, usually referred to as "temp guns," are more accurate because they can be aimed precisely to zero in on the glow plug. Some use laser sighting devices; others use tapered cones around the sensor tip; both methods work well.

NEEDLE-VALVE SETTING FOR MAXIMUM PERFORMANCE & AND BEST COOLING

For any phase of engine operation (idling, transition or wide open throttle), fuel must be added to the available air in the correct proportion (the "air/fuel ratio"), or the combustion process, torque and power will degrade. While extremely rich needle-valve settings should be avoided with ABC-type engines owing to

HIGH-SPEED NEEDLE



Inside the main, or high-speed, mixture needle: counterclockwise rotation richens the mixture allowing an engne to run cooler.

Clockwise rotation: causing an engine to run hotter.

piston-wear considerations, extremely lean runs will cause the engine to overheat and will severely damage it in the process.

It's important that you never operate an engine leaner than the peak power air/fuel ratio for a given fuel. This is the needle-valve setting at which maximum rpm is obtained for any given load. Practical experience has shown that a slightly richer than peak setting will act as insurance against a lean, hot, damaging run.

Some guys insist on adjusting the needle valve to its leanest position in an attempt to squeeze the highest rpm and performance from their engines. This is asking for trouble. The engine may be a click away from disastrous, high-temperature operation. Lean mixtures also promote combustion defects such as pre-ignition and detonation; these add to the engine's already burdensome cooling load. Rich, relatively cool operation reduces the possibility of these problems. Engines can be set noticeably rich and still produce nearly maximum power without fear of temperature-related damage.

COMPRESSION RATIO AND COOLING

When a fresh air/fuel mixture is squeezed in the combustion chamber by the piston, it is said to be compressed. The amount of compression is determined by comparing the volume before and after compression—hence the term "compression ratio."

As the compression ratio increases, so does the pressure in the combustion chamber. Along with the pressure, temperature also increases. High-compression-ratio engines exert more force on the piston; they produce greater torque and power at the crankshaft than low-compression engines. They also generate higher temperatures in the combustion chamber, and these must

Mixing your own fuel

As a general rule, using a mixture of synthetic and castor lubricants can optimize engine performance. A good starting point is 20 percent lube by volume. I particularly recommend the addition of castor oil to the lubrication package when you're dealing with the higher cooling loads and heavier wristpin pressures encountered with high-performance engines.

If you currently use an 18 percent straight synthetic fuel, try adding some castor oil. You can obtain Bakers AA or Klotz Bean oil from your local hobby or motorcycle shop. If the hobby shop doesn't carry castor oil, it can get it from a distributor.

I suggest that for our applications, a mixture of one part castor oil and two parts synthetic is an effective combination.

This formula tells you exactly how much castor oil to add to your fuel blend:

Oz. to add = (F - I) / 100 - F

F = final percentage of oil desired
I = initial percentage of oil already in the fuel
A = number of ounces of fuel you are treating

Example: if you have a gallon (128 ounces) of 18-percent-synthetic-oil fuel and you want to add castor oil to bring it up to 20 percent, find the following:
F = 20
I = 18
A = 128

(20 - 18) x 128 / 100 - 20 = 3.2

So, add 3.2 ounces of castor oil to the gallon of 18-percent-synthetic-oil fuel. Be aware that since the new volume is larger than the original gallon (now 131.2 ounces), the actual percentage of nitromethane and methanol will be decreased slightly but not enough to affect performance.

be dissipated, partially by the engine's cooling system.

WHEN TO ADD A GASKET

Since higher compression ratios mean greater engine performance, why would anyone knowingly lower the compression by adding a gasket (a shim)? The answer is to control the engine's internal temperatures. When a gasket is added between the top of the cylinder and the bottom of the head, the engine's compression ratio and cooling load are reduced.

If you have an over-compressed engine, its sound will likely tell you that something needs immediate attention. Over-compressed engines are prone to pre-ignition and detonation. It's difficult to identify which defect is present because they sound alike (the sizzle of a frying egg or a sharp crackling sound from the exhaust) during operation. Detonation sometimes produces a metallic pinging sound, but this is usually reserved for larger-displacement engines.

Signs of pre-ignition or detonation damage can be found on the engine's piston crown and cylinder head. If otherwise shiny aluminum components look sand-blasted, you have a combustion-defect problem.

The number-one solution to eliminating either of these problems is to reduce the compression ratio: add a head gasket. Engine manufacturers sometimes include an extra head shim in the 0.004

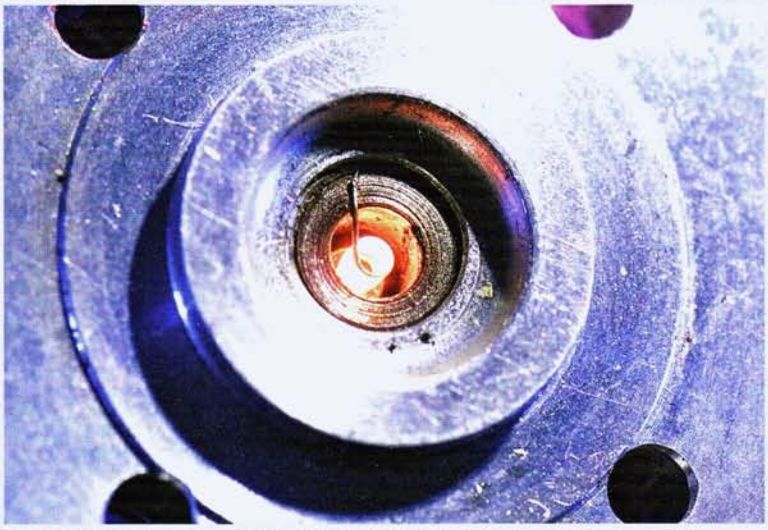
When to change from a hot to a cold plug

By selecting the correct glow-plug heat range, the engine's cooling load may be reduced for a given fuel blend and compression ratio. Here's how it works:

Glow plugs have platinum-rhodium- or platinum-iridium-alloy wire coils (elements) that heat up and glow orange to orange/white when a low-voltage direct current is passed through them. When the engine is running and the current has been disconnected, the coil continues to glow. This is the result of an exothermic (heat-releasing) catalytic reaction between the platinum-alloy coil and the fuel's methanol, plus heat absorbed during combustion.

A "hot" plug retains much of its heat from the previous cycle and helps to ignite the fresh air/fuel mixture during the early part of the compression stroke. A "cold" plug carries less heat from the previous cycle and therefore ignites the air/fuel mixture later in the compression stroke.

By changing from a hot plug to a cold plug, an experienced tuner can retard the ignition point (ignite the air/fuel charge closer to top dead center) and quench a detonation or pre-ignition problem that is sapping power and forcing extra heat into the cooling system without having to reduce the compression ratio. Sometimes, a combination of changing the heat range and the compression ratio works best to restore power and lower the cooling load.



You'll note that the many available glow plugs are listed as having a variety of heat ranges. You can fine-tune your engine just by changing its glow plug.

Explosive results of high temperatures

High combustion-chamber temperatures produced by lean air/fuel mixtures often promote combustion defects such as pre-ignition and detonation. These can adversely affect performance and damage the engine.

PRE-IGNITION

If a portion of the combustion chamber such as a sharp edge from a tapped glow-plug hole or a carbon particle becomes overheated under operating conditions, it's possible to pre-ignite the fresh combustible charge. This potentially damaging early ignition isn't desirable because of erratic and uncontrollable combustion accompanied by soaring temperatures.

DETONATION

Detonation is a major factor that causes designers to limit the compression ratio in any internal-combustion engine. Violent pressure fluctuations accompanying detonation can cause severe mechanical engine damage. Unlike pre-ignition, which occurs before combustion, detonation happens after burning has started. As the normal flame front is progressing across the combustion chamber, the unburned mixture is being compressed. If this mixture reaches its auto-ignition temperature, it will ignite, causing two colliding pressure fronts; detonation is the result.

ENGINE CONDITION & LOAD

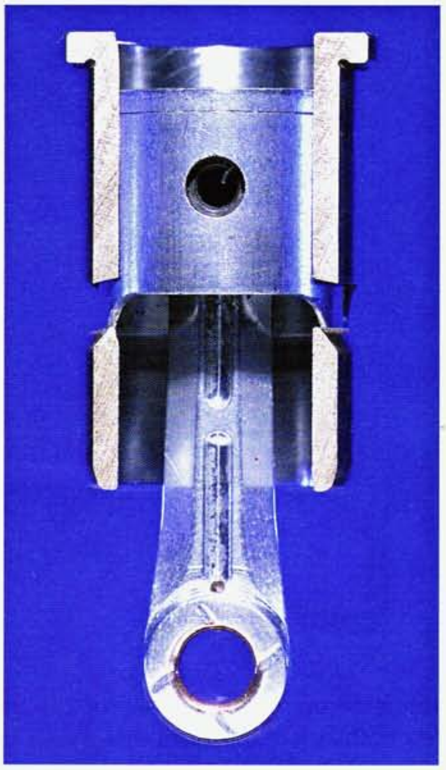
If the piston/cylinder combination is worn out, the engine will overheat. When the ABC-type piston loses its "pinch" (interference fit) near top dead center (TDC), it's a sign that clearances between the piston and cylinder are becoming excessive. When operating at temperature, hot combustion gases will blow by the piston and into the crankcase, increasing friction and adding more heat. The piston can't efficiently transfer heat to the cylinder walls, and hot spots promote pre-ignition.

As head temperatures rise, the cooling system will appear to be overloaded. When any of a number of corrective actions are taken, the engine will lose power. It's time to purchase a new piston, cylinder, connecting rod and wristpin set!

ENGINE LOAD

An engine that is overloaded with too much propeller (diameter and/or pitch) will often overheat at prolonged wide open throttle (WOT) operation.

Rather than changing the glow plug, compression ratio, air/fuel mixture, or other factors, the best solution may be to change to a prop with a smaller diameter and/or pitch that will allow the engine to speed up.



Every ABC-type engine piston has an interference fit near top dead center. If an engine wears and loses this fit, it can overheat because hot combustion gases blow by the piston and enter the engine's crankcase.

to 0.008-inch thickness range. Don't be afraid to experiment with compression ratios, but listen for the telltale frying egg sound, and carefully monitor the head temperature.

WHEN TO INCREASE AIRFLOW

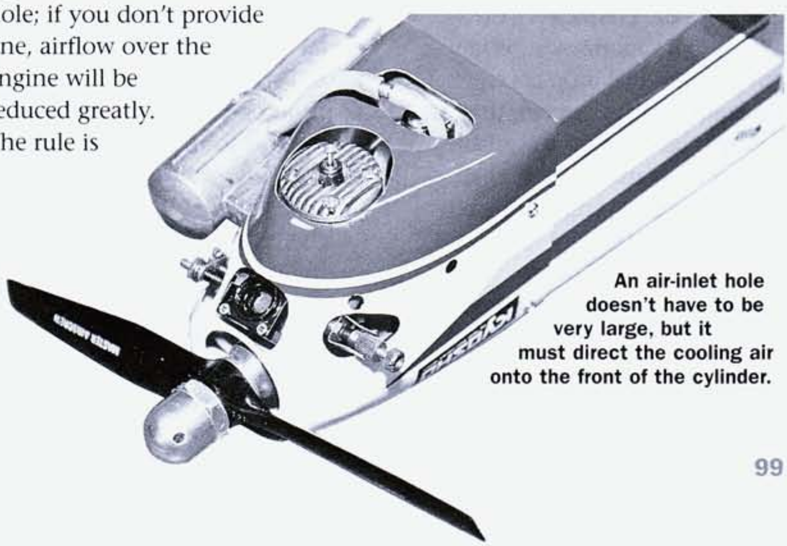
If you have a high-compression engine that runs strongly at the correct needle-valve setting, you want to maintain this performance. But if the head temperature continues to rise (say, above 375 degrees F), you need to decrease the temperature, or chances are good that something will fail. Your best bet is to increase the airflow over the existing fins. Resist reducing the nitro content to lower the temperature, as this will change the expansion rates of the piston and cylinder. That can affect their fit, cause friction and reduce performance and even damage your engine.

WHAT ABOUT COWLS?

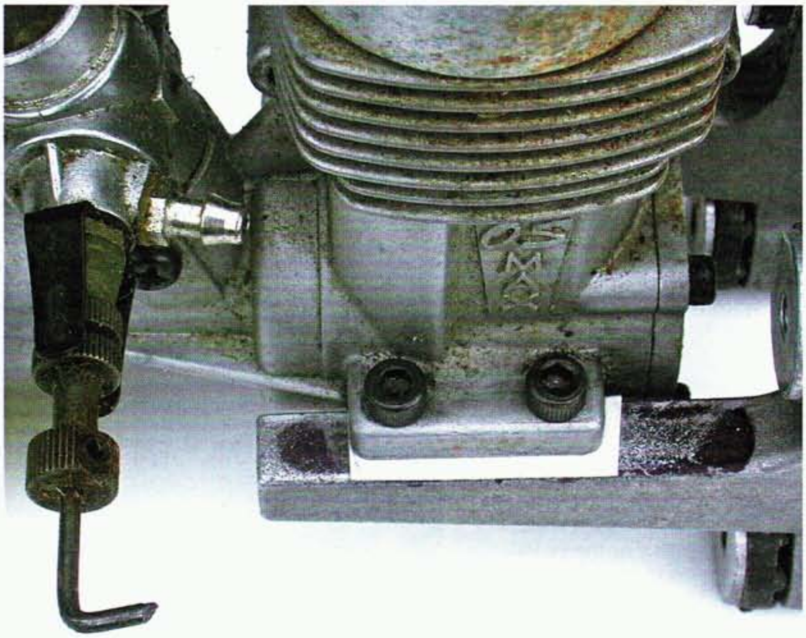
The only engine parts that require cooling are the cylinder and the head—from the bottom of the exhaust stack up. (The crankcase operates at a lower temperature owing to fuel vaporization, which draws most of the heat from that area.) On a .40 sport-model engine, the cowl's air-inlet hole doesn't have to be very large, but it should direct the air onto the front of the cylinder, particularly the cylinder head because convection and radiation direct most of the waste heat there. How big should the hole be?—½ inch wide by 2 inches high should suffice. Equally important is the exit hole; if you don't provide one, airflow over the engine will be reduced greatly. The rule is that you should make the exit hole at least 1½ times the size of the inlet hole.

TOO MUCH COOLING

A cold running engine—one that operates at below 300 degrees F (head temperature)—is inefficient because it wastes fuel. More important: a cold running engine isn't nearly as powerful as it could be. Although such an engine is often free of pre-ignition and detonation, it's likely to display power-robbing, erratic pressure pulses from cycle to cycle. Fuel



An air-inlet hole doesn't have to be very large, but it must direct the cooling air onto the front of the cylinder.



There is no need to drain heat from an engine's crankcase area. Put a thin piece of plywood or card stock between the engine block and the engine mounts to reduce cooling in this area.

The 10hp .40!

If .40 engines were perfectly efficient, they would produce an amazing 10hp! Why? Only about 20 percent of the fuel's energy is converted into work. Here's where the other 80 percent goes:

- 40 percent of the energy is blown out though the exhaust in the form of waste gases and unburned fuel.
- 10 percent is "ground away" by friction within the engine.
- 30 percent of the fuel's energy is shed in the form of heat.

vaporization in the crankcase suffers from lack of heat, and that compounds the problem. A suggestion: run your engine safely on the cool side—less than 400 degrees F but above 350 degrees F.

HEAT-SINK ENGINE MOUNTS

Under normal operating conditions, a methanol-burning 2-stroke engine should be cooled from the bottom of the exhaust manifold to the top of its finned heat-sink head. Although some may disagree, I recommend that nothing below the exhaust manifold be cooled because a substantial amount of the heat being conducted to the lower block can be diverted to the atmosphere rather than into the crankcase. This retards fuel vaporization. When unvaporized fuel droplets enter the combustion chamber, they are poorly mixed with the available air and burn erratically, if at all, before being scavenged (cleared) from the engine.

To prevent this type of unwanted cooling, I do not recommend the use of heat-sink engine mounts. Some experts even believe that conventional metal engine mounts should be thermally insulated from the engine. This can be accomplished by inserting a piece of 1⁄64-inch plywood or card stock between the mounts and the engine-mounting flanges.

HOW MUCH LUBRICATION IS ENOUGH?

Experienced modelers know that using lower percentages of lubricant in the fuel blend—14 to 16 percent—will allow their engines to develop more torque and horsepower. It will also provide a crisp throttle-up.

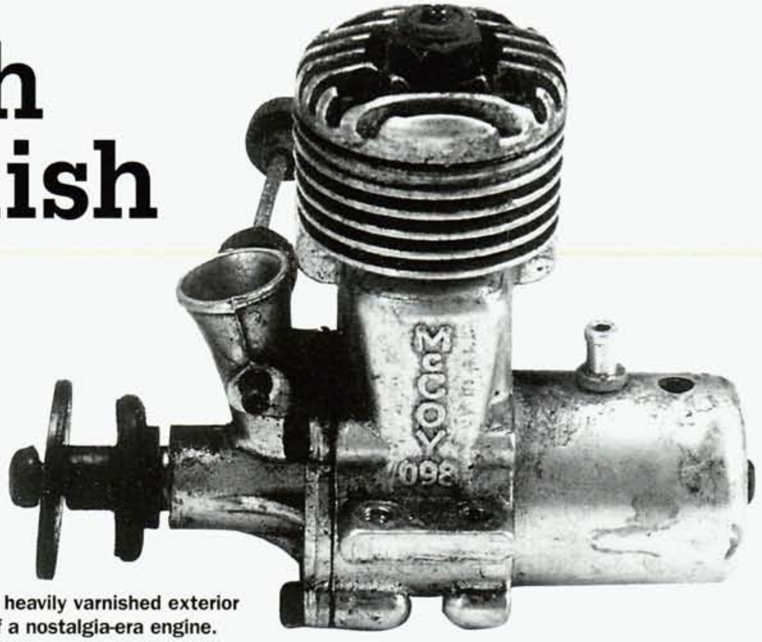
For Sunday fliers, this can be a dangerous tactic. If the engine begins to run hot, the lubricant will have difficulty wetting the metal surfaces while trying to absorb additional excess heat. Lean oil percentages are often spread too thinly and boil off hot cylinder walls, piston skirts and wristpins.

The best strategy is to use a higher percentage of lubricant (minimum 18 to 20 percent) in the fuel. The difference in peak power and throttleability is hardly noticeable.

High cooling loads result when increased engine temperatures must be controlled by the cooling system.

vanquish the varnish

BY DAVE GIERKE



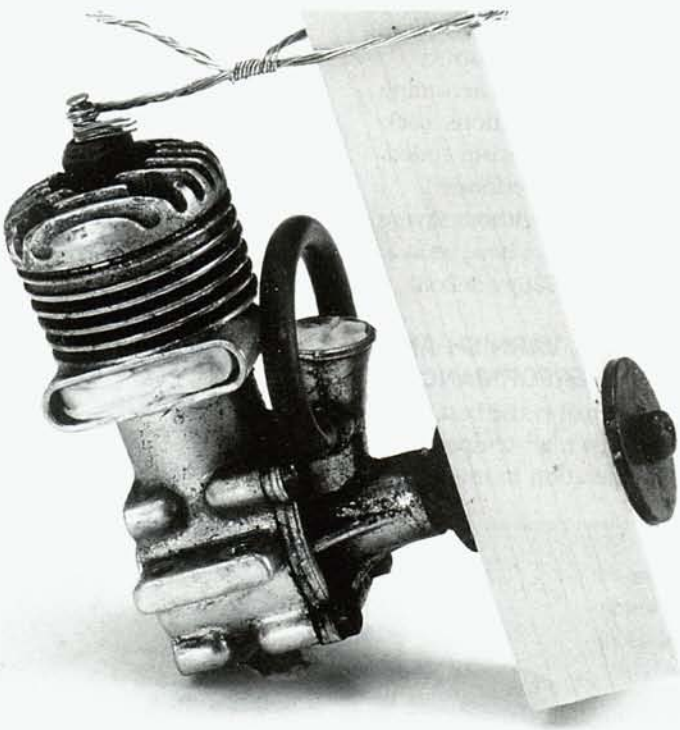
A heavily varnished exterior of a nostalgia-era engine.

Contrary to what you may have heard, clean engines perform better than dirty engines! A clean engine is easier to adjust, runs cooler, and ultimately, will last longer. The dirt I'm talking about is not ordinary abrasive dirt; I'm referring to combustion-generated varnish. If it's ingested, abrasive dirt is public enemy number one; varnish runs a close second.

Ordinary dirt can be prevented from entering an engine by:
• using an air filter;
• minimizing the time an engine runs while sitting on the runway;
• rinsing away dirt after an unintended encounter with terra firma.

Varnish is a more insidious villain; it sneaks up on you. Although an affected engine seems to run well one day and poorly the next, the problem develops over time and will show effects sooner or later depending on the fuel blend you use and the amount of flying you do.

I remember the first time one of my engines needed to be devarnished; the plane sounded good while running on the ground, but "ran away" in the air—lean and hot. After I had struggled with the problem for the better part of the morning, someone at the field informed me about castor-oil-generated varnish. He said it was produced by lean, hot operation and collected on the piston and sleeve. "Varnish is good," he said. "It prevents metal-to-metal contact. Unfortunately, the stuff has to be removed occasionally."



1 For exterior engine cleaning only: remove accessories (in this instance, the needle valve and tank); pack a piece of paper towel into the exhaust port and another into the air intake. Seal the needle valve and spray-bar holes with a length of fuel line. Attach a simple holding stick to the engine crankshaft, then lock the assembly with wire wrapped around the glow-plug stem and stick.

2 Hold the engine over a catch-pan (a pie tin works well), and apply a liberal coat of chemical cleaner with the application brush. Always wear protective rubber gloves and goggles. Give the cleaner 30 to 45 minutes to do its work. (Note: Demon-Clean chemical cleaner may be left on metal surfaces for days or weeks without its causing damage; however, never use it on painted or anodized surfaces.)

3 Using rubber gloves and goggles, brush engine surfaces and components vigorously with an old toothbrush under warm tap water (in some cases, a heavy-duty nylon or wire brush is needed). Dry, lubricate and reassemble the engine.

At first I thought this corn-cob-smoking adviser was just blowing smoke rings—pulling my leg. After all, I had been running engines since I was 11 years old and I had never had this problem before. Those were the days (early 1960s) when we used commercial fuels that contained 100 percent castor oil; Fox Superfuel and K&B 100 are two that come to mind. Anyway, after yet another lean flight, I decided to exorcise the varnish. I removed the engine from the airplane and hurried home; then I cleaned it according to my advisor's instructions. Back at the field, my skepticism ended when the little .35 performed beautifully. It goes without saying that since that day, I have been a believer. Thanks, Pappy deBolt!

CASTOR OIL, VARNISH AND ENGINE PERFORMANCE

Castor oil in fuel is the best protection against high-temperature, over-lean operation in miniature

4 This heavily varnished, antique spark-ignition engine required complete disassembly for inside and outside cleaning. Note the severely varnished piston as viewed through the exhaust port.

5 After the engine has been correctly disassembled, the major components are ready for cleaning with chemical cleaner.

6 Right: after cleaner has been applied, the catch-pan provides a place for the engine to sit while the chemical does its work. Difficult-to-clean areas may require a second application.

7 Left: warm water and a stiff toothbrush are used to complete the cleanup. Remember to wear rubber gloves and goggles. Parts must be thoroughly dried and lubricated before reassembly.

2- and 4-stroke engines. During a high-temperature episode, castor oil forms a tough, protective varnish on the piston and cylinder, and this usually prevents catastrophic damage from the heat. Unfortunately, varnish buildup ultimately, through overheating and viscous piston drag, degrades engine performance.

When fuel spills, castor oil also varnishes the hot outside surfaces of the engine, especially the cylinder head, exhaust stack and muffler. Acting as a thermal insulator, varnish buildup (both inside and out) reduces the engine's ability to cool, thus promoting high-temperature, erratic operation. Revealing itself as an ugly, dark brown smear, varnish stubbornly resists removal with common solvents.

Forty years ago, we removed engine varnish mechanically, using a variety of techniques incorporating wire brushes, steel wool, sandpaper and abrasive soap. Although these products worked satisfactorily to remove

8 Ready for action or ready for the display case, these engines sparkle like new!

buildup, there was always a chance of damaging precision engine components.

Today, we have chemicals that have been specifically tailored to safely and effectively remove varnish without subjecting the engine to potential damage. Keep in mind that it's important for engines to be disassembled and reassembled using the correct tools and techniques. Two reference books concerning these and related topics are "All About Engines," available from Higley & Sons and my "2-Stroke Glow Engines for R/C Aircraft, Volume 1," available from Air Age Media.

death to evil air leaks

BY CHRIS CHIANELLI

There's only one place you want your 2-stroke engine to be sucking air: through the carburetor. If even a little bit of air is leaking anywhere else, it will destroy the necessary negative crankcase pressure—the force that sucks the air/fuel mix into the engine. If your engine isn't drawing the right amount of fuel and air at all rpm levels, it will run poorly—or not at all.

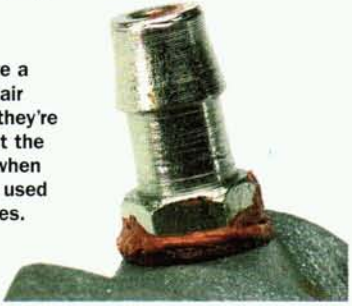
Follow these steps closely, and when the last part has been bolted back onto your engine, you should be ready to go. This procedure is great not only for resealing a poorly running, leaky engine, but also for rebuilding older engines for which gasket sets may be too expensive or not readily available. In the past, when I've been unable to obtain a certain gasket for an otherwise good engine, I used this system in place of the gaskets and was rewarded with a perfect running engine.

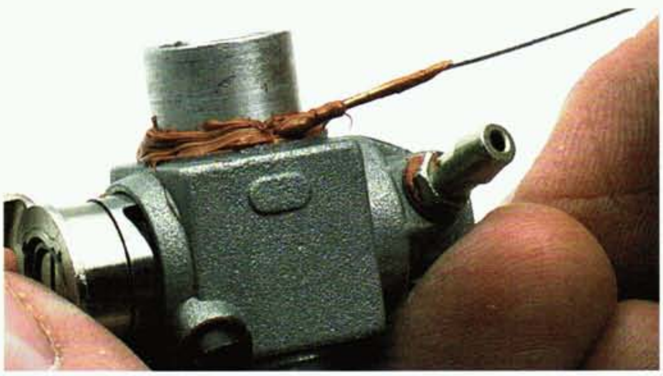
Garden-variety silicone sealants contain ingredients that can corrode the inside of the engine. When you shop for a sealant, read the package to make sure that it's suitable for high-temperature applications and that it is "sensor-safe" or "oxygen sensor-safe."

Clean the engine thoroughly before you begin; I use a can of carburetor cleaner. The spray pressure really gets out the fine dust. If you think an air leak is bad, watch what happens when you seal dirt inside the engine! Clean it, and wear safety glasses.

Less is more. Squeeze some sealant onto a piece of scrap paper and apply it with a piece of thin wire, such as an unbent paper clip, or a toothpick. Use just enough to ensure a proper seal and no more. You don't want excess sealant to get into the engine; it could cause more problems than it solves.

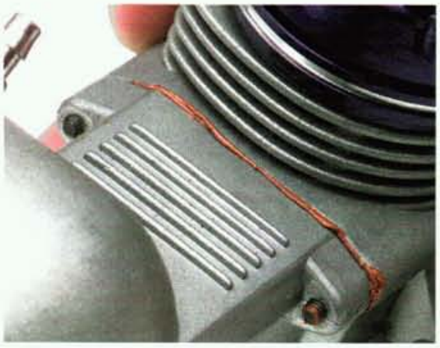
Fuel-inlet nipples are a potential source of air leaks. Sometimes, they're improperly sealed at the factory, especially when plastic gaskets are used instead of paper ones.





Many air leaks occur in and around the carburetor. Carb retainers and the area under the carb where it mates to the engine are usually the trouble spots.

It isn't essential to seal the exhaust, but doing so will keep your model's engine compartment cleaner. Use a bit more sealant with exhaust stacks, since the mating surface between the muffler and exhaust stacks is sometimes less than precise. Yes; this stuff will hold up to exhaust temperatures.

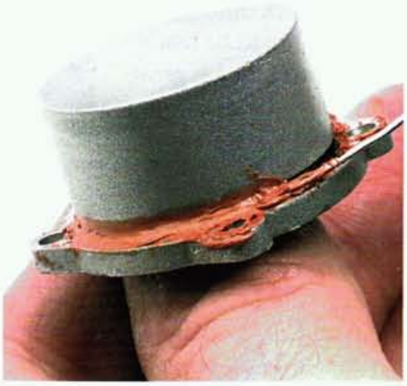


With a clean cloth, wipe away any excess sealant that oozes out of the joint when the screws are tightened. It makes disassembly easier and, if nothing else, the engine will look better.

Torn backing plate gaskets can be a source of air leaks. If you don't have a new gasket—no problem. This method works extremely well in place of the gasket. Don't be fooled into thinking that a backing plate with an O-ring is always properly sealed. It can leak just as badly as a torn gasket.

Seal the backing plate with a small bead of silicone. Seal right over an O-ring if one is present. Don't apply any sealant to the engine block because it might permit a tiny bit of it to be pushed into the crankcase when the backing plate is installed.

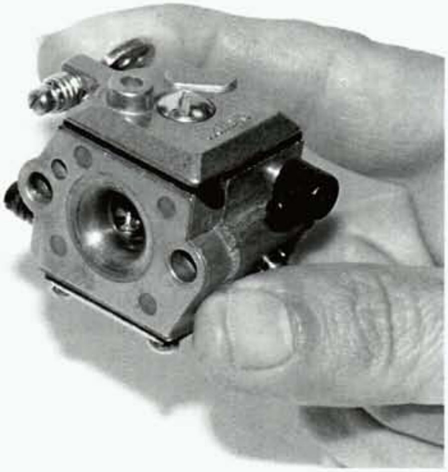
When you re-install the backing plate, apply an equal amount of torque to all of the bolts and wipe things clean before the silicone dries.



maintain your gas carburetor

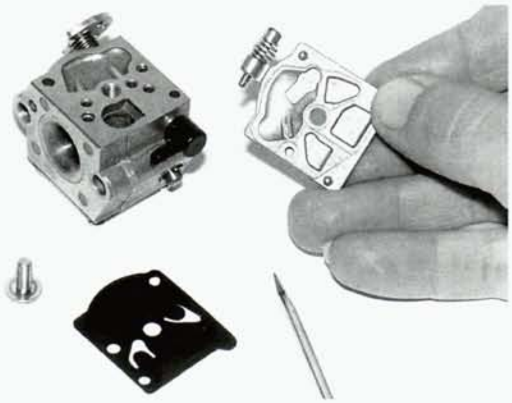
BY RICK EYRICH

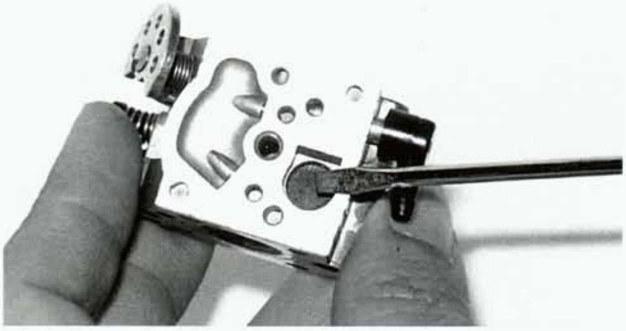
Unlike the carburetors found on nitro engines, most gasoline-burning powerplants rely on the basic Walbro butterfly-valve pumper carb. Walbro carbs share the same fundamental layout of fuel pump/metering diaphragms, high/low mixture screws and needle-valve parts. Routine maintenance on these square carbs involves disassembly, a few simple checks and reassembly—certainly within the capabilities of most model builders.



1 Remove the Walbro from your airplane's engine, and clean the carburetor thoroughly before internal inspection. A clean exterior will prevent you from contaminating the interior of the Walbro, which could result in misleading signs of an internal carb problem.

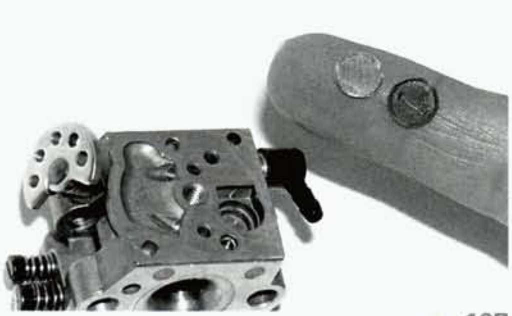
2 The fuel-pump diaphragm is beneath the single-screw plate that usually contains the idle-screw-adjustment arm. The sealing gasket should be pliable, and the pump and gasket should be free of debris; both "flaps" must lie flat against the carb body.





3 The fuel inlet filter—a small, round screen that prevents debris from passing into the metering section—sits inside this recessed area. Lift the screen free with a small pick or screwdriver. Do not push the screen past this lip when you replace it; doing so might reduce the fuel flow through the carb body.

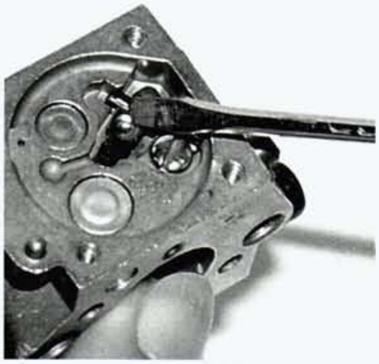
4 Note the variation in the color of these two inlet screens. Tiny contaminants can block the small openings in the screen and cause the engine to run poorly. Use low-pressure air and denatured alcohol to clean the screen. Savvy competitors replace this screen at the beginning of each flying season—not a bad idea for sport fliers, either.



5 Opposite the fuel pump area is the metering/diaphragm zone. Both flat metal plates and primer are held here by four small screws; you'll find a similar diaphragm/gasket combination underneath.

7 Once you have removed the metering arm, spring, pivot shaft and needle valve, inspect for any marks, embedded gunk or deformities; pay particular attention to the tapered rubber tip of the needle.

8 Last, check the high- and low-end mixture screws. At this point, you're ready to clean the Walbro's internal components completely.



6 This side of the Walbro houses the carburetor's fuel-measuring parts. If any debris has managed to get into this area, you'll likely find it on the inner rim of the gasket seal area. Condensation can find its way to this point, and if left unattended, it will ruin the carb body.

9 If you find that replacement gaskets are needed, be sure to completely remove the old gasket material, but never use sharp tools to do so. Scratches and nicks in the carb and sealing plates can cause the engine to run poorly. The raised sealing rib on this pump's cover could easily be damaged by a scraper. Use soft tools or paint remover on the old gaskets.

10 After you've cleaned the carburetor, reassemble the Walbro; do so in the reverse order from which you disassembled it. Be very careful to line up all the components correctly. The fuel pump and metering diaphragms are often reinstalled incorrectly. The diaphragm lies flat against the carb body and is followed by the gasket and the one-screw cover plate. On the metering side, the gasket goes on first, then the diaphragm, which is followed by the four-screw cover plate.

Your Walbro's reassembly should be straightforward; when the carburetor is back together, inspect the mounting gasket, fuel lines, fuel filter and tank. Replace any questionable components. Reinstall the Walbro on your model's engine, and head for the flying field!

ENGINE GUIDE

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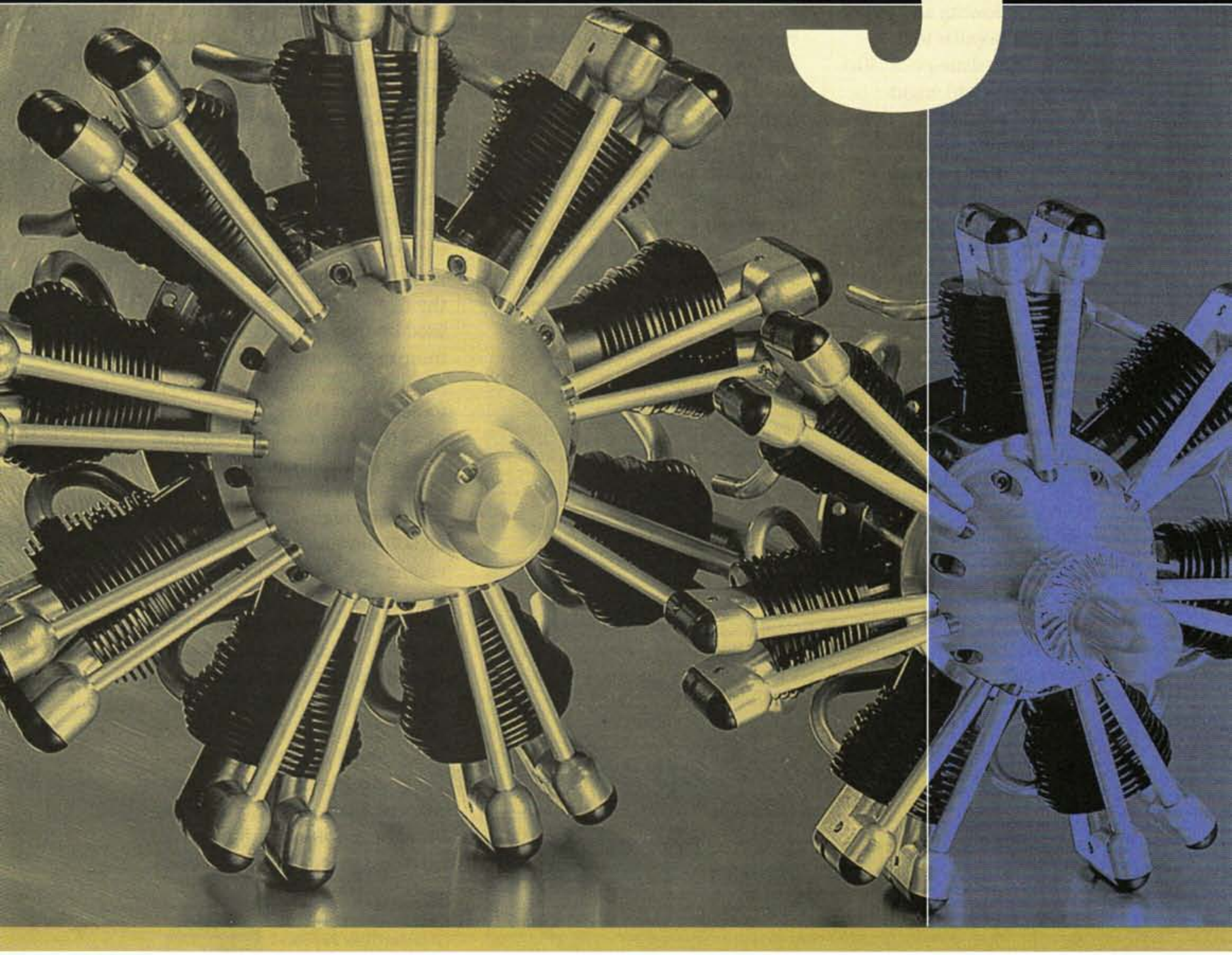


Please note: prices and sources subject to change.

.40 engine comparison

BY DAVE GIERKE

Tower .40 R/C ABC—plain bearing

The following analysis of nine popular low- to intermediate-price .40ci (cubic inch) engines is based on cost, performance, durability and warranty. All fall into the 2-stroke-cycle category; all have single cylinders and incorporate front-rotary-valve mixture induction with rotary-barrel throttle carburetors. All are designed with side exhausts and use simple, non-tuned expansion-chamber-type mufflers. Internally, they differ widely with respect to piston and cylinder design and materials. It should be no surprise that all engines use the Schnuerle system of cylinder porting (a standard for the industry). Crankshafts are supported either by bushings (plain bearings) or dual ball bearings; modelers often turn up their noses at bushings, but most of these will outlast certain cheap (inferior) ball bearings. Unfortunately, ball-bearing failure usually occurs after several hours of operation—beyond the scope of this comparative review.

Sound complicated? It really isn't, provided you understand the pluses and minuses associated with the technologies. A simple way to determine this is to check the materials and technologies used by the manufacturers of more expensive engines (Nelson, Jett, Rossi, YS, etc.), but don't be fooled. Sport flyers don't always need true chromed ABC engines with high-quality ball bearings. There's a big difference between running a high-dollar engine at 20,000rpm plus and a sport engine at 13,000. Don't be swayed by suggestions that ABC-type engines are superior to all others. Truth is—for sport engines—lapped iron and steel components and compression rings are more than satisfactory. Two advantages of ABC-type engines are: a relatively short break-in period and reduced chance of piston damage brought about by running a lean mixture setting. Properly broken

We all want value for our money, but when it comes to evaluating our miniature RC engines, which criteria should we use to determine value? Cost? Performance? Warranty? Durability? Manufacturer and distributor reputation? Availability of parts? Service? Some of this information is relatively easy to obtain.

• **Cost.** Search for the best .40 prices; look at magazine ads, and check discount houses and hobby shops. But are you sure that you want the least expensive engine out there?

• **Performance.** Manufacturers don't always include horsepower data, and they never consider torque. Then there's the matter of truthfulness; engine reviewers such as yours truly can evaluate only 10 to 20 engines a year, and more than 600 are available worldwide!

• **Warranty.** Most manufacturers offer a limited replacement policy to cover defective parts and workmanship; a few offer full replacement for any reason, including crash damage!

• **Durability.** This is very subjective; circumstances play a large role, e.g., if you consistently set the needle valve too lean and use bargain-basement fuel with questionable contents, your engine will wear out quickly (or suddenly!). Likewise, if you buy an engine made of inferior materials or inadequately prepared components, you might need a new one before you're ready!

• **Manufacturer's reputation, availability of parts and service.** When the manufacturer or distributor is respected and has a history of acting honorably (word travels fast), you can expect fair prices for repair service and parts when you need them.

Thunder Tiger Pro .40 (ball bearing).

Thunder Tiger GP-42 (plain bearing)

in and operated iron and steel assemblies have doubled and tripled the durability of certain ABC engines while maintaining their peak performance.

SIMPLIFYING THE SPECS

Study the engines' specifications (see table). Compare engine and muffler weights; notice the differences between carburetors (air-bleed or fuel-metering type). Popular opinion suggests that fuel metering is better; in my opinion, that isn't always the case. Let's take the carburetor bore and cross-sectional area into consideration. Although most small-bore carburetors work nicely with single-needle air-bleed systems, some fuel metering (2-needle) units with relatively large choke bores don't work as well. Among this group of engines, the largest cross-sectional area is 2½ times greater than the smallest; not only is this a good indicator of which engine will produce the most power and torque (the largest) but also which will have the most difficulty idling and transitioning reliably (the largest) owing to fuel-mixture-control deficiencies.

Enya SS .40BB (ball bearing)

THE ENGINES AT A GLANCE

Enya SS .40 ($68.08)
Steel and iron piston/cylinder engine with sweptback needle-valve design for safety. Although it takes awhile longer than others to break in, it will have an extremely long and reliable service life because of its high-quality castings and materials.
Idle: good at 2,500rpm, after extensive break-in with Enya G-type carburetor.
Mid-range: good, with a slight hesitation (rich) through mid-range transition.
Best props: 11x4, 9x6, 9x7.

Enya SS .40BB ($95.98)
The most expensive .40 tested here, this steel and iron lapped piston/cylinder engine features extremely high-quality craftsmanship and materials. It starts easily and provides good torque. Its relatively longer break-in time also equates to longer service life.
Idle: very good at 2,500rpm, using a twin-needle fuel-metering carburetor.
Mid-range: excellent with thorough break-in; engine exhibits flawless transition through mid-range, with an average bore-size carburetor.
Best props: 11x5, 10x6, 9x7.

Magnum XL .40 A2 ($70)
This ABC engine is equipped with ball bearings and a remote needle valve for safety. It has a short break-in time and is especially suited to high-shaft-speed applications.
Idle: fair at 2,700rpm with a fuel-metering, average bore-size carburetor.
Mid-range: very good transition, with no hesitation through mid-range.
Best props: 10x6, 9x7, 9x6.

MDS .38 FS Pro ($74.95)
This ABC, ball-bearing-equipped engine is especially suitable for high-speed applications using a low-drag airframe and relatively small propellers.
Idle: good at 2,500rpm, for advanced crankshaft and cylinder timing.
Mid-range: fair; experienced hesitation (rich) at mid-range with a relatively large bore, twin-needle fuel-metering carburetor.
Best props: 10x5.5, 9x7, 9x6.

O.S. Max .40 LA Silver ($56.99)
This ABN engine has a remote needle valve for safety. It runs well with a hotter glow plug, such as a McCoy MC-59.
Idle: fair at 2,500rpm, with non-fuel-metering, air-bleed carburetor design.
Mid-range: excellent transition, due to a tiny carburetor bore.
Best props: 11x4, 10x6, 9x7.

SuperTigre GS .40 ($74.99)
This ringed engine has ball bearings and an aluminum alloy piston and press-fit steel cylinder. It requires a hotter glow plug, such as a K&B 1L. The GS .40 performed well throughout the tests.
Idle: fair at 2,600rpm, with a fuel-metering carburetor.
Mid-range: good transition with some spitting (rich) at mid-range, with large-bore carburetor.
Best props: 11x5, 10x6, 9x7, 10x7.

Tiger GP-42 ($64.99)
This plain-bearing, ABN engine performed favorably compared to the other plain-bearing engines. It has a sweptback needle valve for safety.
Idle: fair at 2,500rpm; about the best to be expected from a non-fuel-metering air-bleed carburetor design.
Mid-range: excellent transition through mid-range, due in part to a tiny carburetor bore.
Best props: 11x4, 10x6, 9x7.

Thunder Tiger Pro .40 ($84.99)
This ball-bearing, ABN engine has a sweptback needle valve. It performed well with some additional torque added from a partially tuned expansion-chamber muffler.
Idle: good at 2,400rpm without loading fuel into the crankcase.
Mid-range: very good transition, with a slight richening at mid-range.
Best props: 11x5, 10x7, 10x6, 11x6.

Tower .40 R/C ABC ($54.95)
This plain-bearing ABC engine has a sweptback needle valve. The least expensive engine tested, it has the highest torque per dollar ratio.
Idle: fair at 2,600rpm, with a non-fuel-metering air-bleed carburetor design.
Mid-range: excellent transition, due in part to a tiny carburetor bore.
Best props: 11x5, 10x6, 9x7, 9x6.

Enya SS .40 (plain bearing)

Magnum XL .40 A2

FUELING TIPS

Pay attention to the fuel used for each engine type. It's important to note that all fuel-component percentages are calculated and measured by volume—never by weight. Wildcat Fuels was kind enough to supply me with two custom blends that worked beautifully for all the engines I tested. I used the 24-percent-lubrication fuel in all the iron and steel piston/cylinder engines and the ringed SuperTigre. All ABC-type


SuperTigre GS .40 Ring R/C

combinations used the 20-percent-lubrication fuel—half castor oil and half synthetic. After break-in, I used less lubrication—20 percent for all except one iron and steel unit that also featured a bushed crankshaft bearing (with this, I used 24 percent for break-in and subsequent performance tests).


MDS .38 FS Pro

WHAT TO COMPARE

Don't pay much attention to the peak brake horsepower produced by these engines; it's meaningless for sport applications. You'll notice that the high horsepower levels are achieved with tiny propellers (APC 8x6, etc.), none of which can be used with typical .40 sport models. High-horsepower, small-prop applications are the domain of racers and the far more sophisticated (and expensive) engines that are bolted into low-drag, high-speed airframes.

Torque is a more useful performance parameter for sport engines. Torque determines the size of the prop your engine is able to turn within a useful rpm range. If you're really interested in the true horsepower story, take the rpm value for a given prop on the chart above, and look up that value on the engine's power graph. Notice how much less power is generated at that rpm than is produced at the peak horsepower? Now check the torque for the same prop and rpm. You'll notice that for props used to fly sport planes, the rpm they turn put us closer to peak torque than brake horsepower.

For any sport engine, it's practical to look at peak torque per dollar invested (street price). For example, if the engine produces 100 oz.-in. of torque and costs $100, it generates 1 oz.-in. for each dollar spent.

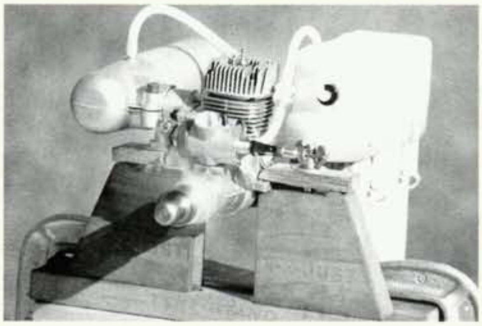
Finally, compare the noise (decibel levels) of the engines. This is a useful indicator as to how well your new mill will be accepted at your flying field. Remember that every 3 decibels (dB) represents a doubling or halving of the perceived noise. Have fun comparing!

O.S. Max .40 LA Silver (plain bearing)

Behind the scenes

I inspected and photographed the engines after I had read the instructions that came with each one. I mounted each engine on a stand, and after break-in, tested each proposed flight propeller's rpm. Then I mounted each engine in my dynamometer stand and tested it again. After I dismantled the engines and measured and checked their internals, I cleaned and photographed the parts then reassembled them. How long did all of this this take? Approximately 118 hours!


An engine is torque-tested on the dyno.


The author's break-in stand.


A disassembled O.S. Max .40 LA.

Comparison of rpm with various APC propellers

PROP	ENYA SS .40	ENYA SS .40 BB	MDS .38 FS	O.S. MAX .40 LA	SUPERTIGRE GS .40	THUNDER TIGER GP-42	THUNDER TIGER PRO .40	TOWER .40	MAGNUM XL .40
	RPM								
8x6	15,500	16,800	17,200	15,400	17,100	16,500	16,900	15,900	17,400
8x7	14,500	15,700	16,200	14,100	15,900	15,100	15,800	14,600	16,000
9x6	14,100	15,300	15,500	13,400	15,600	14,600	15,700	14,100	15,400
9x7	13,200	14,400	14,200	12,700	14,800	14,000	15,200	13,400	14,500
10x6	12,500	13,300	12,900	12,100	14,000	13,000	14,900	12,700	13,600
10x7	11,100	11,600	11,200	10,900	12,600	11,600	13,200	11,300	12,100
11x6	10,500	12,100	10,400	10,400	12,000	10,900	13,000	10,900	11,300
11x7	10,100	11,000	10,000	10,200	11,400	10,500	12,700	10,300	10,900
12x6	9,000	9,500	8,500	9,100	10,000	9,200	12,100	9,300	9,600
12x7	8,800	8,700	7,700	8,500	9,000	8,400	10,100	8,600	8,800

In all the tests, Wildcat custom blended fuel was used: 10 percent nitro/20 percent lube (castor and synthetic oil) and 10 percent nitro/24 percent lube worked beautifully for all engines.

This ball-bearing Magnum XL .40 A2 has a remotely located needle valve and a true chrome ABC piston and cylinder.

Magnum XL .40 A2

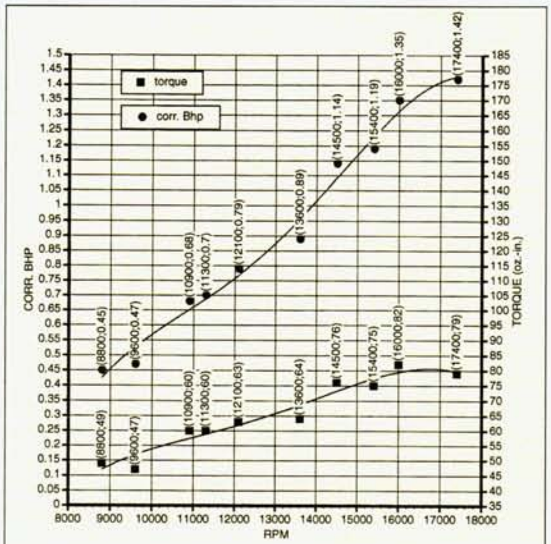
General impressions. ABC cylinder seems remarkably similar to '70s ST units– Schnuerle and boost transfer ports; carburetor action is rough (barrel in carb housing); finish on crankshaft and piston is rough; I found a few aluminum chips inside. (You should inspect any new 2-stroke with its rear plate removed for any residual factory machining chips.)

Features. Expansion chamber type muffler is fitted with an internal baffle, pressure fitting and a gasket; remote needle valve assembly is mounted off rear cover; engine is fitted with a removable back cover that's fitted with a gasket; a twin-needle fuel metering carburetor is sealed to the front of the crankcase with an O-ring; carburetor is held in the crankcase by a cinch bar; narrow squish band aluminum-alloy head is fitted with a soft aluminum gasket; true chrome plating used with the brass cylinder; piston contains high-silicon aluminum alloy; piston wristpin hole is blind-bored and has a Teflon end pad; the wristpin is press-fit into the piston; ST-type bar-stock aluminum connecting rod is bushed at both ends and has drilled oiling holes; crankshaft is held on the inner race of the front bearing by a truncated split-cone locking system (this maintains an interference fit at the rear of the drive washer); crankshaft is made of a single piece of steel and features a massive counterbalance; twin ball bearings (both shielded) support the crankshaft in the crankcase; the piston is interference-fit in the cylinder at top dead center in typical ABC fashion.

Performance. Wildcat 10-percent nitromethane, 20-percent oil fuel; after only 20 minutes of break-in, the engine held a peak rpm needle setting without overheating–a significant advantage (you can get into the air more quickly). After that, engine immediately needled to a rich 2-cycle setting at which it was allowed to operate for approximately 2 minutes before being shut down for cooling. After several runs of this type, I peaked rpm for several seconds by momentarily pinching the fuel line. At the end of the procedure, the engine held a slightly rich peaked setting of 15,400rpm with the APC 9x6 break-in propeller.

At one point during break-in, the two-piece muffler came apart and had to be retightened. Since the mating surfaces didn't have a gasket, the joint leaked. This can be a problem on many 2-strokes; a simple fix is to form a gasket using high-temp silicone sealant.

In the performance graph, note that torque and horsepower peak at a very high rpm (82 oz.-in. at 16,000 and 1.42 bhp at 17,400). Although these absolute values are impressive, they occur beyond the practical operating range for most sport flying.



Magnum XL .40 A2
Temp. - 67 deg. F
Bar. - 29.30 in. Hg
Wet bulb temp. - 61 deg. F
Bhp corr. factor - 1.04

The engine produced 82 oz.-in. of torque at 16,000rpm. The horsepower at this rpm is 1.35. Depending on the type of airframe, the best flight propellers seem to be 10x6, 9x7 and 9x6.

Specifications

	Enya SS .40	Enya SS .40 BB	Magnum XL .40 A2	MDS .38 FS Pro
Cylinder bore and stroke (mm)	20.9x18.9	20.9x18.9	20.66x19.28	21.0x18.1
Displacement	0.396ci	0.396ci	0.40ci	0.38ci
Engine weight w/muffler	14.1 oz.	15.2 oz.	16.4 oz.	15.7 oz.
Muffler	Enya M402X	Enya M402X	Baffled, expansion chamber	Expansion chamber
Carburetor type	Enya Type G	Enya 2-needle	Twin-needle fuel metering	Twin-needle fuel metering
Carb. bore and cross-sectional area	0.238 in./0.044 in.^{2}	0.295 in./0.068 in.^{2}	0.295 in./0.068 in.^{2}	0.315 in./0.078 in.^{2}
Crankshaft nose thread	¼-28	¼-28	¼-28	¼-28
Fuel (break-in/running)	10% nitro, 24% lube	10% nitro, 24%/20% lube	10% nitro, 20% lube	10% nitro, 20% lube
Glow plug	Enya no. 3	Enya no. 3	Not supplied (K&B 1L used)	Supplied (not known)
Idle rpm (best reliable after break-in)		2,500	2,500	2,700
Sound level (decibels)	97 @ 14,100	98 @ 14,400	95 @ 14,500	94.5 @ 14,200
Peak torque	67.4 oz.-in. @ 14,500	80.5 oz.-in. @ 14,400	82 oz.-in. @ 16,000	84 oz.-in. @ 16,200
Peak bhp (corrected)	1.01 bhp @ 15,500+	1.27 bhp @ 16,800	1.42 bhp @ 17,400	1.38+ bhp @ +17,200
Warranty	5-year (full to limited)	5-year (full to limited)	2-year (limited)	3-year (limited)
Price	**$68.08**	**$95.98**	**$70**	**$74.95**

This plain-bearing O.S. Max .40 LA Silver has a remotely located needle valve, an ABN piston and a thin-wall cylinder.

O.S. Max .40 LA Silver

General impressions. As is usual for O.S. products, a high degree of machining excellence (casting, grinding, honing, turning and milling); an extremely thin cylinder wall (0.030 inch); provisions were made in the crankcase for a boost transfer port bypass passage, but none was machined or cast in place; cylinder porting consists of two Schnuerle transfer ports and a single exhaust; engine was very clean inside; no gaskets were included for the two-piece muffler or its interface with the exhaust stack ... and none were needed; the components fit so closely that nothing leaked.

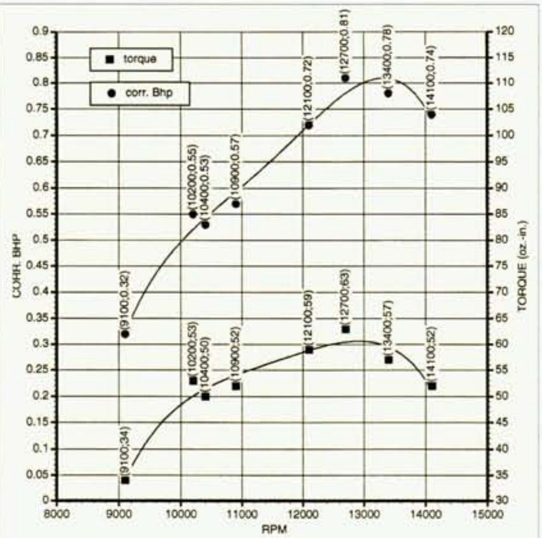
Features. Expansion chamber muffler fitted with an internal cone-type baffle, and pressure fitting; a remote rear cover mounted needle valve assembly; rear cover is molded from reinforced-plastic—one piece, includes gasket; air-bleed type carburetor (40D) with O-ring seal to front of crankcase; carburetor is held on the front of the crankcase by two 180-degree opposed Phillips-head machine screws; the cylinder head, retained by four machine screws, is of the wide-squish-band variety with a soft aluminum gasket; the cylinder is rotated 45 degrees clockwise (viewed from the head side of the engine); the thin-wall brass cylinder is nickel-plated and has Schnuerle porting (no boost); the lapped piston is made of high-silicon aluminum alloy; the wristpin is free-floating and is fitted with two Teflon end pads to prevent cylinder scoring; the connecting rod is machined from bar-stock aluminum alloy and is bronze bushed at both ends before being drilled with lubrication holes; the crankshaft is produced in one piece; the shaft portion of the crankcase is bronze bushed for support; an interference fit between the piston and cylinder at top dead center is evident, indicating the use of a typical tapered cylinder.

Performance. Wildcat 10-percent nitromethane, 20-percent-oil fuel; break-in was achieved with an undersize APC 9x6 reinforced-plastic propeller.

The engine started easily and was immediately needled to a rich 2-cycle setting. After 20 minutes (total), the engine ran roughly and rattled—possibly because of a combustion defect such as detonation— when peaked to maximum rpm. I changed from the K&B 1L glow plug to a hotter McCoy MC-59 hoping to solve the problem. Although the noise subsided, it was still there. I decided on extra break-in to see what would happen; after 15 minutes of running, the condition had disappeared. Who said that break-in was a waste of time?

Although the .40 LA operated smoothly during the torque tests, its overall performance was disappointing. Part of this can be attributed to the carburetor's tiny choke diameter.

The engine produced 63 oz.-in. of torque at 12,700rpm. The horsepower at this rpm is 0.81. Depending on the type of airframe, the best flight propellers seem to be 11x4, 10x6 and 9x7.



O.S. Max .40 LA Silver
Temp. - 58 deg. F
Bar. - 29.61 in. Hg
Wet bulb temp. - 49 deg. F
Bhp corr. factor - 1.02

O.S. Max .40 LA Silver	SuperTigre GS .40	Thunder Tiger GP-42	Thunder Tiger Pro .40	Tower .40 R/C ABC
21.2x18.4	0.846x0.701	Not applicable	20.9x19.0	Not applicable
0.396ci	0.39ci	0.42ci	0.398ci	0.40ci
12.6 oz.	18.26 oz.	12.5 oz.	16.6 oz.	11.5
Baffled, expansion chamber	ST Silent	Thunder Tiger	Baffled, expansion chamber	Tower no. TOWG4720
Air-bleed type	ST Mag	Air-bleed type	2-needle, fuel metering	Tower no. TOWG4100
0.220 in./0.038 in.^{2}	0.350 in./0.096 in.^{2}	0.220 in./0.038 in.^{2}	0.295 in./0.068 in.^{2}	0.240 in./0.045 in.^{2}
¼-28	¼-28	¼-28	¼-28	¼-28
10% nitro, 20% lube	10% nitro, 24%/20% lube	10% nitro, 20% lube	10% nitro, 20% lube	10% nitro, 20% lube
Not supplied (see text)	SuperTigre and K&B 1L	Not supplied (K&B 1-L used)	Not supplied (K&B 1L used)	Not supplied (K&B 1L used)
2,500	2,500	2,600	2,500	2,450 2,600
94 @ 14,100	94 @ 14,000	94 @ 14,000	95.5 @ 14,600	95 @ 14,100
63 oz.-in. @ 12,700	85.1 oz.-in. @ 14,800	70 oz.-in. @ 14,000	85.2 oz.-in. @ 13,600	70.1 oz.-in. @ 14,100
0.78 bhp @ 13,400	1.36 bhp @ 17,100	1.11 bhp @ 16,500	1.29 bhp @ 16,000	1.02 bhp @ 14,600
2-year (limited)	2-year (limited)	3-year (limited)	3-year (limited)	2-year (limited)
$56.99	**$74.99**	**$64.99**	**$84.99**	**$54.95**

This ball-bearing MDS .38 FS has a large expansion-chamber muffler and a true chrome ABC piston and cylinder.

MDS .38 FS Pro

General impressions. Smooth-acting throttle-barrel carburetor; rough cylinder-port machining (chromed-over burrs); bead-blasted exterior, including the muffler.

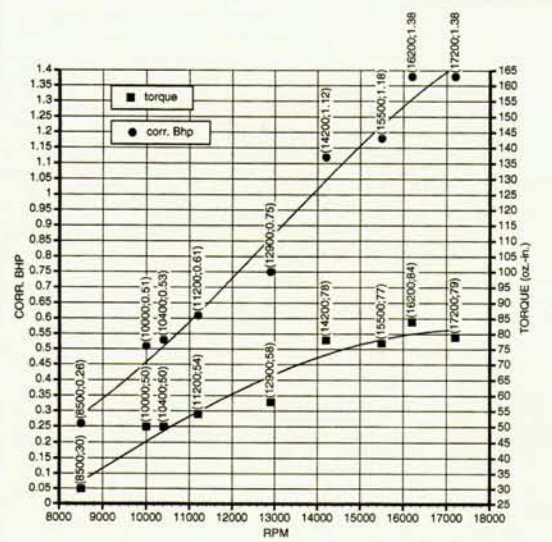
Features. Large, heavy (4.6-ounce) expansion chamber muffler with pressure fitting but no exhaust-stack gasket; twin-needle fuel metering carburetor with O-ring seal and a unique cinch-clamp way of attaching it to the crankcase; squish-band-type head with soft aluminum gasket; truncated split cone attaches the drive washer to the crankshaft; O-ring-sealed rear cover (difficult to remove); ABC cylinder and piston construction with a heavy wall cylinder (0.080 inch); high silicon aluminum alloy lapped piston; full-floating wristpin is held by two music-wire clips in the piston; the SuperTigre-type bar-stock aluminum-alloy connecting rod is bushed only on the crankpin end; one-piece crankshaft; twin ball-bearing-supported crankshaft with dust shield on the front unit; lower crankcase is grooved; the supplied idle-bar glow plug is only intended for break-in. The instructions state, "It's common for these plugs to burn out within several runs of the engine." I'd prefer to have the engine sent out without a plug, as other manufacturers do.

Performance. Wildcat 10-percent nitromethane, 20-percent lube fuel; break-in propeller—APC 9x6. After the first start-up and needling to a rich 2-cycle setting, I noticed that the muffler/exhaust-stack interface leaked. Again, this could be fixed with high-temp silicone sealant. As predicted in the instructions, the idle-bar glow plug burned out after only 7 minutes of running. I replaced it with a McCoy MC-59 non-idle-bar unit. The engine required a 15-minute break-in to a point at which it held a peaked needle setting without overheating. At this point, it turned the 9x6 propeller at 15,500rpm.

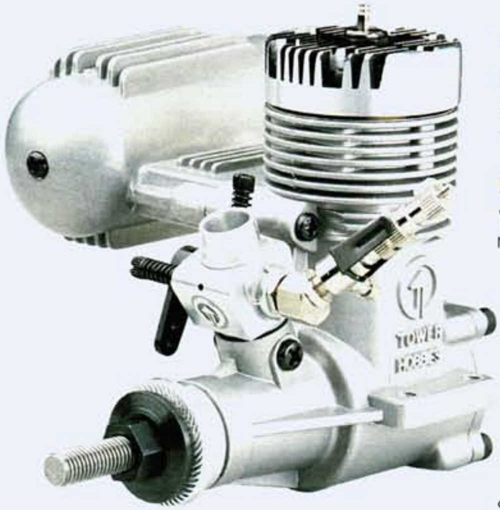
Torque tests revealed that maximum torque and horsepower were achieved at very high rpm—beyond the speed range of the average sport model.

The MDS appears more suited to use as a high-speed racing engine; tiny propellers and low-drag airframes could make full use of its power. For example, if you look at the 10x6 prop (recommended for the .38) in terms of rpm (12,900), torque (67 oz.-in.) and brake horsepower (0.88), the engine operates at below its stated potential.

The engine produced 84 oz.-in. of torque at 16,200rpm. The horsepower at this rpm is 1.38. Depending on the type of airframe, the best flight propellers seem to be 10x5.5, 9x7 and 9x6.



MDS .38 FS Pro
Temp. -62 deg. F
Bar. - 29.58 in. Hg
Wet bulb temp. - 51 deg. F
Bhp corr. factor - 1.02



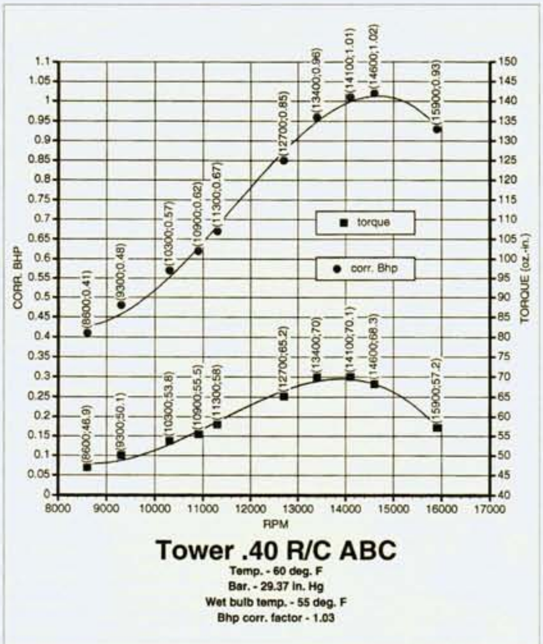
A plain-bearing Tower .40 R/C ABC with swept-back needle valve; it features a true chrome ABC piston and cylinder.

Tower .40 R/C ABC

General impressions. Nice machine work; no chips or dirt inside; clean; extremely crisp cylinder-port machining and chrome plating; piston has minimum wristpin boss material for support.

Features. Expansion- chamber type muffler with pressure fitting and no gasket provided between muffler and exhaust stack; air-bleed type carburetor with swept-back needle-valve assembly and O-ring seal between carburetor neck and front of the crankcase; squish-band combustion chamber cylinder head retained by six Allen capscrews; rear cover is held by four Allen capscrews (gasket included); crankshaft has a hardened and ground steel washer behind the drive washer to absorb crankshaft axial thrust (starter motor application); high-silicon-content cast-aluminum alloy lapped piston with chrome-plated brass cylinder (ABC); cylinder porting consists of two Schnuerle transfers and a single boost; free floating, hardened and ground steel wristpin with Teflon end pads; the connecting rod is of the SuperTigre type with two bronze bushings and drilled lubrication holes; crankshaft is one piece with a ¼-28 nose thread; crankshaft is supported by a bronze bushing within the crankcase casting; the cylinder is music-wire pin aligned with the top of the crankcase; an interference fit of the piston top to the tapered cylinder occurs at top dead center.

Performance. Wildcat 10-percent nitromethane and 20-percent lubricant fuel was used for all break-in and performance testing. An APC 9x6 propeller was used for break-in; a K&B 1L glow plug was used for all tests. This engine produced some of the cleanest ("textbook") torque and bhp curves of the combined testing sessions.



The engine produced 70.1 oz.-in. of torque at 14,800rpm. The horsepower at this rpm is 1.01. Depending on the type of airframe, the best flight propellers seem to be 11x5, 10x6, 9x7 and 9x6.

This ball-bearing SuperTigre GS .40 Ring R/C has a large, positionable expansion-chamber muffler, a hard steel cylinder and a ringed, aluminum-alloy piston.

SuperTigre GS .40 Ring R/C

General impressions. Cylinder is press-fit into the crankcase; to extract it, heat had to be applied to the crankcase. When installed at the factory, the cylinder badly scored its interface with the crankcase, causing a series of rolled-up burrs.

The crankcase has huge transfer and boost port bypass channels. The skirt on the single-ring aluminum alloy piston is heavily cross-hatched for oil retention. The hardened steel cylinder is ground and honed with little or no cross-hatching. Of thenine engines, the SuperTigre (ST) Mag carburetor has the largest choke diameter/cross-section.

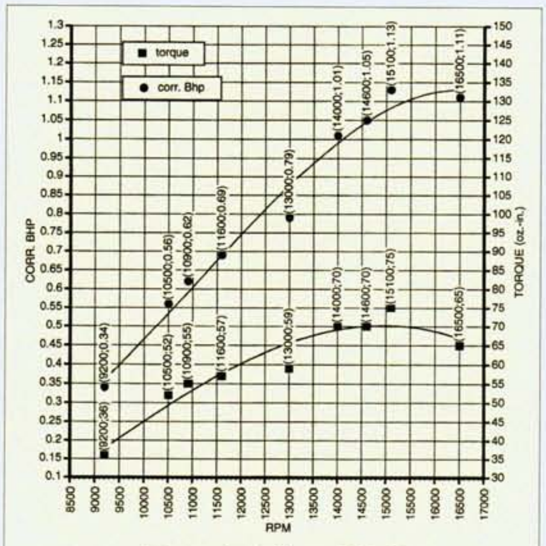
Features. The large, heavy muffler has a positionable fitting off its round header pipe; muffler comes complete with pressure fitting and header to exhaust stack gasket; muffler header pipe fastens to engine crankcase with two bolts and nuts; muffler fastens to the header with an integral clamp-ring; Mag carburetor is a large, 2-ounce, 2-needle fuel-metering unit with a positionable output arm; the cylinder head has large fins and a squish-band combustion chamber; head is outfitted with a bronze glow-plug thread insert and a copper gasket; an O-ring seal is used for the rear cover; the aluminum alloy piston is equipped with a cast-iron (meehanite) compression ring, which is immobilized at its end-gap by a radial music-wire pin pressed into a small hole within the ring groove; the cylinder porting consists of two conventional Schnuerle transfers with a single boost supplemented by two flow-control ports; the hardened and ground steel wristpin is held in the piston by two music-wire clips; the connecting rod is a standard ST bar-stock aluminum alloy unit with bronze bushings at both ends, including the appropriate oil holes; the crankshaft is a one-piece

Thunder Tiger GP-42

The plain-bearing Thunder Tiger GP-42 has aswept-back needle valve (for safety) and an ABN piston and cylinder.

General impressions. Above average castings, machine work and finish on all components. Excellent attention to detail, e.g., bushings, gaskets and deburring of components. Interference fit between piston and cylinder at top dead center, indicating a tapered cylinder with consistent, precise tolerances; ABN (aluminum piston with nickel-plated brass cylinder). Allen-head capscrews used throughout (one was completely loose on the rear cover–check this periodically on all of your engines!); engine was very clean inside.

Features. Bolt-on air-bleed carburetor (similar to that on the Fox); swept-back needle valve; squish-band cylinder head retained by four machine screws; nickel-plated brass cylinder; two Schnuerle ports and a single boost transfer port; 45-degree rotation on the cylinder as viewed from the top; cast aluminum alloy, high-silicon-content lapped piston; one Teflon pad for rear-facing wristpin end. The other end of wristpin sits in a blind-bored seat within the forward facing piston boss; an alignment pin in the top of the crankcase keys with the cylinder to ensure perfect internal positioning of the ports; bar-stock aluminum alloy connecting rod is brass bushed at both ends and drilled for lubrication; one-piece crankshaft is incorporated; a bronze bushing is used for crankshaft support; a baffled expansion-chamber muffler with pressure fitting and exhaust stack gasket is provided. Also, an O-ring sealing gasket was provided between the two halves of the muffler body to prevent exhaust residue from becoming a problem.



Thunder Tiger GP-42
Temp. - 64 deg. F
Bar. - 29.30 in. Hg
Wet bulb temp. - 59 deg. F
Bhp corr. factor - 1.04

Performance. Wildcat 10-percent nitromethane/20-percent lube; break-in prop–APC 9x6; engine was started and needled to a rich 2-cycle. Performance data revealed that the Tiger .42 peaked at 14,000rpm for torque and 16,500rpm for brake horsepower. Although a bit fast for typical sport airplanes, individual propellers compared favorably with other engines in this plain bearing category–especially when the tiny (0.220-inch) carburetor choke diameter is taken into consideration.

The engine produced 70 oz.-in. of peak torque at 14,000rpm. The horsepower at this rpm is 1.01. Depending on the type of airframe, the best flight propellers seem to be 11x4, 10x6 and 9x7.

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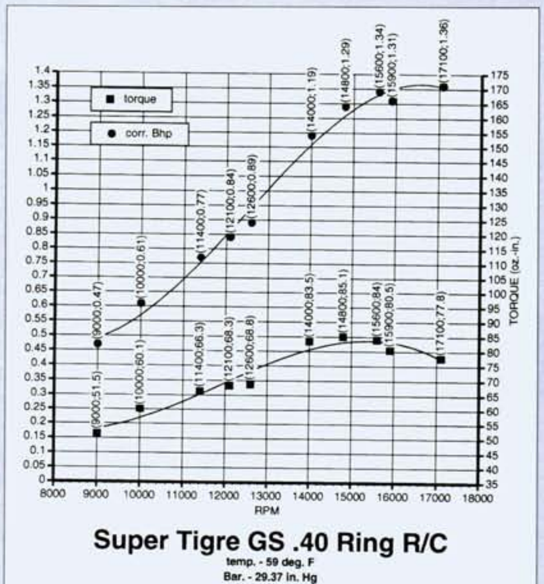
unit; drive washer is retained on the crankshaft by a truncated split cone; twin ball bearings support the crankshaft.

Performance. Break-in was accomplished with Wildcat 10-percent nitromethane fuel and 24-percent lubricant. The standard APC 9x6 propeller was used throughout. Because the Tigre is a ringed engine, break-in procedures are similar to those used with the lapped steel and iron engines: short running periods (3 minutes) at a rich 4-cycle to maintain a cool and oily condition. Because the engine refused to continue running after the glow heat had been removed, I replaced the SuperTigre glow plug with a hotter K&B 1L; this solved the problem. After 45 minutes of running (using the pinch technique to briefly elevate rpm into the 2-cycling mode of operation), the engine began showing signs of improvement. Shortly, it held a peaked needle setting without sagging.

Dynamometer torque tests and propeller rpm determination were performed with Wildcat 10-percent nitromethane and 20-percent lubricant fuel. These tests confirmed that the Tigre .40 was performing admirably.

The engine produced 85.1 oz.-in. of torque at 14,800rpm. The horsepower at this rpm is 1.29. Depending on the type of airframe, the best flight propellers seem to be 11x5, 10x6, 10x7 and 9x7.



Super Tigre GS .40 Ring R/C
temp. - 59 deg. F
Bar. - 29.37 in. Hg
Wet bulb temp. - 54 deg. F
Bhp corr. factor - 1.03

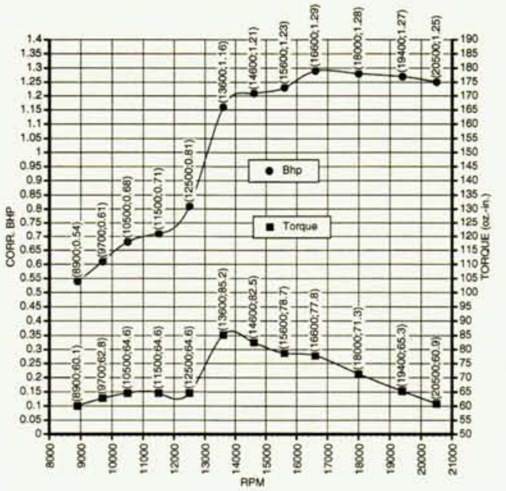
Thunder Tiger Pro .40

■ **General impressions.** Beautiful machine work and castings; high attention to detail (gaskets, finish, etc.); precise (interference) fit between piston and tapered cylinder at top dead center; high squish-band angle on cylinder head; clean, chip-free interior; initial inspection revealed that the rear cover machine screws were loose.

■ **Features.** Baffled, expansion chamber muffler with pressure fitting and gasket; 2-needle-valve fuel metering carburetor retained to crankcase intake manifold by a cinch-bar-type fastener; O-ring seal between carburetor and crankcase; squish band cylinder head with six machine screws; soft aluminum head gasket; gasket between rear cover and crankcase; cylinder is nickel-plated brass with two Schnuerle and one boost transfer port; silicon aluminum-alloy piston completes the ABN set; Super-Tigre-type connecting rod with brass bushings at each end and drilled lubrication holes; one-piece crankcase; twin ball-bearing supported crankshaft; split tapered cone drive washer lock to crankshaft; blind-bored piston for free-floating wristpin, retained by a music- wire clip; Allen-cap machine screw fasteners are used throughout; top of the crankcase is pinned for cylinder location.

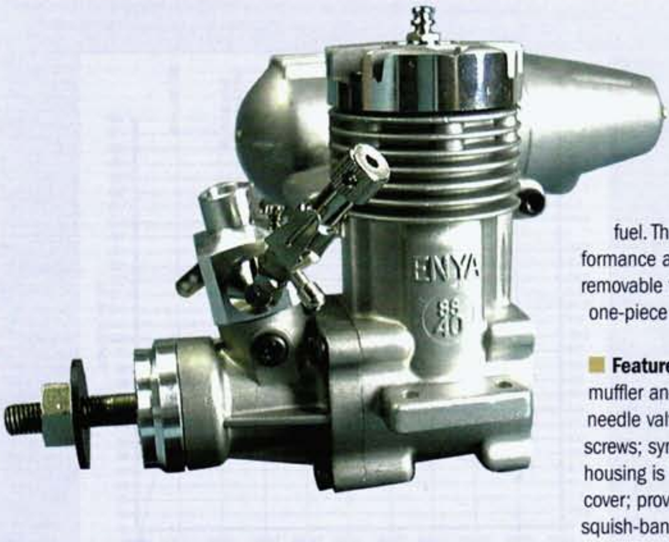
This ball-bearing Thunder Tiger Pro .40 has a non-swept needle valve and an ABN piston and cylinder.

■ **Performance.** The 10-percent nitromethane/20-percent lubrication fuel was used for all break-in and torque testing. Accepted ABC-type break-in procedures were applied for 30 minutes. Dynamometer testing produced an unusual torque and brake horsepower graph; torque jumped beginning at 12,500rpm. This trend can be attributed to the tuning effect of the expansion chamber muffler in conjunction with the design specifications of this engine. This was probably serendipitous but resulted in flight propellers turning higher rpm than otherwise expected. Although I didn't have time to experiment, the best propeller might be the APC 10x7 trimmed in diameter to about 9.75 or 9.5 inches (allowing it to "jump up on the pipe").



Thunder Tiger Pro .40
Temp. - 62 deg. F
Bar. - 29.42 in. Hg
Wet bulb temp. - 55 deg. F
Bhp corr. factor - 1.01

The engine produced 85.2 oz.-in. of torque at 13,600rpm. The horsepower at this rpm is 1.16. Depending on the type of airframe, the best flight propellers seem to be 11x5, 10x7, 10x6 and 11x6.



Enya SS .40 BB

■ **General impressions.** High-quality castings, materials and clean machine work (no chips left inside); attention to detail is evident in gaskets, bushed connecting rod ends and the threaded brass glow plug cylinder-head insert. The steel and iron lapped cylinder and piston set requires a relatively long break-in with a higher percentage of castor oil in the fuel. The ball-bearing-supported crankshaft suggests that after break-in, good performance and longevity can be expected with less lubrication (20 to 22 percent). The removable front crankcase housing requires more machine work than the more usual one-piece crankcase and removable back cover.

■ **Features.** Expansion-chamber-type muffler with pressure fitting and gasket between muffler and exhaust stack; twin-needle-type, fuel-metering carburetor with angled-back needle valve; carburetor is held on the front housing by two Phillips-type machine screws; synthetic rubber gasket between the housing and carburetor body; crankcase housing is removable; crankcase is unusual–one-piece unit without a removable rear cover; provision is made for a pressure fitting at the rear of the crankcase; narrow squish-band head with brass glow-plug threaded insert is an interesting touch; twin ball-bearing-supported crankshaft; one-piece crankshaft with ¼-28 nose thread; internally tapered steel cylinder (hardened, ground and honed); cast-iron piston (no baffle) with two music-wire clips holds the wristpin; bronze-bushed cast-aluminum-alloy connecting

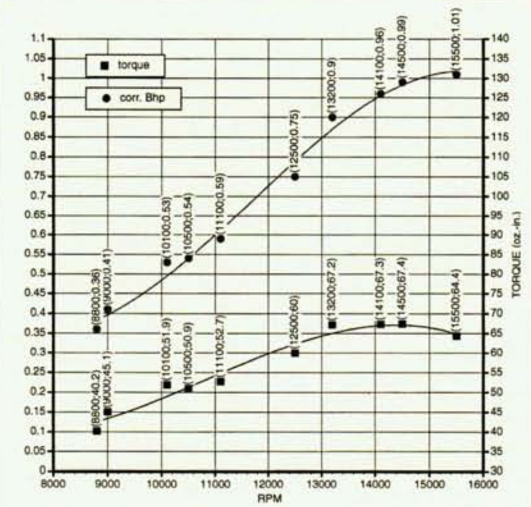
This ball-bearing Enya SS .40 has a swept-back needle valve and a meehanite iron piston and steel cylinder (requires a longer break-in).

Enya SS .40

General impressions. High-quality castings, materials and machine work; attention to detail is evident in items such as gaskets, bushed connecting-rod ends and the threaded-brass cylinder-head insert for the glow plug (these suggest good performance). The steel and iron lapped cylinder and piston set requires a relatively long break-in with a higher percentage of castor oil. The bronze-bushed crankshaft support is as good as a ball bearing unit as long as the engine is always given enough lubrication. The removable front crankcase housing requires more machine work than the more common one-piece crankcase and removable back cover.

A plain-bearing Enya SS .40 with swept-back needle-valve; it has an iron piston and a steel cylinder, so it requires a longer break-in.

Features. Expansion-chamber-type muffler with pressure fitting; gasket between muffler and exhaust stack; fuel-metering single-needle carburetor with air-bleed mixture adjustment; swept-back needle-valve assembly for safety; carburetor is sealed to the front housing with an O-ring-; carburetor is held on the front housing by two 180-degree opposed machine screws; removable front-end housing (no back cover); all fasteners are Allen-cap type; one-piece crankshaft (no pressed-in crankpin); gasket interface between front crankcase housing and crankcase; bronze-bushed crankshaft support; bushed connecting-rod ends; threaded-brass cylinder-head insert for glow plug; hardened, ground and honed (tapered) steel cylinder; two Schnuerle transfer ports with boost port opposite exhaust; wristpin is held on the piston by two music-wire clips; piston is the lapped cast-iron variety; provision at the rear of crankcase for pressure fitting; interference-fit between piston and cylinder at top-dead-center (unusual for a steel and iron piston and cylinder set).



Enya SS .40 (plain bearing)
Temp. - 57 deg. F
Bar. - 29.46 in. Hg
Wet bulb temp. - 52 deg. F
Bhp corr. factor - 1.02

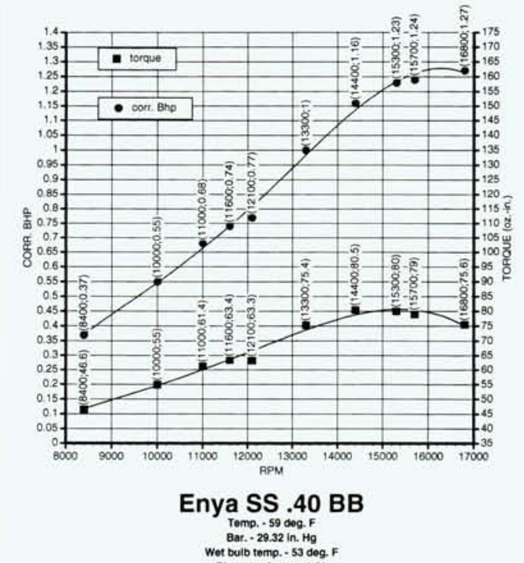
Performance. Easy first start and run at a rich 4-cycle with APC 9x6 break-in prop; 10-percent nitromethane/24-percent lube. After 12, 3-minute rich runs (with cool-down between runs), the engine held a steady peaked needle setting at 14,100rpm. Enya suggests that up to three hours of careful operation may be required for complete break-in. Torque tests ran with 24-percent-lubrication fuel.

The engine produced 67.4 oz.-in. of torque at 14,500rpm. The horsepower at this rpm is 0.99. Depending on the type of airframe, the best flight propellers seem to be 11x4, 9x7 and 9x6.

rod (both ends) with oil holes; two Schnuerle cylinder transfers with single boost port; interference-fit between piston and cylinder at top dead center–unusual for an iron and steel setup.

Performance. Easy start and first run at very rich 4-cycle with 24-percent lube; very steady operation during early break-in; no loss of rpm when glow heat was removed, (indicates a good piston-to-cylinder seal and the correct glow-plug-heat range). After 15 minutes of very rich 3-minute runs to allow a complete cooling and heating cycle, I leaned the engine to a fast 4-cycle. During the next 15 minutes, I pinched the fuel line occasionally to elevate rpm toward the 2-cycling peak. After 30 minutes, the engine wouldn't hold a peaked setting without overheating; I had to run it rich for 15 more minutes before it would maintain a slightly rich peaked setting (15,300rpm with APC 9x6 propeller). Enya suggests that a complete break-in may take as long as three hours. Torque tests were conducted with 20 percent lubricant in the fuel mixture.

The engine produced 80.5 oz.-in. of torque at 14,400rpm. The horsepower at this rpm is 1.16. Depending on the type of airframe, the best flight propellers seem to be 11x5, 10x6 and 9x7.



Enya SS .40 BB
Temp. - 59 deg. F
Bar. - 29.32 in. Hg
Wet bulb temp. - 53 deg. F
Bhp corr. factor - 1.01

.60 engines which is right for you?

BY DAVE GIERKE

This analysis of 10 popular, low- to intermediate-price .60 engines is based on cost, performance, durability and warranty. All are 2-stroke-cycle, have single cylinders; they use front rotary-valve induction systems with rotary-barrel carburetors; they have side exhausts and are fitted with non-tuned expansion-chamber mufflers. Two of the group were first designed, produced and sold decades ago.

Certain design features, fabrication techniques and materials are similar for each engine; rather than repeat these in each review, I discuss deviations.

Engine characteristics

ABC- or ABN-type piston and cylinder sleeve. All engines are either ABC (aluminum piston, brass cylinder sleeve and chrome-plated) or ABN (aluminum piston, brass cylinder sleeve and nickel-plated).

Ringless (lapped) pistons are made of silicon-aluminum alloy. ABC assemblies offer two primary advantages over ringed aluminum pistons that have steel or iron cylinder sleeves: a relatively short break-in period and a reduced incidence of piston damage during prolonged lean, high-temperature running.

Cylinder-sleeve ports. All 10 engines use Schnuerle ports with boost transfer ports, including a single or double (bridged) exhaust port.

Wristpin supported by a film of oil within the piston bosses (free floating). Made of alloy steel, they're bored for lightness, hardened for durability and precision-ground to final size; with the exception of two engines, they are retained within the piston by music-wire clips that snap into shallow grooves.

Connecting rod. Made of bronze-bushed aluminum alloy with a single lubricating hole at the wristpin end and two holes at the crankpin end.

Crankshaft. With the exception of one engine, the steel-alloy cranks are machined, one-piece, surface-hardened and ground to final size; with the exception of two engines, they have $\frac{5}{16}$x24 nose threads.

Muffler. Some use a baffle and provide sealing gaskets, and others don't; all have positionable exhaust outlets and a brass fitting (nipple) for tank pressurization.

Cylinder head. Units are fastened to the crankcase with four, six, or eight machine screws; heads use the squish band/hemispherical combustion chamber design.

Crankshaft. Supported by bushings (plain bearings) or dual ball bearings.

Thunder Tiger Pro .61 BB ABC

Tower .61 BB ABC

O.S. .65 LA

O.S. Max FX-61

Thunder Tiger GP-61 ABC

Fox Eagle .61 ABC

Magnum XL61A BB FSR

MDS .58 FS Pro

Irvine .61 MK II ABC

Megatech M-61

THE ENGINES AT A GLANCE

Fox Eagle .61 ABC

Although this engine has most of the desirable components, including a truechrome/brass cylinder sleeve, twin ball bearings, etc., it's a very unconventional design.

Performance comparison. This came first in the torque, specific torque and torque-to-weight ratio tests and second in bhp, specific horsepower and horsepower-to-weight ratio. This performance was produced with the least powerful fuel (5 percent nitromethane) and the fourth smallest carburetor-choke bore; the engine/muffler combination is the third lightest. The Eagle is the easiest to start when hot and the smoothest running overall. It's also the loudest engine/muffler combo tested.
Idle: excellent at 2,400rpm; midrange: crisp acceleration to wide-open throttle; best props: APC 12.5x9, APC 13x7, APC 11x10, APC 12x8. Price $110

Irvine .61 MK II ABC

The crankcase's glossy, maroon, baked-on finish is beautiful! The true chrome/brass cylinder sleeve is part of the engine's ABC subassembly; twin ball bearings support the crankshaft; the slick, 2-needle, fuel-metering carburetor is made of bar-stock aluminum; its rotary barrel and needles are made of hardened, precision-ground steel; its other components are brass.

Performance comparison. The second largest carburetor-choke bore helped the Irvine .61 to crank out the third highest bhp and specific horsepower. But it's the second heaviest engine/muffler combination tested, so its torque-to-weight and horsepower-to-weight ranks are mediocre (ninth and sixth, respectively). It was the second loudest engine/muffler combination tested.
Idle: good at 2,500rpm; midrange: rich, hesitant acceleration to wide-open throttle; best props: APC 13x7, APC 12x8, APC 11x11. Price $206.99

Magnum XL61A BB FSR

This has several desirable features, including a ball-bearing-supported crankshaft, a fuel-metering carburetor and chrome plating for the brass cylinder sleeve (ABC); some machine-tool operations are rough, as is the engine's general appearance.

Performance comparison. With the largest carburetor-choke bore, the Magnum XL61A ranks in the bottom half of those tested for torque, specific torque, bhp and specific horsepower; its engine/muffler combination is, however, the second lightest, so it's fourth in the torque-to-weight category.
Idle: very good at 2,450rpm; midrange: excellent throttle-up; best props: APC 13x7, APC 11x11, APC 12x7. Price $109.99

MDS .58 FS Pro

A relatively small, light engine, the MDS .58 is the only one tested with a displacement of less than .60ci; it's also the only one equipped with a smallish—¼x28-inch—crankshaft nose thread; twin ball bearings support the crankshaft, and it comes with a good-quality fuel-metering carb.

Performance comparison. From the aspect of torque and power production, the MDS is handicapped by a relatively small displacement (.58ci), and it has the third smallest carburetor-choke bore, so it finished last in these four categories. Because it is the lightest engine/muffler combination tested, it ranks better in torque to weight and horsepower to weight, finishing second and third, respectively, in these areas.
Idle: excellent at 2,400rpm; midrange: crisp, smooth transition to wide-open throttle; best props: APC 13x7, APC 12x8, APC 11x10. Price $89.95

Megatech M-61

The brass cylinder-sleeve is a casting that includes all of the ports; chrome plating has been applied in a conventional manner; the engine has twin ball bearings and a fuel-metering carburetor that is similar to the O.S. type 7H but doesn't have the mid-range adjustment.

Performance comparison. With the third-largest carburetor-choke bore, the Megatech M-61 ranks fourth in bhp and specific horsepower; sixth in torque; fifth in specific torque. It is the heaviest engine tested and finished last in torque to weight and horsepower to weight.
Idle: excellent at 2,400rpm; midrange: slightly rich; hesitant acceleration to wide-open throttle; best props: APC 13x7, APC 11x10, APC 12x8. Price $99.99

O.S. Max FX-61

A beautifully built ABN engine with a ball-bearing-supported crankshaft and remotely mounted primary needle valve.

Performance comparison. With the fifth smallest carburetor-choke bore, the O.S. Max FX-61 was eighth in torque and tied for seventh in horsepower. The fifth lightest engine, it ranks seventh in torque to weight,and seventh in horsepower to weight. It's the second quietest engine/muffler combination tested.
Idle: excellent at 2,400rpm with its twin-needle, fuel-metering carburetor; mid-range: slightly hesitant (rich) throttle-up; best props: APC 11x10, APC 11x11, APC 12x7. Price $149.99

O.S. .65 LA

Highlighted by flawless castings and precision machine-tool operations, this ABN engine has a cylinder sleeve made of thin-wall (0.057-inch) seamless brass tube; it has a bronze bearing for crankshaft support; an air-bleed carb is standard equipment.

Performance comparison. With the smallest carburetor-choke bore of the group tested, the O.S. .65 LA also has the largest cylinder displacement (.65); it ranks sixth in bhp and ninth in specific horsepower. Torque and specific torque were similarly low—possibly an indication of a breathing problem. Because it's the sixth lightest engine tested, the O.S. performs reasonably well in torque to weight and horsepower to weight. It's the quietest engine/muffler combo tested.
Idle: excellent at 2,400rpm; midrange: excellent, crisp throttle-up; best props: APC 13x7, APC 12x8, APC 11x11. Price $104.99

Thunder Tiger GP-61 ABC

Great castings and machine-tool operations; an ABN piston and cylinder-sleeve set; a traditional bronze bushing for crankshaft support; an elementary air-bleed-type carburetor with an angled-back needle-valve assembly (a welcome safety feature).

Performance comparison. This engine tied with the O.S. .65 LA for having the smallest carb-choke bore among the engines tested. This probably explains why its bhp and specific horsepower rank in the lower half. With its ability to breathe somewhat restricted, the GP-61 still ranks a credible fourth in torque and specific torque. As the fourth heaviest engine/muffler combo, it ranks sixth in torque to weight and eighth in horsepower to weight.
Idle: very good at 2,450rpm; midrange: excellent throttle-up; best props: APC 12.5x9, APC 13x7, APC 12x8. Price $84.99

Thunder Tiger Pro .61 BB ABC

Thunder Tiger mass-produces high-quality engines that have fine castings and accurate machine work, and the Pro .61 displays these throughout, including in its ABN piston and cylinder-sleeve assembly. The crankshaft is supported by two ball bearings; the carburetor is a 2-needle fuel-metering type with a sweptback primary needle valve and a healthy choke diameter of 0.357 inch.

Performance comparison. This engine tied for the fourth largest carburetor-choke bore. It is third best in torque and specific torque; this confirms its ability to breathe efficiently and to turn high-load props at relatively high speeds. Its bhp and specific horsepower rank in the middle of the pack. The engine/muffler combination is the third heaviest and puts it at the bottom of the pack for torque to weight and horsepower to weight.
Idle: fair at 2,550rpm; midrange: sputtering (rich) acceleration to wide-open throttle; best props: APC 12.5x9, APC 13x7, APC 12x8. Price $99.99

Tower .61 BB ABC

Twin-ball-bearing-supported crankshaft and fuel-metering carburetor; true ABN piston and cylinder sleeve; a remotely located primary needle valve enhances safety.

Performance comparison. First in bhp and specific horsepower, this has a carburetor-choke bore that tied for fourth largest. As the fourth lightest engine, it ranks first in the horsepower-to-weight category and has a second-best ranking in torque and specific torque. The Tower .61 can turn large propellers faster than all except one other engine tested. It ranks third in torque to weight.
Idle: good at 2,500rpm; midrange: very good throttle-up (slight hesitation); best props: APC 12.5x9, APC 13x7, APC 11x10, APC 12x8. Price $89.99

WHAT TO COMPARE

Don't pay much attention to the peak brake horsepower (bhp) produced by these engines; you'll notice that the highest horsepower levels are achieved with small (low-load) propellers (APC 11x6, etc.), none of which are used with typical .60 sport models. High-horsepower, small-prop applications are the domain of racers with more sophisticated (and expensive) engines that are used in low-drag, high-speed airframes.

Torque is a more useful performance parameter for sport engines. Torque determines the size of the propeller your engine is able to turn within its usable rpm range. If you're interested in the true horsepower story, take the rpm value for each given prop on the "Comparison of rpm with various APC propellers" table, and look up that value on the engine's power graph; do you see how much less power is generated at that rpm than is produced at the peak horsepower point? Now check the torque value for the same prop and rpm; you'll notice that for sport-plane props, the rpm they turn is closer to peak torque than to peak bhp—a good thing. Example: engine: O.S. .61 FX; propeller: APC 13x7; prop rpm: 9,900; torque: 99.8 oz.-in. at 9,900rpm; horsepower: 1.02bhp at 9,900rpm.

Dynamometer "load beams" are pitchless propellers that allow uniform increases in rpm from one size to the next; the author's beams are in ¼-inch increments from 2 to 10 inches.

For any sport engine, it's practical to look at peak torque per dollar invested (street price). For example, if the engine produces 100 oz.-in. of torque and costs $100, it generates 1 oz.-in. for each dollar spent.

None of the engines featured in this article have exactly the same displacement (they range from .58 to .65ci), so it's useful to know their "specific torque" (oz.-in./ci) to "neutralize" this discrepancy. Example: if a .58ci engine produces 100 oz.-in. of torque, its specific torque is 172 oz.-in./ci (100/.58). If a .65 engine also produces 100 oz.-in. of torque, its specific torque is 154 oz.-in./ci (154/.65).

Since the weights of the engine/muffler combinations also vary, it's useful to compare them in terms of torque to weight (oz.-in./lb.). Example: if an engine produces 100 oz.-in. of torque and weighs 1.34 pounds, its torque-to-weight ratio is 74.6 oz.-in/lb. (100/1.34). If a 1.74-pound engine also produces 100 oz.-in. of torque, its torque-to-weight ratio is 57.5 oz.-in./lb. (100/1.74).

If you're interested in neutralizing the cubic-inch-displacement discrepancy for the bhp of the shootout engines, you can use specific horsepower (bhp/ci); horsepower to weight (bhp/lb.) is also useful.

Finally, compare the noise (decibel levels) of the engines. This will tell you how well your new mill will be accepted at the flying field. Remember that every 3-decibel (dB) increase or decrease represents a doubling or halving of the perceived noise. All of this information is listed in the "Performance comparisons at a glance" table. Have fun comparing!

Comparison of rpm with various APC propellers

APC PROP	RPM O.S. FX-61	O.S. .65 LA	MAGNUM XL61A	THUNDER TIGER GP-61	TOWER .61	THUNDER TIGER PRO .61	IRVINE .61	FOX EAGLE .61	MEGATECH M-61	MDS .58
11x6	13,150	13,350	13,250	13,150	14,450	13,450	13,600	13,850	13,500	12,950
11x7	13,000	13,250	13,000	13,050	14,150	13,300	13,400	13,550	13,300	12,650
11x8	12,250	12,350	12,350	12,350	12,850	12,450	12,600	12,900	12,600	11,800
12x6	11,750	11,750	11,750	11,925	12,150	12,050	12,000	12,300	12,100	11,200
12x7	10,950	11,000	10,950	11,150	11,250	11,200	11,200	11,550	11,200	10,450
11x11	10,450	10,550	10,500	10,650	10,950	10,750	10,800	11,150	10,650	10,100
12x8	10,300	10,150	10,150	10,350	10,800	10,450	10,500	10,950	10,500	9,700
11x10	10,000	10,350	9,750	10,250	10,650	10,650	10,100	10,850	10,200	9,250
13x7	9,900	9,950	9,750	10,150	10,450	10,250	10,100	10,650	10,100	9,250
12.5x9	9,250	9,450	8,950	9,450	9,750	9,500	9,100	9,850	9,400	8,550

Performance comparisons at a glance

ENGINE	TORQUE PER $	PRICE	TORQUE	SPECIFIC TORQUE	TORQUE /LB.	BHP	SPECIFIC BHP	BHP/LB.	SOUND LEVEL (DB)
Thunder Tiger GP-61	1.26	$85	106.7	175	69.7	1.24	2.03	0.81	95.0
Tower .61	1.25	$90	112.7	185	76.7	1.59	2.61	1.08	98.5
Thunder Tiger Pro .61	1.07	$100	107.2	176	64.2	1.33	2.18	0.80	98.0
Fox Eagle .61	1.05	$110	115.6	190	82.0	1.41	2.31	1.0	103.0
Megatech M-61	1.05	$100	105.1	172	60.4	1.34	2.20	0.77	99.0
MDS .58	1.03	$90	92.6	160	77.2	1.16	2.00	0.97	96.0
O.S. .65 LA	1.00	$105	105.6	162	70.4	1.31	2.02	0.87	92.0
Magnum XL61A	0.90	$110	98.9	162	73.8	1.24	2.03	0.93	98.0
O.S. FX-61	0.68	$150	101.3	166	66.6	1.24	2.13	0.82	94.0
Irvine .61	0.50	$207	104.5	171	62.2	1.39	2.28	0.83	102.0

Fox Eagle .61 ABC

General impressions. The Fox Eagle design has been around since 1979, and it looked ancient back then! Disassembling the current Eagle reminded me of tearing down a postwar Hornet .60 racing engine: its two-piece crankcase (split horizontally below the exhaust) brought back a flood of memories.

Performance. As recommended by Fox, for break-in, propeller-rpm determination and dynamometer testing, I used Sig 5-percent-nitromethane fuel with 22-percent lubricant. An APC 11x6 2-blade propeller was used for low-load break-in. The Fox idle-bar long-reach glow plug allowed the engine to slow almost 600rpm from peak when glow-heat was removed; a hotter Thunderbolt RC long-reach plug solved the problem and was used for all subsequent runs. For break-in, the Eagle was run uneventfully for 20 minutes; afterward, it peaked at a strong 13,850rpm.

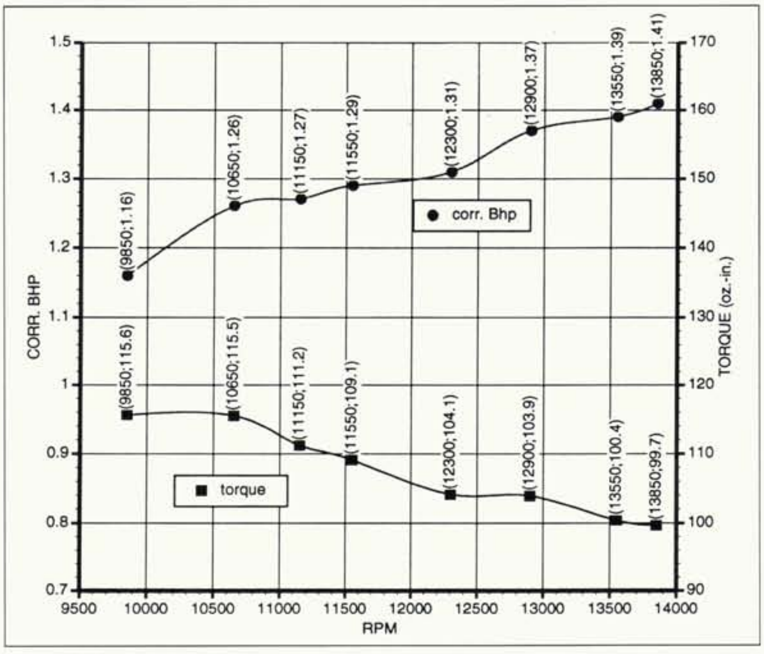
TESTING CONDITIONS

Temperature—65 deg. F
Barometric pressure—29.60 in. Hg
Wet-bulb temperature—60 deg. F
Correction factor—1.03

Dynamometer-generated torque and horsepower curves indicate:

- **torque peak**—115.6 oz.-in. @ 9,850rpm (rank: 1st)
- **corrected bhp peak**—1.41 @ 13,850rpm (rank: 2nd)
- **specific torque (oz.-in./ci)** —190 (rank: 1st)
- **specific horsepower (bhp/ci)**—2.31 (rank: 2nd)
- **torque-to-weight ratio (oz.-in./lb.)**—82 (rank: 1st)
- **horsepower to weight (bhp/lb.)**—1 (rank: 2nd)

Sig Champion Fuel was used for break-in and for many flight, propeller-rpm and dynamometer tests.



Specifications

	O.S. Max FX-61	O.S . 65 LA	Magnum XL61A	Thunder Tiger GP-61	Tower .61	Thunder Tiger Pro .61
Bore-stroke (mm)	24x22	24x24	24x22	24.2x23	24x22	23.5x23
Displacement	0.607ci	0.662ci	0.607ci	0.646ci	0.607ci	0.609ci
Engine & muffler weight	24.3 oz.	24 oz.	21.5 oz.	21.46 oz.	23.45 oz.	26.75 oz.
Muffler type	E-4010 Expansion	E-4010 Expansion	Expansion	9225 Expansion	TOWG 4727 Expansion	9295 Expansion
Carburetor type	O.S. 60C Fuel metering	O.S. 60J Air-bleed	Fuel metering	9241N Air-bleed	TOWG 4106 Fuel metering	9240N Fuel metering
Carb. bore (mm/in.)	8.5/0.334	8/0.315	9.76/0.385	8/0.315	9.07/0.357	9.07/0.357
Crank nose thread	UNF 5⁄16-24	UNF 5⁄16-24	8mm	UNF 5⁄16-24	UNF 5⁄16-24	UNF 5⁄16-24
Fuel: all running (% nitro/oil)	10/20%	10/22%	10/20%	10/22%	10/20%	10/20%
Glow plug (all long)	O.S. no. 8	O.S. no. 8	Thunderbolt R/C	NS; O.S. no. 8	NS; O.S. no. 8	NS; O.S. no. 8
Warranty (limited)	2-year	2-year	2-year	3-year	2-year	3-year

NS = glow plug was not supplied by the manufacturer

Irvine .61 MK II ABC

General impressions. You would have to be blind not to notice the Irvine .61 crankcase's glossy, baked-on maroon finish—beautiful! Although I'm not familiar with the factory process used to apply this great-looking, fuelproof paint, it appears to be a powder-coating technique because the interior bypass channels are also colored; all the machining was done after the coating had been applied.

Performance. Break-in, propeller rpm determination and dynamometer tests were all run using Sig 10-percent-nitromethane fuel containing 20 percent lubricant (the standard blend for ABC-type engines equipped with ball-bearing crankshaft support). An APC, 11x6, 2-blade propeller and a Thunderbolt R/C long-reach glow plug were used.

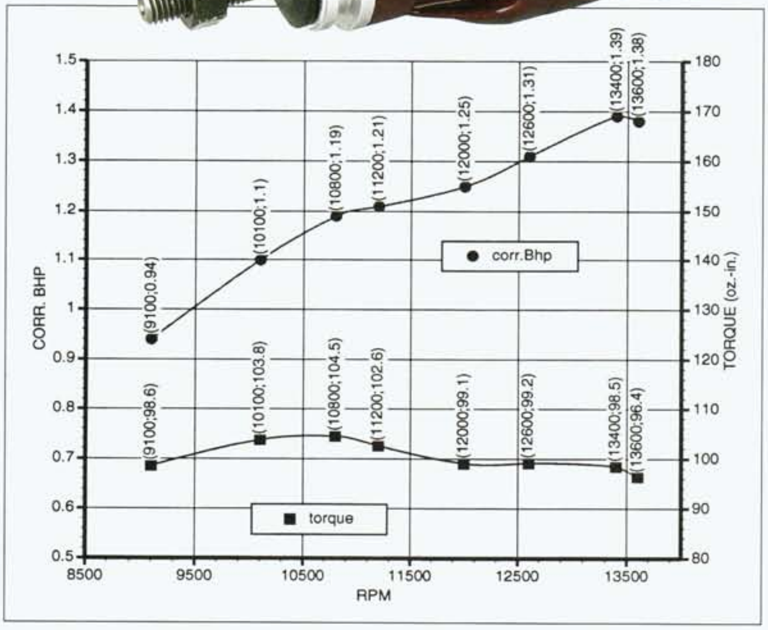
For break-in, the Irvine .61 MK II was run for 20 minutes. It started, needled and maintained a steady operation throughout; at the end of this period, it peaked at 13,600rpm.

TESTING CONDITIONS?

Temp. 79 deg. F
Bar. pres. 29.30 in. Hg
Wet-bulb temp. 67 deg. F
Corr. fact. 1.06

Dynamometer-generated torque and horsepower curves indicate:

- **torque peak**—104.5 oz.-in. @ 10,800rpm (rank: 7th)
- **bhp peak**—1.39 @ 13,400rpm (rank: 3rd)
- **specific torque (oz.-in./ci)**—171 (rank: 6th)
- **specific horsepower (bhp/ci)**—2.28 (rank: 3rd)
- **torque-to-weight ratio (oz.-in./lb.)** —62.2 (rank: 9th)
- **horsepower to weight (bhp/lb.)** —0.83 (rank: 6th)



Irvine .61 MK II ABC	Fox Eagle .61 ABC	Megatech M-61	MDS .58 FS Pro
24x22	23x23.8	23x23.8	23.7x21.6
0.607ci	0.604ci	0.604ci	0.58ci
26.81 oz.	22.5 oz.	27.78 oz.	19.21 oz.
S-61-2340 Expansion	90262 Expansion	Expansion	04600300 Expansion
CJ-1900 Fuel metering	27050B E-Z Air-bleed	Fuel metering	C-2 Fuel metering
9.42/0.371	8.43/0.332	9.4/0.370	8.2/0.322
UNF 5⁄16-24	UNF 5⁄16-24	UNF 5⁄16-24	UNF 5⁄16-28
10/ 20%	5/22%	10/ 20%	10/20%
Thunderbolt R/C	NS; Fox idle bar O.S. no. 8	NS; O.S. no. 8	MDS
2-year	2-year	2-year	3-year

Engine performance was determined by measuring torque and rpm at various load points while operating the engine at wide-open throttle. The author's dynamometer measures torque while a precision tachometer measures rpm; by running the engine many times with a progressively smaller load, he acquired data that allows him to plot a graph of the engine's torque and rpm. Brake horsepower was calculated from the torque/rpm data, and it's also graphed with respect to rpm.

Magnum XL61A BB FSR

General impressions. This engine has several desirable features, including: a ball-bearing-supported crankshaft, a fuel-metering carburetor and state-of-the-art piston/cylinder-sleeve materials. Some machine-tool operations are rough, as is the engine's general appearance.

Performance. Engine break-in, propeller rpm determination and dynamometer testing were all run using Sig 10-percent-nitromethane fuel containing 20 percent lubricant (my standard blend for ABC-type engines equipped with ball bearings for crankshaft support). I used an APC, 11x6, 2-blade propeller and a Thunderbolt R/C long-reach glow plug.

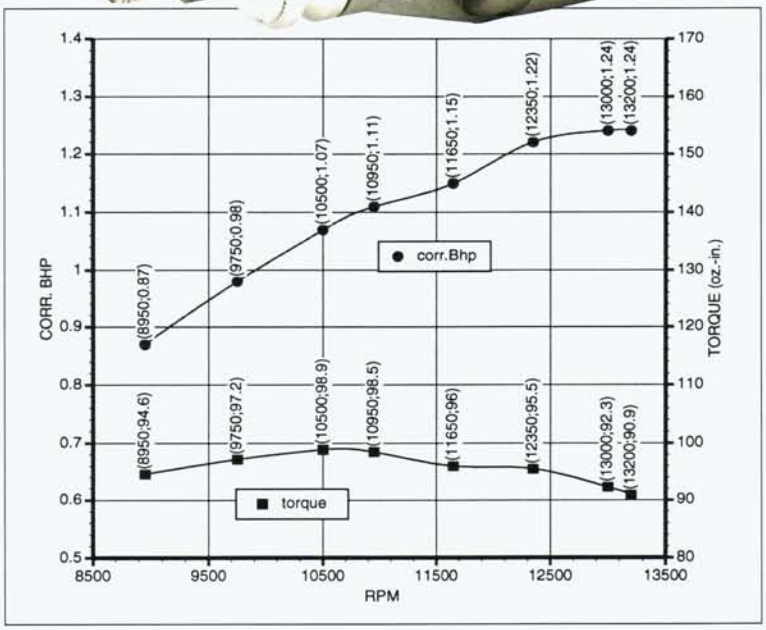
For break-in, I ran the Magnum XL61A for a total of 20 minutes; afterward, the engine peaked at a smooth and steady 13,250rpm.

TESTING CONDITIONS?

Temp. 79 deg. F
Bar. pres. 29.30 in. Hg
Wet-bulb temp. 67 deg. F
Corr. fact. 1.06

Dynamometer-generated torque and horsepower curves indicate:

- **torque peak**—104.5 oz.-in. @ 10,800rpm (rank: 7th)
- **bhp peak**—1.39 @ 13,400rpm (rank: 3rd)
- **specific torque (oz.-in./ci)**—171 (rank: 6th)
- **specific horsepower (bhp/ci)**—2.28 (rank: 3rd)
- **torque-to-weight ratio (oz.-in./lb.)**—62.2 (rank: 9th);
- **horsepower to weight (bhp/lb.)** —0.83 (rank: 6th).



MDS .58 FS Pro

General impressions. A relatively small, light engine with delicate features; it's the only one of the 10 engines tested to be equipped with a ¼x28 crankshaft nose thread and a thin-wall (0.066-inch) cylinder sleeve.

Performance. For break-in, propeller rpm determination and dynamometer testing, I used Sig 10-percent-nitromethane fuel containing 20 percent lubricant (the standard blend for ABC-type engines equipped with a ball-bearing crankshaft support). I also used an APC, 11x6, 2-blade propeller and an MDS long-reach glow plug.

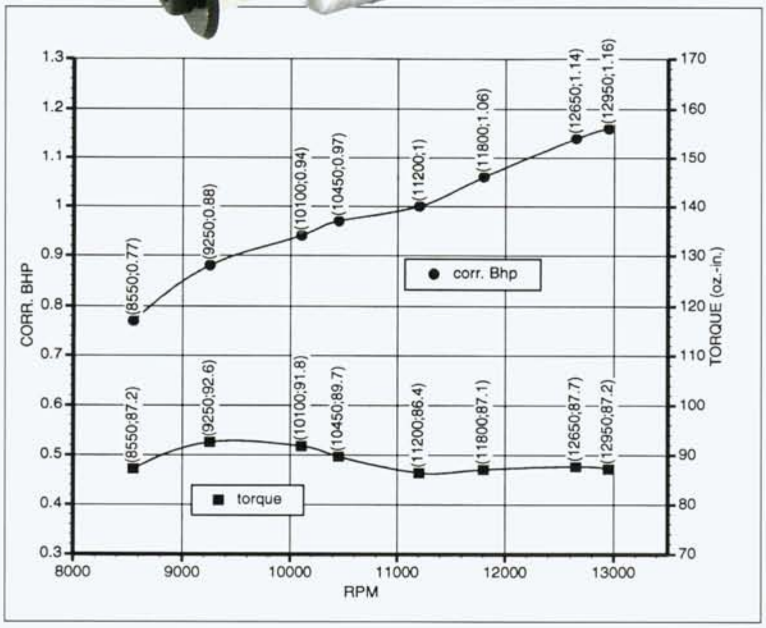
For break-in, I ran the MDS .58 for 30 minutes; break-in was uneventful, as the engine started, needled and maintained a steady operation throughout. At the end of this period, the engine peaked at 12,950rpm.

TESTING CONDITIONS

Temp. 65 deg. F
Bar. pres. 29.41 in. Hg
Wet-bulb temp. 59 deg. F
Corr. fact. -1.04

Dynamometer-generated torque and horsepower curves indicate:

- torque peak—92.6 oz.-in. @ 9,250rpm (rank: 10th)
- bhp peak—1.16 @ 12,950rpm (rank: 10th)
- specific torque (oz.-in./ci)—160 (rank:10th)
- specific horsepower (bhp/ci)—2 (rank: 10th)
- torque to weight ratio (oz.-in./lb.) —77.2 (rank: 2nd)
- power to weight (bhp/lb.)—0.97 (rank: 3rd)



Tower .61 BB ABC

General impressions. If the Tower .61 BB ABC looks familiar to old-timers, it should; it's the latest variation on the Italian SuperTigre S.61 that began in 1982 as a lapped ABC engine. This latest Tower Tiger is made in China with much of the original ST tooling.

My initial inspection revealed a roughness when I turned the engine over. After removing the backplate, I discovered grinding compound in the crankcase and the rear crankshaft ball bearing, so I had to take the engine apart and clean it.

Performance. Using Sig 10-percent-nitromethane fuel containing 20 percent lubricant (my standard blend for ABC-type engines equipped with ball-bearing crankshaft support), I broke the engine in for 28 minutes while also determining propeller rpm and doing the dynamometer tests. My prop was an APC, 11x6, 2-blade, and I used an O.S. no. 8 long-reach glow plug.

Initially, the engine was very difficult to turn over because of a tight piston/cylinder-sleeve pinch fit; considered normal, this condition can be overcome by briefly heating the cylinder/cylinder-head area with a heat gun or a hair dryer to expand the sleeve away from the piston and allow the mill to be started normally. After break-in, the engine peaked at a strong 14,250rpm.

The torque peak for the Tower .61 is interesting: there are actually two—one between 9,750 and 12,150rpm and another between 12,150 and 14,450rpm. This anomaly produces the stepped bhp curve shown on the graph. Testing error was ruled out when similar data were collected during a dyno rerun. Engines occasionally display strange performance characteristics that seem to defy logic; in this case, I suspect a serendipitous supercharging effect from the muffler/manifold and cooperative cylinder-port timing.

Megatech M-61

General impressions. The chrome-plated brass cylinder-sleeve is cast with the ports in place (a new technology emerging?); the carburetor is very similar to the O.S. type 7H (a fuel-metering type) but doesn't have the midrange adjustment. My initial inspection revealed loose cylinder-head and backplate screws. Including the muffler (7.5 ounces), the M-61 is the heaviest engine evaluated.

Performance. I used Sig 10-percent-nitromethane fuel containing 20 percent lubricant (the standard blend for ABC-type engines with ball-bearing crankshaft support) for break-in, propeller rpm determination and dynamometer testing. I also used an APC, 11x6, 2-blade propeller and an O.S. no. 8 long-reach glow plug.

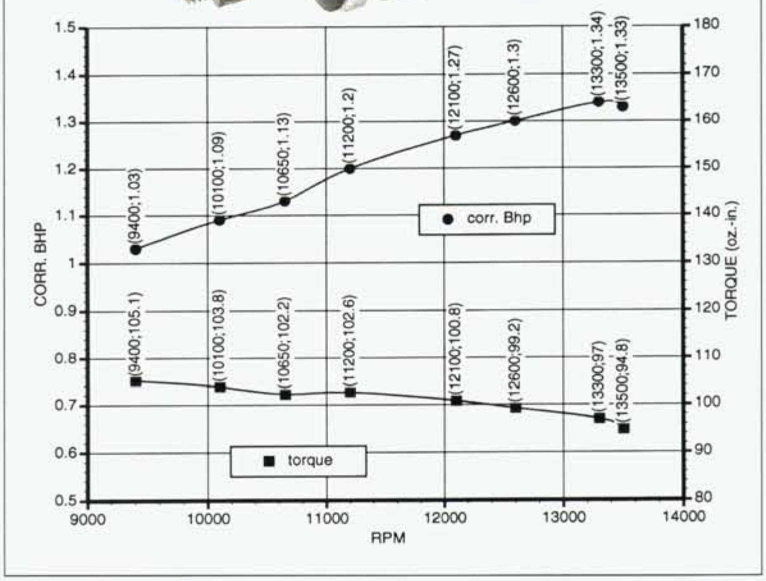
For break-in, I ran the Megatech M-61 for 20 minutes; the first two runs resulted in burned-out glow plugs. I added a 0.010-inch-thick aluminum head shim, which improved the situation. The rest of the break-in was uneventful: the engine started, needled and maintained a steady, if somewhat rough, operation. At the end of break-in, the M-61 peaked at 13,200rpm. A parting thought: the M-61 may still be over-compressed; this would account for its roughness at high speeds.

TESTING CONDITIONS

Temp. 72 deg. F
Bar. pres. 29.30 in. Hg
Wet-bulb temp. 62 deg. F
Corr. fact. 1.05

Dynamometer-generated torque and horsepower curves indicate:

- torque peak—105.1 oz.-in. @ 9,400rpm (rank: 6th)
- bhp peak—1.34 @ 13,300rpm (rank: 4th)
- specific torque (oz.-in./ci)—172 (rank: 5th)
- specific horsepower (bhp/ci)—2.20 (rank: 4th)
- torque to weight ratio (oz.-in./lb.)—60.4 (rank: 10th)
- horsepower to weight (bhp/lb.)—0.77 (rank: 10th)

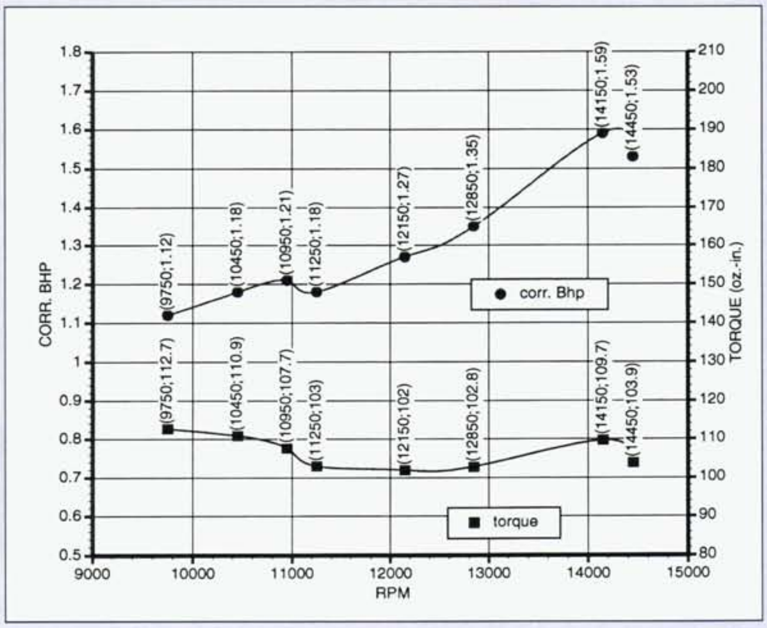


TESTING CONDITIONS

Temp. 63 deg. F
Bar. pres. 29.46 in. Hg
Wet-bulb temp. 58 deg. F
Corr. fact. 1.03

Dynamometer-generated torque and horsepower curves indicate:

- torque peak—112.7 oz.-in. @ 9,750rpm (rank: 2nd)
- bhp peak—1.59 @ 14,150rpm (rank: 1st)
- specific torque (oz.-in./ci)—185 (rank: 2nd)
- specific horsepower (bhp/ci)—2.61 (rank: 1st)
- torque to weight ratio (oz.-in./lb.)—76.7 (rank: 3rd);
- horsepower to weight (bhp/lb.)—1.08 (rank: 1st)



O.S. Max FX-61

■ **General impressions.** Beautiful casting and machine work throughout—O.S. trademarks. The hemi-head combustion-chamber components are not machined but are bead-blast finished—an unusual but time-saving procedure.

The engine's drop-in cylinder-sleeve shows a dedication to excellence that's rarely duplicated in the miniature-engine industry. Technical highlights include: precisely machined ports, smooth nickel-plating and flawless taper honing. The impressive unit should be mounted on a display stand for all engine lovers to admire.

■ **Performance.** For break-in, propeller-rpm determination and dynamometer testing, I used Sig 10-percent-nitromethane fuel containing 20 percent lubricant (my standard blend for ball-bearing-equipped ABN engines). For low-load break-in, I used an APC, 11x6, 2-blade propeller, and for all runs, I chose an O.S. no. 8 long-reach glow plug.

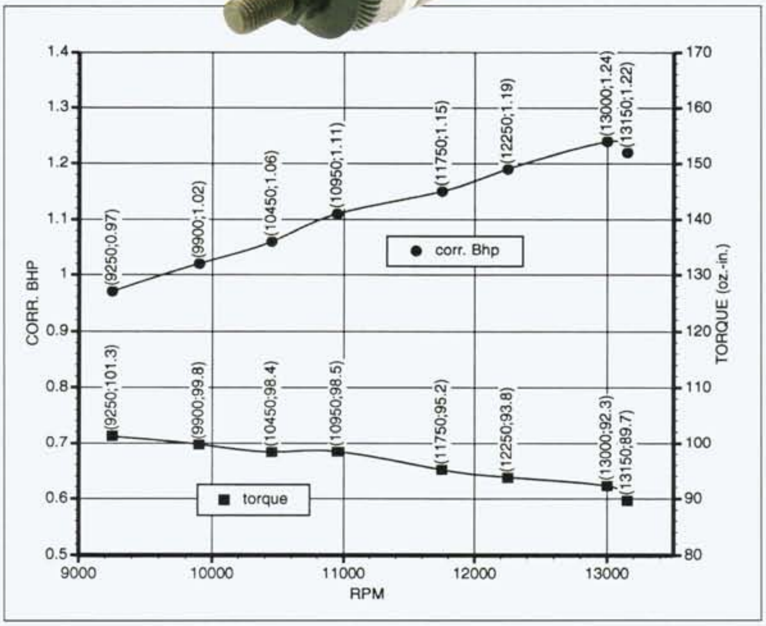
I ran the O.S. Max FX-61 for 20 minutes of break-in; at the end of this, it held a peaked setting of 13,150rpm.

TESTING CONDITIONS

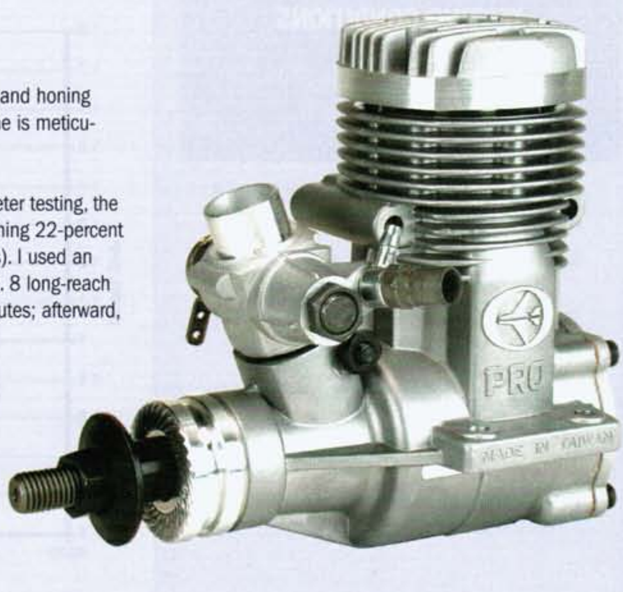
Temp. 70 deg. F
Bar. pres. 29.39 in. Hg
Wet-bulb temp. 60 deg. F
Corr. fact. 1.04

Dynamometer-generated torque and horsepower curves indicate:

- torque peak—101.3 oz.-in. @ 9,250rpm (rank: 8th)
- bhp peak—1.24 @ 13,000rpm (rank: tied for 7th)
- specific torque (oz.-in./ci)—166 (rank: 7th)
- specific horsepower (bhp/ci)—2.03 (rank: tied for 6th);
- torque-to-weight ratio (oz.-in./lb.)—66.6 (rank: 7th)
- power to weight (bhp/lb.)—0.82 (rank: 7th)



Thunder Tiger GP-61 ABC



■ **General impressions.** Beautiful castings, lathe turning, milling, grinding and honing operations; a traditional bronze bushing supports the crankshaft. This engine is meticulously produced.

■ **Performance.** For break-in, propeller-rpm determination and dynamometer testing, the Thunder Tiger GP-61 was run with Sig 10-percent-nitromethane fuel containing 22-percent lubricant (my standard blend for plain-bearing-equipped, ABC-type engines). I used an APC, 11x6, 2-blade propeller for low-load break-in and installed an O.S. no. 8 long-reach glow plug for all runs. For break-in, I ran the GP-61 uneventfully for 22 minutes; afterward, the engine peaked at a smooth 13,150rpm.

When I had a technical difficulty while testing this engine, I was pleased by the prompt and courteous attention of the Ace Hobby representatives.

O.S. .65 LA

General impressions. A powder-coated external finish; a remote, backplate-mounted needle-valve assembly; an inexpensive air-bleed carburetor; a cylinder sleeve made of seamless brass tube; a composite-plastic backplate; a bronze bushing for crankshaft support; flawless castings and precision machine-tool operations are standard for O.S. engines.

Performance. Engine break-in, propeller rpm determination and dynamometer testing were all done using Sig 10-percent-nitromethane fuel with 22 percent lubricant (my standard blend for ABC-type engines equipped with plain bearings). I also used an APC, 11x6, 2-blade propeller along with an O.S. no. 3 glow plug (later changed to an O.S. no. 8 long-reach glow plug).

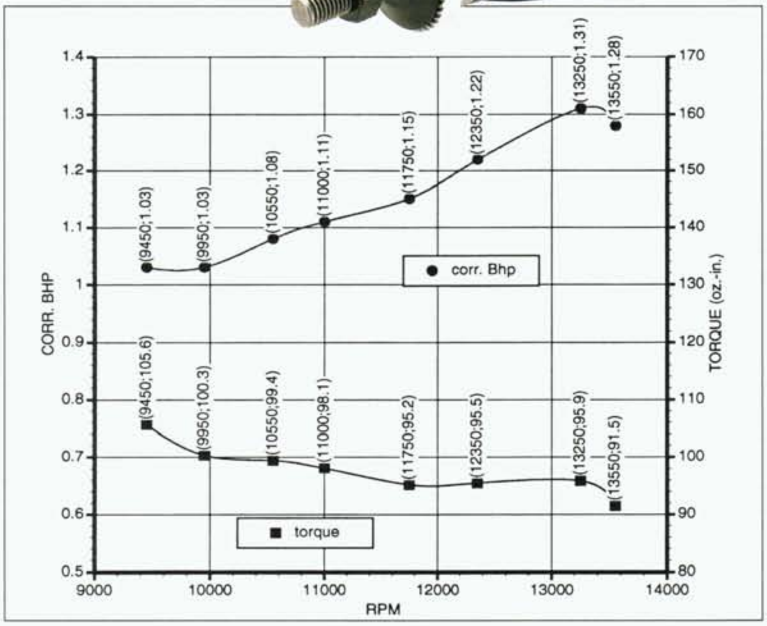
For break-in, I ran the O.S. .65 LA for 20 minutes and noted a moderate crankshaft-seal leak. Although high-speed performance didn't seem to be affected, fuel consumption increased slightly. With the engine almost peaked (about 300rpm on the rich side), I noticed that it dropped about 500rpm when the glow-plug heat was removed. A number of factors may cause this, but the quickest fix is to change to a hotter glow plug. I changed to an O.S. no. 8; subsequent runs showed a marked improvement. After break-in, the .65 held a steady, peaked 13,350rpm.

TESTING CONDITIONS

Temp. 67 deg. F
Bar. pres. 29.40 in. Hg
Wet-bulb temp. 57 deg. F
Corr. fact. 1.04

Dynamometer-generated torque and horsepower curves indicate:

- **torque peak**—106.7 oz.-in. @ 9,450rpm (rank: 4th)
- **corrected bhp peak**—1.24 @ 12,350rpm (rank: tied for 7th)
- **specific torque (oz.-in./ci)**—175 (rank: 4th)
- **specific horsepower (bhp/ci)**—2.03 (rank: tied for 6th)
- **torque-to-weight ratio (oz.-in./lb.)**—69.7 (rank: 6th)
- **power to weight (bhp/lb.)**—0.81 (rank: 8th)

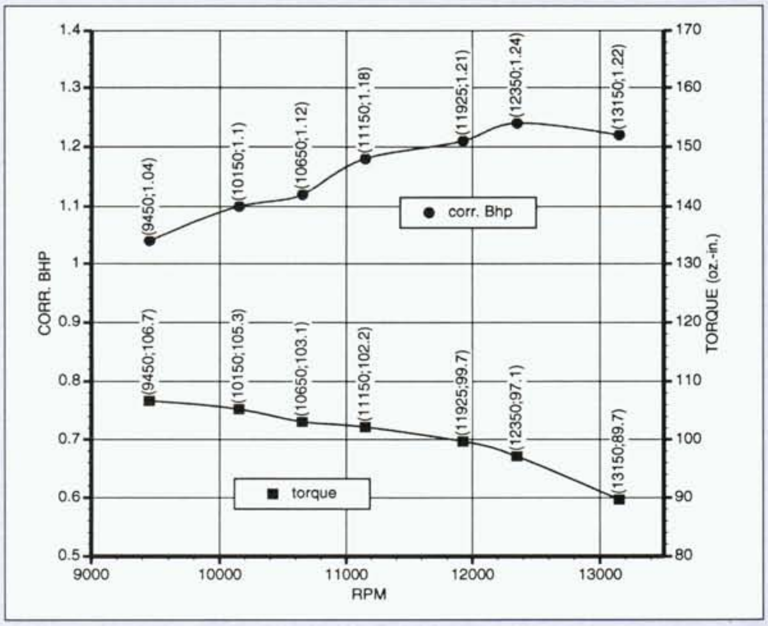


TESTING CONDITIONS

Temp. 75 deg. F
Bar. pres. 29.47 in. Hg
Wet-bulb temp. 62 deg. F
Corr. fact. 1.04

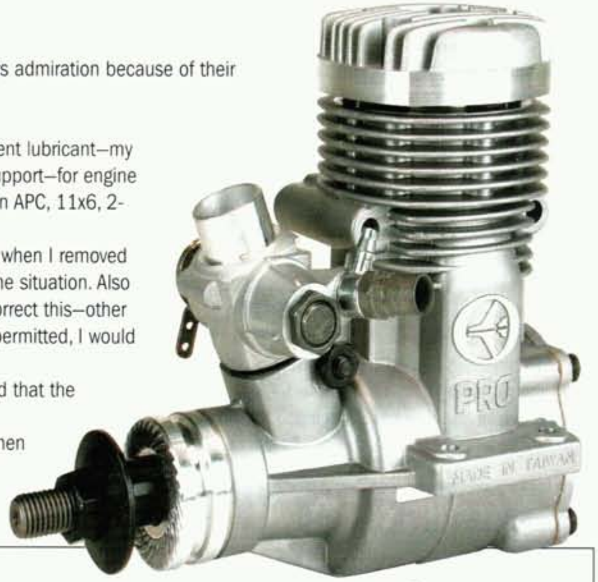
Dynamometer-generated torque and horsepower curves indicate:

- **torque peak**—105.6 oz.-in. @ 9,450rpm (rank: 5th)
- **bhp peak**—1.31 @ 13,250rpm (rank: 6th)
- **specific torque (oz.-in./ci)**—162 (rank: tied for 8th)
- **specific horsepower (bhp/ci)**—2.02 (rank: 9th)
- **torque-to-weight ratio (oz.-in./lb.)**—70.4 (rank: 5th)
- **power to weight (bhp/lb.)**—0.87 (rank: 5th)



Thunder Tiger Pro .61 BB ABC

General impressions. My first reaction to all Thunder Tiger engines is always admiration because of their spectacular castings and machine-tool work.



Performance. I used Sig 10-percent-nitromethane fuel containing 20-percent lubricant—my standard blend for ABC-type engines equipped with ball-bearing crankshaft support—for engine break-in, propeller-rpm determination and dynamometer testing. I also used an APC, 11x6, 2-blade propeller and a Fox R/C long-reach glow plug.

For break-in, I ran the Thunder Tiger Pro .61 for 20 minutes; initially, it quit when I removed the glow-plug heat, so I changed to a hotter O.S. no. 8 plug, which improved the situation. Also during the first run, the front bearing leaked fuel; since little can be done to correct this—other than to replace the crankcase—I tolerated it. If my tight testing schedule had permitted, I would have returned the engine for a replacement.

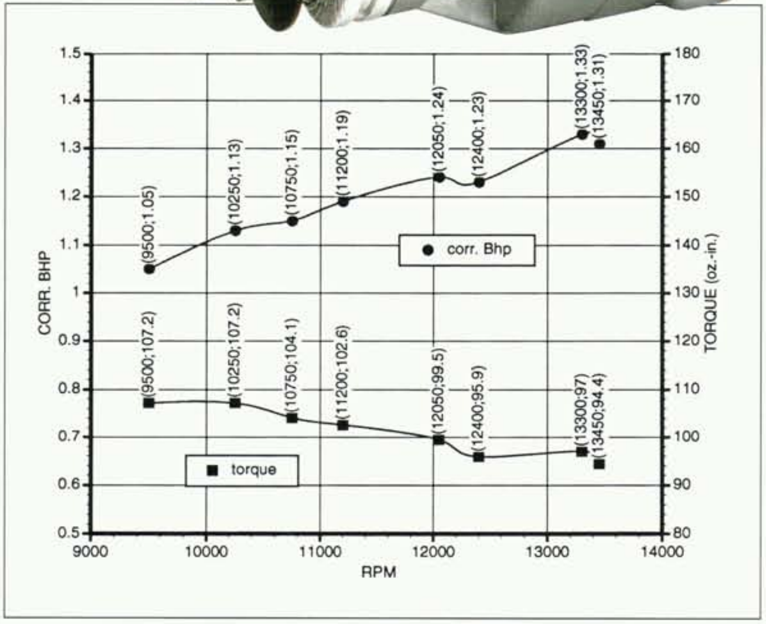
Early break-in runs produced two burned-out plug elements; this suggested that the engine's compression ratio was too high, so I removed the cylinder head and inserted an additional 0.010-inch-thick aluminum shim (gasket). The engine then ran more smoothly and didn't trash any more plugs. I had difficulty obtaining a reliable idle below 2,550rpm; this may be the result of the reduction in fuel draw caused by the pressure/vacuum leak at the crankshaft seal. At the end of break-in, the Pro .61 ran steadily at 13,450rpm.

TESTING CONDITIONS

Temp. 68 deg. F
Bar. pres. 29.43 in. Hg
Wet-bulb temp. 59 deg.F
Corr. fact. 1.04

Dynamometer-generated torque and horsepower curves indicate:

- **torque peak**—107.2 oz.-in. @ 9,500rpm (rank: 3rd)
- **bhp peak**—1.33 @ 13,300rpm (rank: 5th)
- **specific torque (oz.-in./ci)**—176 (rank: 3rd)
- **specific horsepower (bhp/ci)**—2.18 (rank: 5th)
- **torque-to-weight ratio (oz.-in./lb.)**—64.2 (rank: 8th)
- **power to weight (Bhp/lb.)**—0.80 (rank: 9th)



gas engines for giant scale

BY GERRY YARRISH

When you make the transition from normal-size sport .40 models to giant-scale airplanes, the biggest difference you have to deal with is the gasoline engine. For many, these big-bore hunks of metal are a mystery because they look and operate so differently from the more familiar glow-powered (nitro) engines. In practice, however, starting, running and adjusting a gasoline engine is only slightly different and no more difficult than operating any other internal combustion engine. If you can operate a chain saw or a weed trimmer, then you'll be right at home powering your next giant-scale project with a gas burner.

Gas engines are much easier to adjust and have excellent fuel efficiency; a gas engine consumes roughly ⅓ as much fuel per minute as a glow engine of the same displacement burns. Gasoline engines tolerate heat much better than glow powerplants, and they require fewer fuel-mixture adjustments to keep them happy. You might need to adjust your gasoline carburetor only once during a flying season! Though the typical gas burner produces less rpm than its glow-powered cousin, it produces more low-end torque. Thrust is produced more efficiently with that bigger, slower turning prop. Because they are heavier than nitro engines, gas engines are often used in scale airplanes that have a shorter nose moment, and their weight helps eliminate some of the lead ballast needed to balance the airplane. In giant-scale, unlimited Tournament of Champions and International Miniature Aircraft Club (IMAC) events, big-bore gas engines are the norm, and you can't argue with success!

If you're leery about using a gas engine, this guide will clear everything up.

3W Modell Motoren

The German-made 3W engines have been used in several giant-scale competitions, including the Tournament of Champions and many giant-scale unlimited air races. 3W engines come with an electronic auto-advance ignition system and are designed to operate at lower rpm for more thrust and less prop noise. **3W 60I (shown)—$519.**

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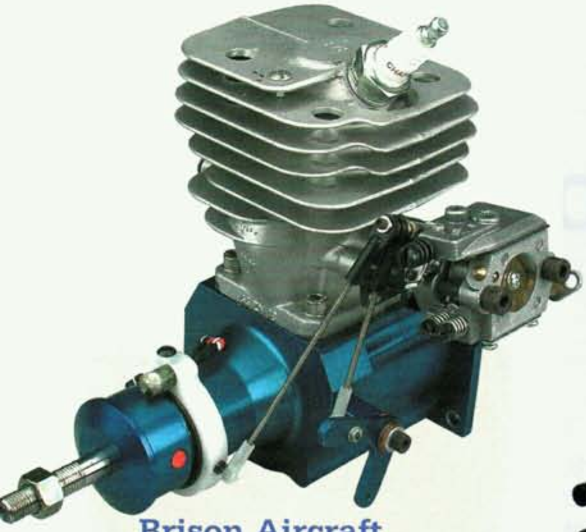
(732) 761-0997; aircraft-intl.com.
Cactus Aviation
(520) 721-0087; cactusaviation.com.

BME

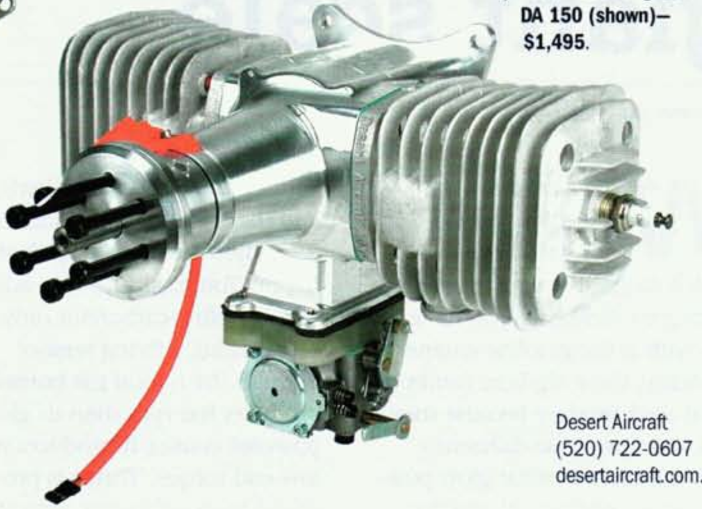
Designed specifically for light overall weight while retaining excellent crankcase stiffness and crankshaft support, BME engines are known for their smooth operation and user-friendliness. Most BME engines come with the CH syncro spark-ignition system and fiber-reed induction (except the BME 44 single, which is piston ported), plus a 2-year warranty. **BME 102 (shown left)—$1,149; BME 44 (shown right)—$499.**

BME Engines
(254) 836-0835;
bmeengine.com.



Desert Aircraft

Using some of the latest tools and techniques, including 3D CAD and stereo lithography, the DA-150 has been designed from the ground up with Tournament of Champions and World Masters-style competition aerobatics in mind. The DA-150 is ideally suited to aircraft for which existing 120cc and 140cc engines aren't quite enough. It can also power aircraft that are designed for heavier, 4-cylinder, 160cc engines.
DA 150 (shown)—$1,495.

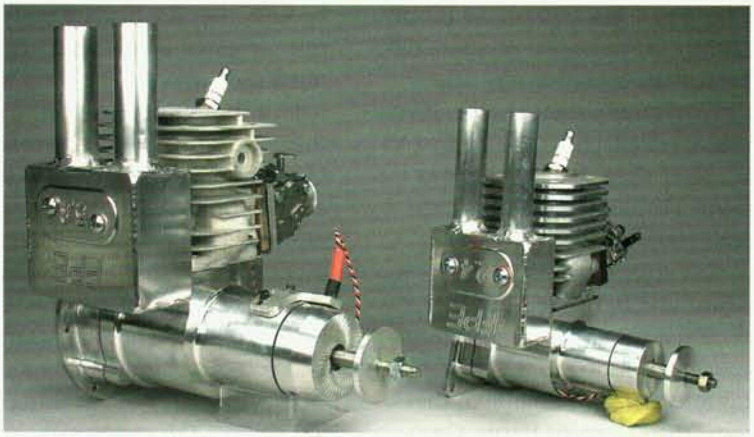


Desert Aircraft
(520) 722-0607
desertaircraft.com.

Brison Aircraft

Designed with giant-scale modelers in mind, Brison engines' enhanced power and reliability make them ideally suited to Sunday fliers, scale modelers and IMAC competitors. Available in six sizes, ranging from a 2.4ci (39.33cc) single to a big 6.4ci (104.64cc) twin cylinder, all Brison engines come standard with nicasil-lined cylinders, metal bellcranks and anodized cases, and all the crankshafts are unconditionally guaranteed for one year. Every engine is test-run and tuned before being shipped.
Brison 3.2 (shown)—$549.

Brison Aircraft
(972) 241-9152;
brisonaircraft.com.



Fox Mfg.

With its long history of manufacturing model airplane engines, Fox Mfg. offers custom-built RC aircraft engines. Each has a nicasil-lined cylinder/piston assembly (made by Makita/Dolmar USA), a Walbro pumper carb and a cantilevered crankshaft with a single bolt (3/8-24NF-thread) prop hub. Each is equipped with mechanical auto-spark advance with a CH electronic ignition system. The crankcase is machined aluminum with a polished finish; the cylinder is bead blasted.
Fox 3.2 (shown)—$575.

Fox Mfg.
(479) 646-1656;
foxmanufacturing.com.

First Place Engines

Distributed by Sig Mfg., the First Place Engine (FPE) line consists of four, light, powerful gas engines designed specifically for large RC aircraft use. They offer a good power-to-weight ratio and come with a light, tig-welded, custom aluminum muffler that may be modified to accept a smoke system. All four engines come with an electronic ignition, complete instructions and a one-year warranty; a 50:1 oil/gas ratio is recommended.
FPE (5.8ci, on left) $699.95;
FPE (2.4ci, on right)—$499.

Sig Mfg. Co. Inc.
(800) 247-5008;
sigmfg.com.

Use premium-quality 2-stroke engine oil when you mix your fuel.

Oil-to-gasoline ratios

The 2-stroke, air-cooled, giant-scale engines we use to power our models do not have separate oil tanks (unlike full-size aircraft engines), so we must add the oil to the gasoline. Your engine manufacturer provides a mixture ratio recommendation in the engine's operation manual. Here are some common ratios.

RATIO	OUNCE OF OIL PER GALLON OF GASOLINE
100:1	1.28
90:1	1.42
75:1	1.7
64:1	2
50:1	2.5
40:1	3.2
32:1	4
24:1	5.3
16:1	8

FIRING UP A GAS ENGINE

Before you start a gasoline engine for the first time, it is best to review and become familiar with its operation manual. Even for bench-running, always have a helper. If the engine is already installed in a model, fully assemble the model and have your helper hold it securely. Tell him how to turn the ignition on and off and how to operate the choke, if the engine has one.

If your engine has an electronic ignition system, make sure that it is attached properly and that the ignition battery is fully charged. If you have a magneto-equipped engine, always install a kill switch to stop the engine.

For the very first engine run, close both the high- and low-end needles fully, and then open the high-end needle 1½ turns and open the low-end (idle) needle 1¼ turns. These settings are a good starting point for a reliable idle and a rich high end. Check the manual for the recommended oil-to-gas mix ratio, and fill the tank with fresh, filtered fuel.

Always ask a helper to assist you when you start a gas engine; make sure he knows how to operate the choke and how to shut off the engine.

STARTING THE ENGINE
Be sure that the ignition, or the kill switch, is turned off. Set the throttle full open, and close the choke. If the carb does not have a choke, use your thumb to cover the venturi to choke it. Turn the prop counterclockwise several times until fuel starts to flow through the fuel line to the carb. Flip the prop a few more times until fuel is in the carb.

If your engine does not have a choke, turn the ignition on, set the throttle to ¼, and flip the prop until the engine begins to run. If you have a choke-equipped carb, leave the choke closed, turn the ignition on, open the throttle fully, and flip the prop until you hear the engine cough as it tries to start. Then open the choke, set the throttle to ¼, and flip the prop several times until the engine starts. If it does not fire, begin again from the start; let the engine warm up for a few minutes before you advance the throttle.

Fuji

Distributed by Tower Hobbies, Japan's Fuji engines are very popular. They come with a one-piece, solid-state capacitive discharge ignition system (no breaker points). The Walbro carburetor is standard, and the propeller hub is knurled to hold the prop securely. Three hub lengths are available. The muffler is designed specifically for RC use.
Fuji BT-50SA (2.1ci, shown)—$399.99.

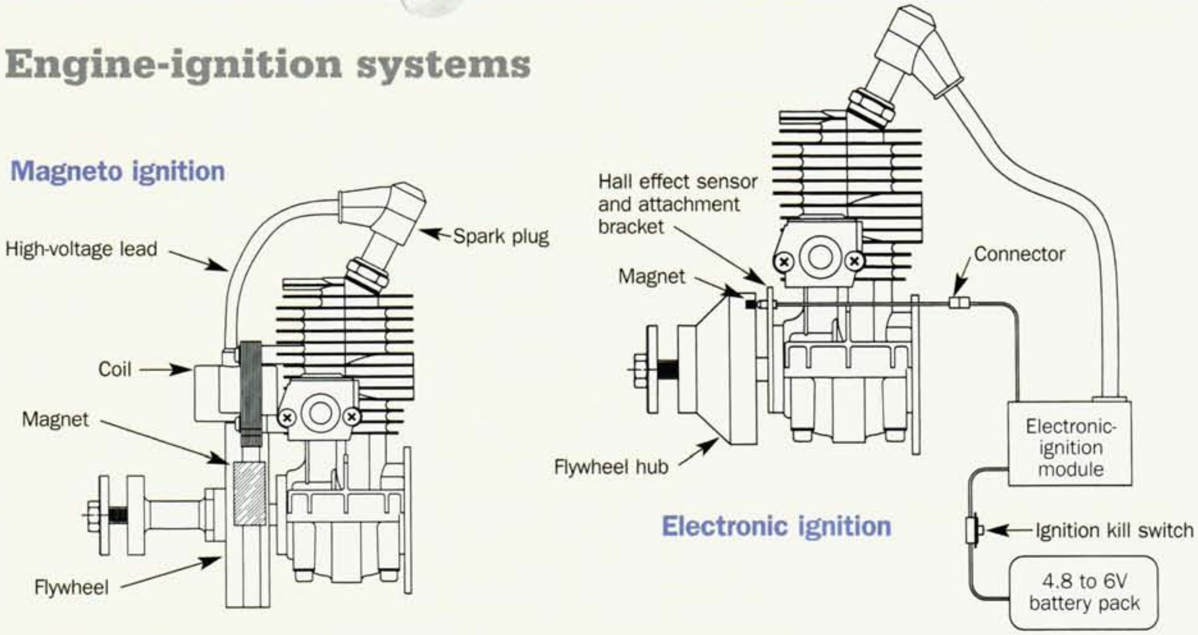
Distributed by Great Planes Model Distributors Co.
(217) 398-6300-7660; (800) 628-8948;
fujiengines.com.

Quadra-Aerrow

Manufactured since 1975, Quadra-Aerrow engines are among the most reliable and durable in the RC industry. Available in nine sizes and 17 variants, they produce from 3.9 to 45hp and can be equipped with battery-powered or magneto ignition systems. Ideal for aerobatics competition, all except one feature a reed-valve induction system for quick throttle response and high-torque midrange performance. Features include chrome or nicasil-plated cylinders with high-silicon/aluminum pistons, single and dual piston rings (pegged and chamfered), ball-bearing and needle-bearing support throughout, and on some models, semi-automatic compression release. **Q75B (shown)—$734.**

Quadra-Aerrow Inc.
(613) 264-0010; quadraaerrow.com.

Engine-ignition systems



This Brison 3.2ci engine has a mechanical timing-advance ring coupled to its throttle arm. The ring advances and retards the engine timing as the throttle settings are changed.

IGNITION TIMING

Many manufacturers offer their engines with either a magneto or an electronic ignition system. Depending on your requirements, either type will provide reliable performance. In addition to supplying the spark plug with current, ignition systems also regulate engine timing. Magneto ignitions have fixed timing, while with electronic ignitions, you can advance or retard the timing. Electronic ignitions can be microprocessor controlled (with auto-spark advance) or equipped with a mechanical timing-advance ring that is coupled to the throttle.

■ Fixed timing. With a fixed ignition timing, the engine must operate in a timing range that maintains a good power setting while still being fairly easy to start. Since a good starting timing is between 0 and 5 degrees before top dead center (BTDC), and maximum power is achieved at somewhere around 25 to 30 degrees BTDC, engines with fixed timing cannot offer optimum performance. Engines that are timed for optimum high-end output offer good overall performance but do not idle as low as those with adjustable timing.

■ Microprocessor control. There are several microprocessor-controlled timing units on the market. They have a fixed timing sensor placed at a specific timing setting and use a microprocessor to change the timing to suit the engine's rpm. They work very well, but they are usually limited to about 25 degrees of timing (advance or retard).

■ Mechanical advance. Engines with a mechanical timing-advance ring tend to be very easy to start and can be adjusted to optimize an engine's full power range. Usually made of a non-metallic material, the ring holds the timing sensor; this ring is coupled to the throttle arm, and it moves the sensor to change the timing from 0 degrees BTDC for starting up to about 30 degrees BTDC for optimum top-end performance.

ZDZ

Manufactured in the Czech Republic and distributed in the U.S. by RC Showcase, ZDZ giant-scale gas engines have rotary disc valves and rear-induction carburetors (complete with control links for the choke) and throttle arms. All have a solid-state microprocessor-controlled electronic ignition with auto-advance and are completely shielded to minimize interference. Even the spark-plug lead is fully metal-shielded. ZDZ engines come with a 30-month warranty. **ZDZ 40 RV-L (2.4ci, shown)—$410.**

Distributed by RC Showcase
(301) 374-2197; rcshowcase.com.

Cheetah

Reid's Quality Model Products offers the Cheetah engine with magneto ignition, and the 42DX version with the CH electronic-ignition system with syncro-spark throttle linkage. Suitable for 15- to 25-pound airplanes, the Cheetah 42DX has a chrome-plated cylinder bore and includes a backplate engine mount and spacer, an adjustable velocity stack, a muffler and a 2-year limited warranty. **Cheetah 42DX (shown)—$399.95.**

Reid's Quality Model Products
(315) 548-3779; reidsmodels.com.

Magneto Magic

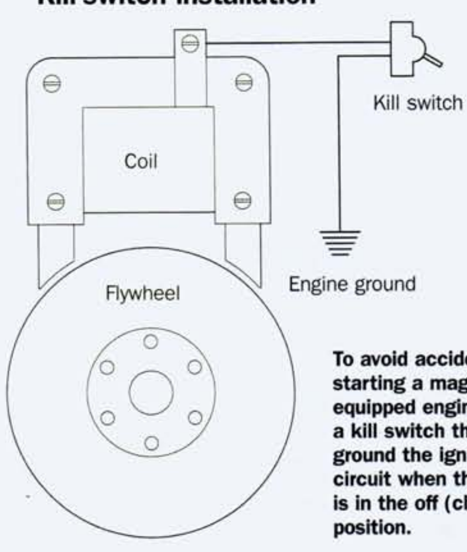
A magneto ignition is nothing more than an old-fashioned generator used to create a pulse of electrical current to fire the spark plug. The magneto ignition system consists of a permanent magnet mounted on a flywheel attached to the crankshaft and a field coil that induces the current when the magnet passes the ends of the coil shoes. The magnet is embedded in the flywheel's rim, and the coil sits right next to the flywheel. A battery isn't required for ignition.

With a magneto-equipped engine, use a kill switch to stop it safely. The switch simply grounds the magneto coil to the engine case and prevents current from firing the spark plug.

Many magnetos have an external secondary coil (or condenser); the current builds up in the primary coil and is then dumped into the condenser to produce a stronger spark while starting the engine. Magneto ignitions are completely self-contained, and if set up properly, they will supply current to the spark plug for as long as the engine is running. To stop the engine, the coil must be grounded to the engine case. A kill switch grounds the magneto coil to the engine case and prevents current from firing the spark plug.

To operate properly, the spark-plug gap and the coil gap (space between the flywheel magnets and the primary magneto coil) must be set up according to the engine's operating manual. For most engines, a spark-plug gap of between 0.018 and 0.025 inch and a coil gap of between 0.020 and 0.025 inch is recommended.

Kill-switch installation



To avoid accidentally starting a magneto-equipped engine, install a kill switch that will ground the ignition circuit when the switch is in the off (closed) position.

RCS

RCS engines are available in displacements that range from 1.4 to 18ci. Designed to replace large glow engines, they deliver as much or more power as glow engines of the same displacement. The engines are equipped with electronic auto-advance computerized ignition. Available as side- and rear-exhaust versions, RCS engines are very easy to hand-start and have linear throttle response. **RCS 140 (shown)—$345.**

RC Showcase (301) 374-2197; rcshowcase.com.

Troubleshooting

A properly adjusted gasoline engine will run smoothly and produce maximum power for a long time. But sometimes, even a well-running engine can become difficult to start or begin to run erratically. Here are some common problems and fixes.

• **Engine doesn't start.** Check the fuel, air and ignition system. If any one of these three isn't correct, it will prevent the engine from firing. Make sure that the kill switch is off (open). Check for a fuel-line blockage and debris in the needle-valve assemblies. Make sure that the choke and "butterfly" operate properly and that the carb body is firmly bolted into place. The pulse pressure passage between the carb and the crankcase must be clear. If you have an electronic ignition system, be sure that the battery is properly charged.

• **The engine runs erratically in flight.** If the engine runs properly on the ground but then operates erratically (too rich or lean), especially when climbing or diving, the problem might be uneven airflow into the carburetor. This can cause fuel to be siphoned out of the venturi, and the mixture will be incorrect. A ¾- to 1-inch-long velocity stack will help stabilize the airflow. If this does not improve engine performance, install a small fairing, or a shield, to help direct airflow away from the carb.

To operate a gas engine, use gasoline-proof fuel plumbing. Always replace the fuel-tank stopper and all fuel and vent lines with gas-compatible ones.

Aftermarket items such as these velocity stacks can help smooth fuel flow through the carb.

• **Engine suddenly runs erratically.** If your engine has been running properly and suddenly starts to act up, you should check several things.

Make sure the ignition battery is fully charged and is supplying the proper voltage. Be sure that all electronic ignition connections are securely plugged in and that the ground strap is still attached to the engine case. Inspect the spark plug and the spark-plug wire and boot. The plug may be fouled with carbon deposits, or the wire connections may be faulty.

Often, the carburetor's internal inlet screen can become blocked, restricting fuel flow. To remedy this, remove the carb's outer cover on the fuel-inlet side, and then carefully remove the gasket. The filter screen sits in a shallow depression and can be inspected easily. If it is clogged, carefully remove and clean it by flushing it with fresh gasoline. Then carefully reinstall it and replace the gasket and cover plate. If it is not clogged, remove both needle valves and flush the entire carb with gasoline.

• **Preventive maintenance.** Use only freshly mixed gasoline and oil; if the fuel is several months old, dispose of it properly and mix a new batch. Always drain the fuel out of the tank after every flying session. When you store your model for an extended time, first empty the tank and then run the engine until it quits; this will remove unburned fuel from the carb. Remove the spark plug and squirt some after-run oil into the cylinder, and turn the engine over by hand. Put a few more drops into the carb, and then plug the venturi and exhaust pipes with some small wads of paper towel. Remove the ignition batteries, charge them and store them in a safe place. Store your engines in a warm dry area; avoid areas that are subject to drastic temperature changes and dampness. Remove and inspect the prop occasionally to check for cracks and other damage; always balance a new prop.

Pumper carburetor basics

For a gasoline engine to run reliably and to produce maximum power, the carburetor must be adjusted correctly. The throttle "butterfly" controls how much air enters the engine, and the needle valves meter the fuel. Walbro-type pumper carbs have two needle-valve screws: the low end—identified with an "L"—and a high end—"H"; the marks are stamped into the carb body. Turning the adjustment screws clockwise (in) leans the mixture (restricts fuel flow). When turned counterclockwise (out), the mixture is richened and allows more fuel to flow through the carb.

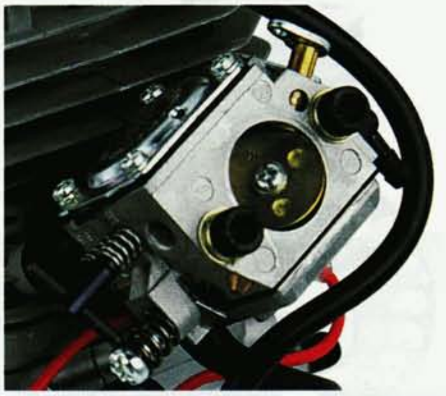
Fuel is constantly delivered to the engine by the low-end (idle) needle. As rpm increase to about 2,000 to 3,000 (the midrange), additional fuel is drawn from the high-end needle. The higher the rpm become, the more fuel is drawn from the high-end needle. A properly adjusted carb will deliver fuel evenly throughout the entire throttle range to produce a smooth throttle transition from idle to full power.

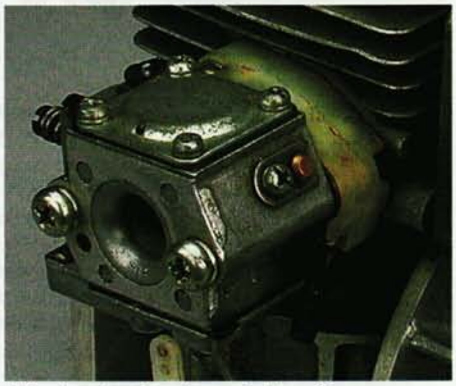
Always adjust the low-end needle first. The low-end mixture should be set as lean as possible but not so lean that the engine doesn't instantly transition from idle to the midrange. If the idle mixture is set too lean, the engine will hesitate and might quit when you advance the throttle quickly. If the idle mixture is set too rich, the engine will sputter and burble with excess fuel as you advance the throttle. You will know the mixture is correct when you advance the throttle quickly and the engine responds cleanly and quickly.

Set the high-end needle so that the engine will produce maximum rpm without overheating. If the high end is set too lean, the engine will sag and slow down as it overheats. Don't run your engine too lean, as this can damage it. If the high-end mixture is set too rich, the engine will run roughly and won't develop full power.

Make small needle-valve adjustments—$\frac{1}{16}$ turn at a time for the idle and $\frac{1}{8}$ turn for the high end. Use a tachometer to adjust the high end until maximum rpm is achieved. After each new adjustment, allow the engine to run for a short time, and continue to lean the mixture until the rpm begin to drop. When this happens, back the needle off $\frac{1}{4}$ turn (rich). Check the idle setting again, and you're done. If you do have to readjust the idle setting, readjust the high end also, as both needles affect overall performance. Once you've set it properly, you shouldn't have to adjust the carb for a long time.

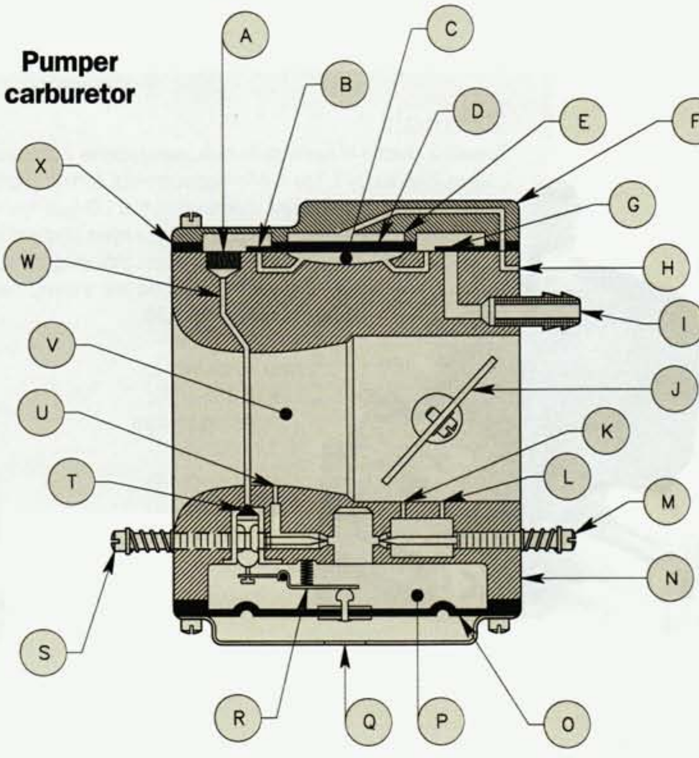
To check the engine's fuel mixture, inspect the spark plug's condition. If the fuel mixture is correct, the electrode should be a light tan color (the color of a brown-paper bag). A lighter color (pasty white) typically indicates a too-lean fuel mixture, and a darker brown (or oily black) indicates an overly rich mixture.





Not all carburetors have chokes; if yours doesn't have a mechanical choke, use your thumb to choke it while you rotate the prop to draw fuel into it.

A. Fuel-inlet filter screen
B. Fuel-outlet valve
C. Fuel chamber
D. Fuel-pump diaphragm
E. Impulse chamber
F. Pump cover
G. Fuel-inlet valve
H. Impulse pressure inlet
I. Fuel-inlet fitting
J. Throttle butterfly
K. Secondary idle-discharge port
L. Primary idle-discharge port
M. Low-end (idle, needle valve)
N. Carburetor body
O. Fuel-metering diaphragm
P. Diaphragm fuel chamber
Q. Atmospheric pressure vent
R. Fuel-inlet-valve control arm and spring
S. High-end needle valve
T. Fuel-inlet needle valve
U. Main fuel-discharge port
V. Venturi
W. Fuel-inlet-supply channel
X. Fuel-pump diaphragm gasket



Taurus Engines

Taurus Engines offers single- and twin-cylinder engines. The singles range from the TS 42 (2.6ci) to the TS 95 (5.8ci), while the twins (in-line and opposed-cylinder configurations are available) range from the TT 85 (5.2ci) to the TT 240 (14.6ci). Taurus Engines also offers its Signature Series HP engines in displacements of 3.5ci to 7.2ci (call for prices). The 2.6 and 3.2 engines have double-web crankshaft counterbalances, 5-hole radial engine mounts, nicasil cylinder liners, auto-advance ignition systems and single-bolt prop hubs. A full 3-year warranty covers workmanship and defects on all engines. **TS 52 (shown)—$559.95.**

Taurus Engines
(734) 283-4813; www.taurus-engines.com.

U.S. Engines

These economical powerplants are available in 35cc and 41cc displacement versions and come with a limited 2-year warranty. Each is equipped with a solid-state capacitive discharge ignition system and a nicasil-coated piston liner. The Walbro carburetor is standard, and throttle linkage for RC use is also included. The engine also comes with a two-exhaust-port muffler, an engine mount that's part of the rear crankcase, and a spring starter. The spark plug comes installed. **U.S.41 (shown)—$249.**

Great Planes Model Distributors Co.
(800) 682-8948;
bestrc.com/usengines.

Zenoah

Zenoah, a division of Komatsu Zenoah, manufactures 2-stroke engines to exacting tolerances at its factory in Japan. Available in 1.3 to 4.87ci displacements, Zenoah engines come with chrome-plated piston liners and are equipped with compact, maintenance-free CDI-type flywheel/magneto ignition systems. Each engine comes with a muffler, an engine mount, a spark plug and plug wrench and a Walbro pumper carb. The G-23 is available in airplane gasoline and glow-plug (nitro), helicopter and marine versions. The twin-cylinder GT-80 has a cast intake manifold and a spring starter. **G-23 (on left)—$289; GT-80 (on right)—$999.95.**

Horizon Hobby Inc.
(800) 338-4639;
horizonhobby.com.

FAQ

Q: What is "RF" noise, and how can I eliminate it?
A: This refers to radio-frequency noise, and it's electrical interference created by the firing of the spark plug. It can affect radio reception, but most of the newer receivers are less susceptible to it. Installing a resistor spark plug will minimize RF noise but won't completely eliminate it.

Use a non-metallic throttle pushrod to further help shield the radio from the interference. Also, install your radio gear (including ignition battery packs) as far from your engine as is practical; 8 to 10 inches should be enough (the farther apart, the better). Also check the engine, engine mount, throttle linkage and muffler for any

Some modelers use soft mounts such as these B&B Specialties mounts to cushion their engine on the firewall, and they isolate the airframe from engine vibration.

loose metal-to-metal contact. If your electronic ignition system has a ground wire, make sure that it is grounded to the cylinder head or engine case.

Q: Which gasoline should I use?
A: High-octane gasoline will make your engine run slightly hotter but won't increase power output. I use standard 87 octane. Higher grades of gasoline (premium or ultra) contain fewer impurities and may help your engine to run more cleanly. Do not use gasoline that contains alcohol; it can damage the rubber parts of the carb. Don't use aviation-grade gasoline (AVGAS); it contains lead and has a 100-octane rating. It will make your engine run hotter, and the lead can foul the plugs. Always filter your fuel to remove contaminants and any small particles of debris that can clog your fuel system. Always use gasoline-grade fuel-tank plumbing and gasoline-rated fuel line.

Q: Which type of oil should I use, and at what ratio should I mix it with the gas?
A: Always use top-quality 2-stroke oil for air-cooled engines; it's found at most automotive- and motorcycle-parts stores. There are several brands. I have used Zenoah, Klotz and Honda XP2 high-performance synthetic oil, but you may also use high-quality petroleum-based oils. Check your engine manufacturer's recommendations; many suggest the use of petroleum-based oil during break-in, as it helps the piston rings seat faster. After about 10 hours of break-in, you can switch to synthetic oil. The ratio of gas to oil depends on the oil type (petroleum or synthetic). I usually use a ratio of between 40:1 and 64:1 (gas:oil) when using petroleum-based oils and 75:1 to 100:1 when using high-quality synthetics.

Q: Should I use a soft mount for my engine, or should I hard-mount it directly to the firewall?
A: Whether or not you use soft engine mounts is a personal preference. Most single-cylinder engines produce a fair amount of airframe vibration. Soft engine mounts absorb a certain amount of this and so shield the airframe from it. They also allow the engine to move and shake more. On lightly built aircraft structures,

The spark-plug boot and wire should always be in good condition. Here is a standard rubber boot with a grounding strap and a metal boot with shielded wire. Make sure you connect the boot to the spark plug properly.

Spark plugs come in several types and sizes; always use a resistor spark plug to minimize RF noise. Always use a spark-plug wrench to loosen or tighten your glue plugs; if you use the wrong tool, you may damage the plug, and that could increase RF noise.

I use very stiff soft mounts, but I do not use them on stronger, stiffer airframes. Try them and see; it's up to you.

Q: Which kind of spark plug should I use, and what should the gap be?
A: Always use a resistor spark plug (indicated by the letter "R" in the model number). I have used Champion RCJ7Y, Bosch WSR6F and NGK BPMR6A and have found them all to work very well. Use a plug of the type and size recommended by the engine's manufacturer. Always check the plug gap before you use it; on most engines, a 0.018- to 0.020-inch gap works well. I use 0.022 on my Brison 3.2 as recommended by its manufacturer. Use an inexpensive spark-plug gap gauge to get it right.

Engine Information

ENGINE	BORE (IN.)	STROKE	CYLINDERS	DISPLACEMENT (CI)	WEIGHT (LB.)	HORSEPOWER	OVERALL DIMENSION (IN.)
3W Modell Motoren							
3W-100iB2	1.73	1.26	2	5.9	7	9.3	11.1x4.6x7.6
3W-105STR3	1.58	1.1	2	4.3	10.1	11	14.4x4.4x9.4
3W-120iB2	1.8	1.42	2	7.2	8.47	11.5	12.4x3.9x6.9
3W-120iB2F	1.8	1.42	2	7.2	8.47	11.5	12.4x4.9x7.7
3W-140iB2	1.88	1.49	2	8.3	8.58	13.5	13x3.9x6.9
3W-140iB2F	1.88	1.49	2	8.3	8.58	13.5	13x4.9x7.7
3W-150iB2	1.93	1.57	2	9.2	8.47	16.5	13x3.9x6.9
3W-150iB2F-TS	1.93	1.57	2	9.2	8.47	17.5	13x4.9x7.7
3W-150iB2-TS	1.93	1.57	2	9.2	8.47	17.5	13x4.9x7.7
3W-150iR2	1.93	1.57	2	9.2	10.14	16.5	6.5x8x10.25
3W-150iR2-TS	1.93	1.57	2	9.2	10.56	17.5	6.5x8x10.25
3W-156B4	1.65	1.1	4	9.4	11.88	14.8	11x6.3x8.7
3W-170B4	1.73	1.1	4	10.3	11.7	16.5	11x6.3x8.7
3W-240iB2	2.26	1.8	2	14.4	14.74	22	14.17x5.5x8.7
3W-24i	1.34	1.03	1	1.5	2.32-2.65	2.5	6.5x2.75x3.9
3W-38i (42.5cc)	1.34	1.03	1	1.5	3.97	4	7.2x3.5x4.6
3W-48B2	1.34	1.03	2	2.9	4.11-4.45	5	10.3x3.5x5.5
3W-50i	1.73	1.26	1	3.0	4.36	6	3.5x5.8x5.8
3W-60i	1.81	1.45	1	3.7	5.32	6	3.9x6.2x6
3W-70i	1.88	1.49	1	4.1	5.32	6.5	3.9x6.4x6
3W-70iUS	1.88	1.49	1	4.1	4.73	6.5	3.9x6.4x5.5
3W-75i	1.93	1.57	1	4.6	5.32	7.5	3.9x6.4x6
3W-75iTS	1.93	1.57	1	4.6	5.42	7.9	3.9x6.4x6
3W-75iUS	1.93	1.57	1	4.6	4.73	7.5	3.9x6.4x5.5
3W-75iUS-TS	1.93	1.57	1	4.6	4.83	7.9	3.9x6.4x5.5
3W-85iB2	1.73	1.1	2	5.2	6.49	7.8	11x3.5x5.7
A.J. Machine							
Wolf Predator 1.8	INS	INS	1	1.8	3.28	3.6	5.5x4.5x4.3
Wolf Predator 3.2	INS	INS	1	3.2	3.75	5.2	6x6x4.5
BME							
BME-102	1.77	1.26	2	6.2	4.7	9.1	10x6x8
BME-44	1.69	1.18	2	2.7	2.7	4.2	6.75x4.3x6.25
BME-61	1.42	1.18	2	3.7	4.2	6.4	8.62x6x8
BME-80	1.57	1.25	2	4.9	4.7	7.5	10x6x8
BME-50	1.77	1.22	1	3	3	4.8	NS
Brison Aircraft							
2.4ci	1.57	1.22	1	2.4	2.75	4.5	5.375x5x4.625
3.2ci	1.73	1.34	1	3.2	3.25	5	6x 5.375x5.25
4.2ci	1.92	1.41	1	4.2	4.75	7.5	6.75x6x6.4.9
4.8ci	1.57	1.22	2	4.8	5.63	8.5	5.5x5.875x8.75
5.8ci	2.16	1.57	1	5.8	6	9	6.5x5.75x6
6.4ci	1.73	1.34	2	6.4	6	9.4	5.5x6x9.75
D&B Engines							
3.7ci	1.42	1.18	2	3.7	5	INS	10.2x5.9x8.8
5.1ci	1.65	1.18	2	5.1	6.4	INS	10.9x5.5x8.9
Desert Aircraft							
DA-100	1.68	1.38	2	6.1	5.8	9.8	11.5x3.5x6.3
DA-150	1.93	1.57	2	9.2	8	16	13.4x4.5x7.7
First Place Engines							
FPE 2.4ci	1.65	1.22	1	2.4	3.2	4	5x6.1x7.6
FPE 3.2ci	1.73	1.34	1	3.2	3.6	5	6x7.25x7.58
FPE 4.2ci	1.92	1.42	1	4.2	5.5	6.5	6.5x8.3x9.3
FPE 5.8ci	2.17	1.57	1	5.8	5.9	9.5	7x8.1x9.5
Fuji							
Bt-32A	1.14	1.49	1	1.5	3.74	2.2	7.5x5x4.4
Bt-86	1.18	1.68	2	3.7	6.38	7.5	7.75x8.6x3
Bt-50SA	1.26	1.69	1	2.1	5.28	5.2	8.5x5.5x4.8

ENGINE	BORE (IN.)	STROKE	CYLINDERS	DISPLACEMENT (CI)	WEIGHT (LB.)	HORSEPOWER	OVERALL DIMENSION (IN.)
Quadra-Aerrow							
A 150B	1.97	1.5	2	9	9.5	13.5-17	7.8x10x8.8
A 200B	2.25	1.5	2	11.9	11.3	17-21	7.8x10.3x8.8
A 200RSS	2.25	1.5	2	11.9	10.4	23.5-27+	7.8x10.3x8.8
Q 1000B	1.65	1.5	2	6.4	6.5	9.4 min.	6.1x10.3x6.8
Q 100B	2.25	1.5	2	6	6.9	9.5-11.9	9x6.8x6
Q 100M	2.25	1.5	2	6	8.3	9.5-11.9	9x6.8x6
Q 100RSS	2.25	1.5	2	6	6.6	11.5-16+	9x6.8x6
Q 400B	1.58	1.18	1	2.3	3.19	3.9	6x5x6.38
Q 400M	1.58	1.18	1	2.3	4.16	3.9	6x5x6.38
Q 52B	1.65	1.5	1	3.2	4.1	4.5	7.6x5x6
Q 52M	1.65	1.5	1	3.2	5.1	4.5	7.6x5x6
Q 65M	1.88	1.44	1	4	6.5	6.8	8.6x6.2x6.95
Q 75B	1.97	1.44	1	4.4	5.2	8-10	8.6x6.2x6.95
Q 75M	1.97	1.44	1	4.4	6.5	8-10	8.6x6.2x6.95
Q 75RSS	1.97	1.44	1	4.4	5.1	10-12	8.6x6.2x6.95
RC Showcase							
RCS 140	INS	INS	1	1.4	1.75	2.9	4.5x2.35x3.6
RCS 180	INS	INS	1	1.8	3	4	7.3x4x4.92
RCS 215	INS	INS	5	13.1	12	13.5	11.5x7.9
RCS 44 B2	INS	INS	2	2.8	4.2	4.8	10.5x4.5x7.25
RCS 75	INS	INS	1	4.6	5	7.5	7.88x4.3x5
RQ Model Products							
Cheetah 42	INS	INS	1	2.5	4.5	3	5x6x6.5
Cheetah 42DX	INS	INS	1	2.5	3.9	3	5x6x6.5
Taurus Engines							
TS 42	INS	INS	1	2.6	3.13	3.9	5.9x5.6x5.44*
TS 52	INS	INS	1	3.2	3.31	5	5.8x2.58x4.61*
TS 62	INS	INS	1	3.7	4.5	5.8	7.29x3x5.13*
TS 69	INS	INS	1	4.2	4.75	6.4	7.29x3x5.13*
TS 72	INS	INS	1	4.4	4.94	8.1	6.68x3x4.8*
TS 95	INS	INS	1	5.8	5	7.2	7.29x3.22x5.55
TT 85	INS	INS	2	5.2	4.5	NS	INS
TT 107	INS	INS	2	6.6	NS	NS	INS
TT 122	INS	INS	2	7.5	NS	NS	INS
TT 144	INS	INS	2	8.8	NS	NS	INS
TT 185	INS	INS	2	11.4	NS	NS	INS
TT 240	INS	INS	2	14.6	NS	NS	INS
US Engines							
US 35cc	1.57	1.28	1	2.5	4.5	2.4	6.5x6x6
US 41cc	1.44	1.28	1	2.1	4.5	3	6.5x6x6
ZDZ							
120 B2 RV	1.77	1.50	2	7.3	6.4	10.5	12.6x3.3x7.8
160 B2 RV	2.05	1.50	2	9.8	6.6	16	12.75x3.3x7.7
210 B2 RV	2.05	1.97	2	12.8	9.6	21	14.3x3.9 x10.8
40 RV-L	1.50	1.38	1	2.4	2.9	4.8	6.2x3.35x5.2
60 RV	1.77	1.50	1	3.7	4.2	5.4	7.75x3.33x5.9
80 B2 RV-L	1.50	1.38	2	4.9	4.2	8.1	11.5x3.33x7.95
80 RV	2.05	1.50	1	4.9	4.3	8.5	11.5x3.33x7.95
Zenoah							
G-23	1.3	1.1	1	1.4	3.19.	2.0	7.09x6.67x7.09
G-38	1.5	1.3	1	2.3	4.19	2.5	7.72x3.55x5.38
G-45	1.7	1.2	1	2.8	4.31	3.3	7.99x3.94x6.78
G-62	1.9	1.4	1	3.8	4.56	4.75	8.55x3.94x6.75
GT-80	1.2	1.2	2	4.9	6.75	5.8	7.99x3.94x6.78

INS = Manufacturer did not supply info.
**Height is from crankshaft center to top of cylinder.*

the magic of radial engines

BY GERRY YARRISH · PHOTOS BY DERON NEBLETT

An old aviation adage says: "The only real airplanes have two wings and round engines!" It's that second part—the round engines—that makes a model airplane really stand out. There's something magical about radial engines; whether they have three, five, seven, or nine cylinders, round engines capture everyone's attention. The sound is unmistakable, and the look? As I said, they're in a class all by themselves.

This guide highlights some of the most popular radial engines available today. Whether you love classic civilian biplanes, early turn-of-the-century WW I dogfighters, or round-nose WW II warbirds, there's a radial engine to hang on each plane's nose. Let's check out some of this round-engine magic!

DESIGN BASICS

Though this article is specific to the radial engine, there are two types of round engine. The earliest was the rotary engine, and in this configuration, the propeller was attached to the engine case and the rear-facing crankshaft was attached to the airframe. The engine and prop revolved in unison around the fixed crankshaft. This was the most popular engine type during WW I and was used by almost all countries to power many of their flying machines (see "Replica Engines" sidebar).

Developed soon after WW I, the radial engine had its case mounted solidly to the airplane, and the propeller was attached to the crankshaft. Powered by multiple pistons moving up and down in their cylinders, the crankshaft faced forward. Both engine types were air-cooled. Basically, a radial engine is made up of multiple 4-stroke cylinders attached to a common engine case. Each cylinder has its own intake and exhaust valves, and commonly, a single carburetor feeds all the cylinders. For exhaust systems, radials have either individual exhaust stacks or they are attached to a single collector ring. Either way, the sound of a running radial is unforgettable!

Above left: almost all radial engines are equipped with a single, rear-mounted carburetor feeding each cylinder with its own induction tube. Second from left: to expel its spent fuel charge, each cylinder has a short exhaust stack. Center: many engines have an optional exhaust-collector ring that's attached to each cylinder's exhaust stack; the ring directs all the exhaust to a single outlet. Second from right: in 4-stroke engines, each cylinder head contains valves and rocker arms. On the RCS 215, the rocker arms and pushrods are exposed! Far right: the Robart R780 has enclosed rocker arms, and the pushrods are inside the rod tubes.

ONBOARD IGNITION

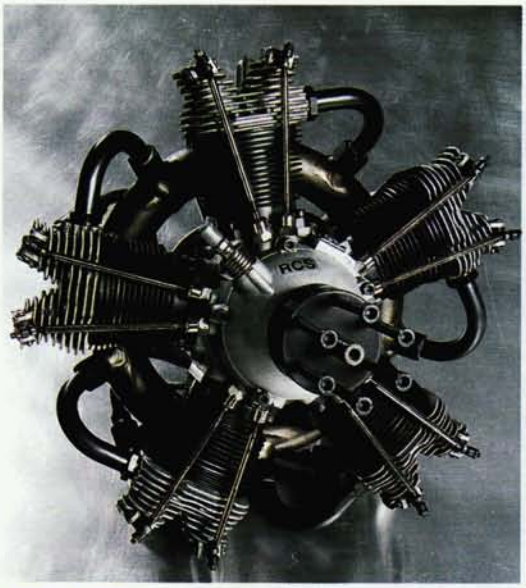
Several radial engines come with their own ignition system, or they're available separately from the engine's distributor. Some do not come with an ignition system, but a recommended aftermarket system is usually available. For several reasons, radial engines should be equipped with an onboard ignition system.

Each cylinder has its own glow plug, and it is very difficult—if not impossible—to use several hand-held glow-driver batteries to start a radial engine. Chances are that a battery igniter could flip off the plug and hit the prop; not good!

The onboard ignition system is the best setup; it is wired with enough connector caps and leads to power each plug, and the caps are securely locked onto the plugs. A rechargeable battery pack supplies power to all of the plugs and is turned on and off with a master ignition switch. All you do is flip the switch and start the engine.

Many ignition systems can also be controlled by the position of the throttle stick. Typically, the ignition system supplies power to the plugs when the throttle is below ¼. As the throttle is advanced to ½ or ⅔, it shuts off because the engine is operating at high enough rpm, and the increased heat keeps all the plugs lit. This type of setup is recommended for two reasons. First, it conserves power because the battery doesn't keep the plugs energized all the time. Second, when the throttle is lowered for cruising around and for landing, the engine turns at lower rpm. This cools the plugs and decreases the chances that one or more of the plugs will stop working. Losing one or more plugs greatly reduces the engine's power. The best way to maintain a happy radial engine is to keep all of its plugs firing.

Top: the engine installation for Nick Ziroli's Stearman PT-17. Notice the multiple orange ignition-system wires that lead to each of the Robart R780's glow plugs. Below left: most radial engines are 4-stroke, glow-powered engines. Each cylinder head has one or more glow plugs. Below right: many radial-engine makers recommend the McDaniels onboard ignition system. It is available in several versions for single- and multi-cylinder engines up to 18 cylinders! Bottom right: the onboard ignition module from the RCS 215 engine. Note the robust wire connector for the gasoline-ignition engine.



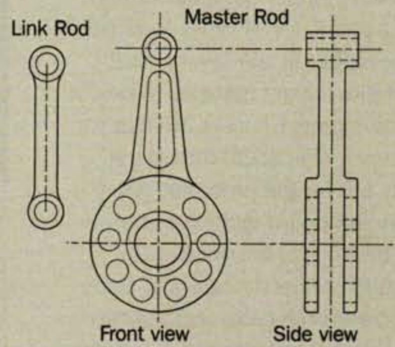
RCS 215

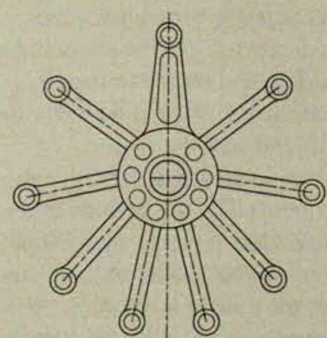
No. of cylinders: 5
Displacement: 13.1ci (215cc)
Bore: 1.535 in. (39mm)
Stroke: 1.417 in. (36mm)
Power output: 13.5hp (turns a 30x12 prop at 5,600rpm)
Weight: 11 lb.
Major diameter: 12.25 in. (311.15mm)
Price: $2,375
Comments: this big radial runs on gasoline and comes with a 4.8 to 6V microprocessor-controlled, auto-advance onboard ignition system. It has a 6-bolt prop hub and uses miniature NGK CM-6 spark plugs. A standard choke-equipped Walbro carb is positioned center aft on the engine case and inside the circular cast-aluminum engine mount.

RC Showcase (301) 374-2493; rcshowcase.com.

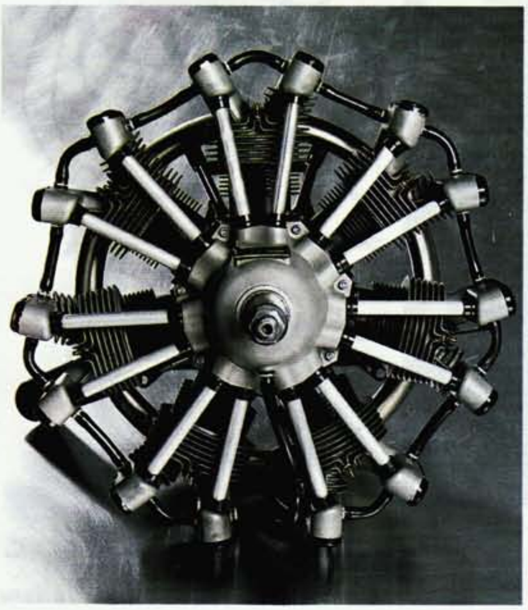
The radial connection

To build a radial engine, you can't just take several single-cylinder engines and stick them all together with a common crankcase. The challenge lies in joining all the connecting rods to a single crankshaft. Unlike a conventional multi-cylinder engine, a radial engine has all its pistons arranged on a single plane, and only one connecting rod (the master rod) is attached to the crankshaft. All the other connecting rods (link rods) are attached to the bottom of the master rod. The large web of the master rod follows the path of the crankpin and transfers the power from all the pistons to the crankshaft. Pins similar to the wristpins that connect the pistons to the connecting rods attach the link rods to the master rod's web. This simple setup works very well and contributes to the radial engine's reliable power output.





This illustrates how the many cylinders and pistons are connected to a single output. The master rod and link rods that are connected to it form the mysterious, spider-like connection that's inside every conventional radial engine.



ROBART R780

No. of cylinders: 7
Displacement: 7.8ci (128cc)
Bore: 1.125 in. (28.57mm)
Stroke: 1.125 in. (28.57mm)
Power output: 10hp (turns a 26x12 prop at 5,500rpm)
Weight: 7.65 lb.
Major diameter: 10 in. (254mm)
Price: $4,000
Comments: the Robart R780 is a 22.5-percent-scale miniature of a Jacobs 7-cylinder radial engine. The output shaft has a 6-bolt prop adapter that is slipped over a tapered brass collet and is attached to the main output shaft with a single nut in the center. Pistons feature twin rings, and the hemi-head design uses large valves with steel seats and bronze guides. Roller lifters and ball bearings are used throughout, and the engine is equipped with an oil pump. A boost fan aids air intake. A steel tube mount with rubber dampers is included. Collector-exhaust ring and 7-cylinder onboard glow driver, battery and charger are available separately.

Robart Mfg. (630) 584-7616; robart.com.

O.S. SIRIUS FR5-300

No. of cylinders: 5
Displacement: 3.035ci (49.763cc)
Bore: 0.945 in. (24mm)
Stroke: 0.866 in. (22mm)
Power output: 4hp at 8,500rpm
Weight: 5 lb. 5 oz.
Major diameter: 9.25 in. (234.95mm)
Price: $1,400

Distributed by Great Planes Model Distributors

SAITO FA-325R5D

No. of cylinders: 5
Displacement: 3.234ci (53cc)
Bore: 0.976 in (24.8mm)
Stroke: 0.866 in. (22mm)
Power output: 3.8hp (turns 20x8 to 20x10 props)
Weight: 84.86 oz. with muffler
Major diameter: 9.125 in. (231.775mm)
Price: $1,450
Comments: this powerful 5-cylinder, 4-stroke ABC engine is equipped with two glow plugs per cylinder (10 total). To start the engine, only the rear five plugs need to be lit; the front plugs come online after the engine reaches operating temperature. The engine comes with a strong, formed-metal engine mount with mounting hardware, engine primer lines and fittings, a fuel primer injector, five short exhaust stacks and five glow-driver attachment wires with plug clips attached. It also includes basic tools and a high-efficiency fuel filter.

Horizon Hobby (800) 338-4639; horizonhobby.com.

Saito also offers the FA-170R3 ($799.95) and FA-450R3D ($1,069.95) 3-cylinder radial engines.

RADIAL CARE & OPERATION

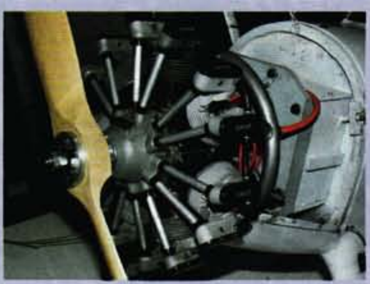
Well-known scale-RC designer Nick Ziroli Sr. has been flying for many years and has used all types of engines to power his designs. Nick was one of the first modelers to operate the Robart 7-cylinder R780 engine, and he has used it in a number of his competition models. Here's what Nick says about operating and caring for round engines.

One of the great things about radial engines is their scale appearance. This and their smooth operation make them ideal for many scale models. The Robart R780 is, in fact, a 22.5-percent-scale copy of a Jacobs 7-cylinder engine. It has enclosed rocker arms and pushrods and a welded, steel-tube engine mount. I have flown both my 87-inch-span Stearman PT-17 and my 100-inch SBD Dauntless dive-bomber with the R780.

For fuel, I use my own mixture of alcohol, 8-percent Klotz Benzoil and just a kick of nitro to improve its idle. Typically, I run a 24x12 prop. On my Dauntless, I flew with a 3-blade 25x12 that gave very good performance. I use a McDaniels onboard glow driver and O.S. F plugs to fire all the cylinders.

To start the engine, I close the choke, turn it over a few times, advance the throttle slightly and hit it with my belt-reduced Miller RC starter; when it starts, I open the choke. I use a 3000mAh battery for the onboard glow driver, and it is set to supply power only when the throttle is below ¼. This makes engine starting easy, and it ensures that the engine operates reliably at idle and at reduced throttle settings. I charge the glow-driver battery between each flight.

For extended engine storage, I run the engine dry of fuel and then remove the cylinder-head oil-supply line from the crankcase. I add a bit of after-run oil (Marvel Mystery Oil) and turn the engine over several times to draw it into the crankcase. Aside from checking valve clearances, very little maintenance is required to keep the R780 happy. —Nick Ziroli Sr.



Nick Ziroli's new Stearman PT-17 is an ideal candidate for a radial engine. Powered by the Robart R780, the biplane looks and flies very scale! Left: close-up of Nick's engine installation.

SAITO FA-90R3

No. of cylinders: 3
Displacement: .92ci (15.09cc)
Bore: 0.787 in. (20mm)
Stroke: 0.629 in. (16mm)
Power output: .95hp (turns 13x6, 13x8, 14x6 props)
Weight: 29.98 oz. with muffler
Major diameter: 7 in. (177.8mm)
Price: $699.99
Comments: the FA-90R3 3-cylinder, 4-stroke engine is the smallest in Saito's radial lineup and is ideally suited to .60 to .90 biplanes and other models with round engine cowls. It has a formed-metal engine mount, ABC cylinder/piston construction and a single, rear-mounted, twin-needle carb. Basic valve-adjustment tools, three glow-plug driver wires and three short exhaust pipes are also included.

Distributed by Horizon Hobby (800) 338-4639; horizonhobby.com.

Replica Engines Gnome Monosoupape Rotary

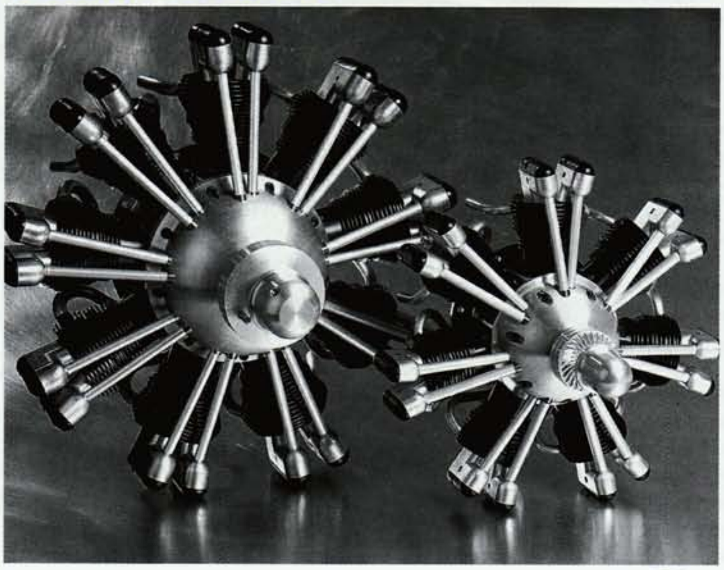
No discussion of round model engines would be complete without mention of the Replica Engines rotary Gnome. This ¼-scale miniature is an exact copy of the engine made famous during WW I, and it operates in exactly the same way: the prop and engine case revolve around the fixed crankshaft. If you are a lover of giant-scale Great War aeroplanes, this is the ultimate powerplant for you!

Engine: ¼-scale 1913 Gnome Monosoupape Rotary
Number of cylinders: 9
Displacement: 3.97ci (65.057cc)
Bore: 0.750 in. (19.05mm)
Stroke: 1 in. (25.4mm)
Prop: 24x10
Rpm: 2,800
Price: $3,800
Comments: first used around 1909, the full-size Gnome was the first really successful aircraft engine, and all future rotary engines were variations on its simple, effective design. The single-valve Gnome had no carburetor as such; air and fuel entered the engine through the stationary, hollow crankshaft, then entered the cylinders via a series of ports opened by the piston at the bottom of the intake stroke. The valve timing was such that air was admitted into the cylinders at the end of the exhaust stroke. The cylinder was already filled with air when the very rich fuel mixture was admitted through the ports. The air/fuel mixture was then compressed and combusted to complete its power cycle. The engine had no throttle and ran wide open, or not at all. An interrupt-ignition switch cut power to some, or all, of the spark plugs to control engine rpm.

The Replica Engines ¼-scale Gnome faithfully reproduces the design and operation of the full-size engine. It has 4-cycle, ported intake and poppet-valve exhaust, a hardened, ground crankshaft and valves, roller cam followers and ¼-32 spark plugs. An electronic-ignition and coil system is also available.

Replica Engines

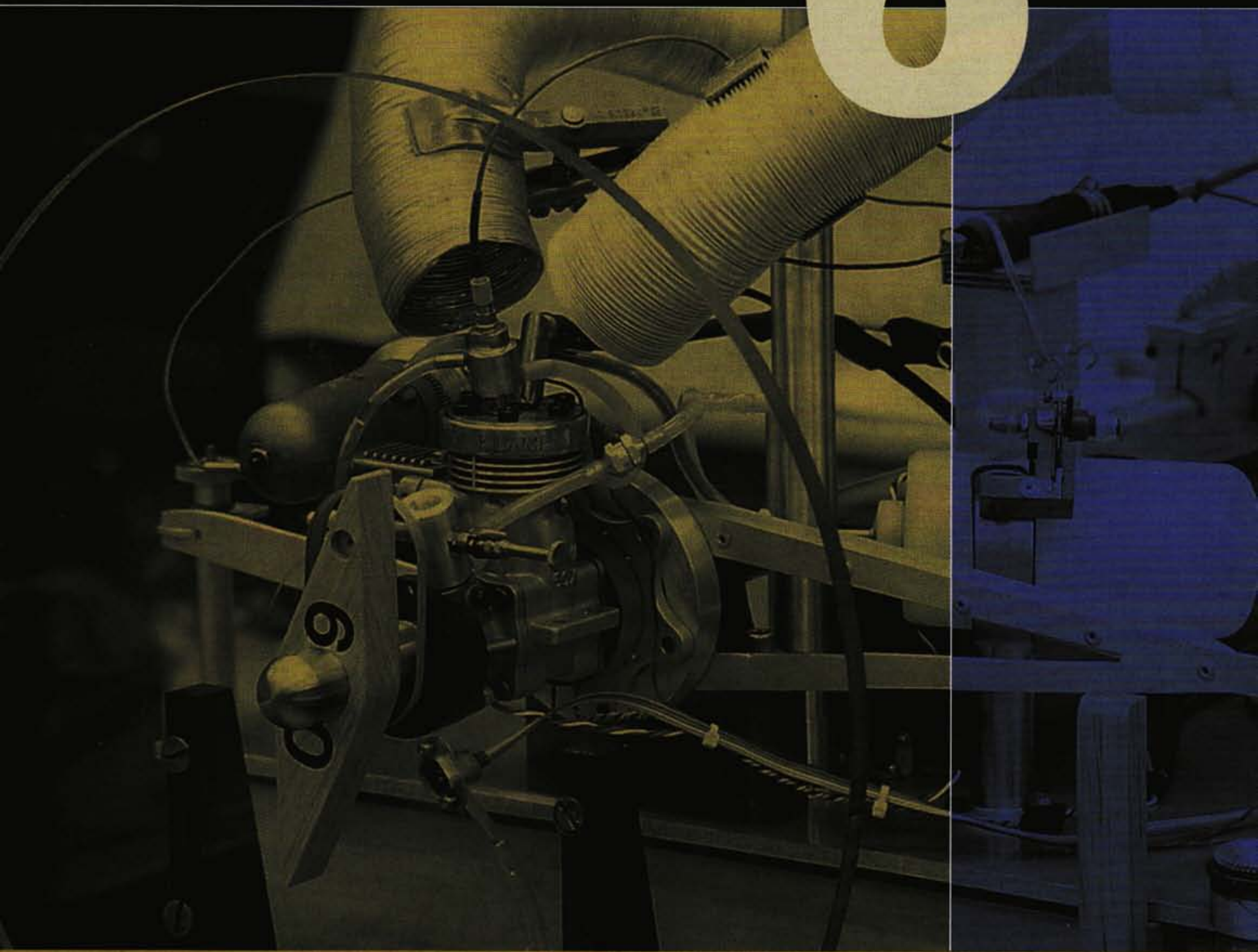
TECHNOPOWER 9C



Number of cylinders: 9
Displacement: 4.06ci (66.51cc)
Bore: 0.875 in. (22.23mm)
Stroke: 0.750 in. (19.05mm)
Power output: turns 18x8 to 24x6 props
Weight: 73 oz.
Major diameter: 9 in.
Price: $2,580 (call for pricing updates as engine development continues)
Comments: under new management, TechnoPower has plans to re-release four of the company's most popular radial engines—the 7A (0.625-in. bore), 7B (0.750-in. bore), 9B (0.750-in. bore) and the 9C (specs above). TechnoPower is updating the engines' designs and drawings using CAD programs and upgrading engine materials and manufacturing processes. The first engine to be offered will be the 9C along with an optional exhaust-collector ring and an engine mount. The 7-cylinder 7B (⅙ scale) and the 9-cylinder 9C (⅕ scale) are shown.

TechnoPower Engines (800) 741-8150; technopower.com.

Q & A 6



engine tech Q & A

BY DAVE GIERKE AND CHRIS CHIANELLI

UNRELIABLE 4-STROKE

Q I bought a Thunder Tiger F-91S during a stay in Manhattan, but I've never been able to get it running smoothly in an airplane; that's why it has mostly been sitting in a box. The engine has been broken in nicely (according to the manufacturer's specifications) on a Graupner 11x11 propeller; I used a test bench to do this. I've now fitted the engine with an APC 13x9 prop running at top revs of 10,500rpm, static. The fuel I use is 5-percent nitro with 18-percent castor oil. (I'm not sure about this because the manufacturer doesn't specify oil content or type, although it certainly has castor in it.) The fuel is claimed to be suitable for 2- and 4-stroke engines.

When mounted in an airframe, the engine performs well when flying horizontally, but it leans out drastically when the nose is pointing upward. When I set the high-speed needle valve, it takes only four "clicks" to run it either lean or too rich, and both show as a power loss. When the high-speed needle is set rich on purpose, the engine still leans out excessively on vertical climbs, and it stops at a nose-down attitude due to the extremely rich mixture.

A conventional clunk-type plastic tank is used with exhaust pressure; I have tried setting the tank as close as possible to the engine; I disassembled the engine and fuel system to check for leaks (none found); I checked the piston and cylinder for excessive wear or signs of overheating (none found), and I re-lapped the valves on their seats. Compression is very good for a ringed engine; I used an O.S.-F plug throughout.

Dave, I'm absolutely lost. I've never lost an airplane in all my years of flying 2-stroke engines, and I don't intend to let it happen with an unreliable 4-stroke.

Saito 1.50 Black Knight

A *Since your engine leans out in a vertical climb, runs dead rich in a dive and you haven't found fuel-system or engine air leaks, it suggests that the problem originates elsewhere. I'm suspicious of your fuel; anytime the ingredients and percentages aren't disclosed on the label, a red flag should go up.*

Three factors are critical to successful 4-stroke engine operation: type and percentage of lubricant in the fuel blend; glow-plug type; and nitromethane percentage in the fuel blend.

Although I usually recommend using a liberal percentage of castor oil in 2-stroke fuel blends, it isn't a good idea with 4-stroke engines. Here's some background: in 1979, when the first modern production 4-stroke engine was released (O.S. FS-60), many of us tried using standard 2-stroke glow fuel with all-castor-oil lube; after all, castor provided the best protection against damagingly hot, lean runs (and still does). Although the new engine was able to fly our models, it ran roughly at wide-open throttle (WOT), had poor throttling characteristics and a narrow needle-valve range between rich and lean operation.

The late George Aldrich discovered that by reducing the fuel's oil content from 20 to about 14 percent (by volume), the engine ran much better. George guessed that castor oil droplets in the 20-percent mix cooled the glow plug's heating element during the non-firing portion of the cycle and caused a misfire or flameout. Because 4-stroke engines fire only once on every other revolution of the crankshaft (half as often as their 2-stroke counterparts), his theory made sense. Although the lean oil trick worked OK, it didn't leave room for mistakes; inadvertent lean needle-valve settings quickly deprived the engine of vital lubricant and wal-

lowed-out bearings, wristpin bores and scored pistons.

Today, we have a better understanding of the problem and how to handle it. First, "hot" 4-stroke glow plugs have been developed to help continue ignition from cycle to cycle. Your choice of the O.S.-F plug is a good one. Second, castor-oil content has been severely curtailed or eliminated altogether in 4-stroke fuel blends. Why? Castor oil does a very effective job of carrying away excess heat—not a good thing with relatively cool-running 4-stroke engines. The next time you're at the flying field, identify two models powered by 2-stroke-cycle engines: one that uses all synthetic oil and one that uses all castor oil in the fuel blend. After each engine has been started, warmed and adjusted to peak power at WOT, place a finger or two in the exhaust stream far enough behind the muffler outlet to avoid getting burned but close enough to feel the heat. You may be surprised to find a cooler exhaust with synthetic lube. Synthetic oils do a better job of lubricating than they do of cooling the 4-stroke engine; a greater percentage of the engine's waste heat, with its higher temperature, is carried over to the next cycle and helps to keep the plug element hot.

Finally, increased percentages of nitromethane release more heat into the cycle, and that enhances glow-plug operation. Four-stroke engines tolerate elevated percentages of nitro, although cost is a concern; however, since the 4-stroke is more fuel-efficient than a 2-stroke, fuel expenses are somewhat offset.

Your fuel is deficient in two of three areas: it's too low on nitro content, and you're using the wrong type of lube; try some 15- to 20-percent-nitromethane fuel with 20- to 22-percent synthetic lubricant; I think your engine will like it.
—Dave Gierke

4-STROKE BREAK-IN

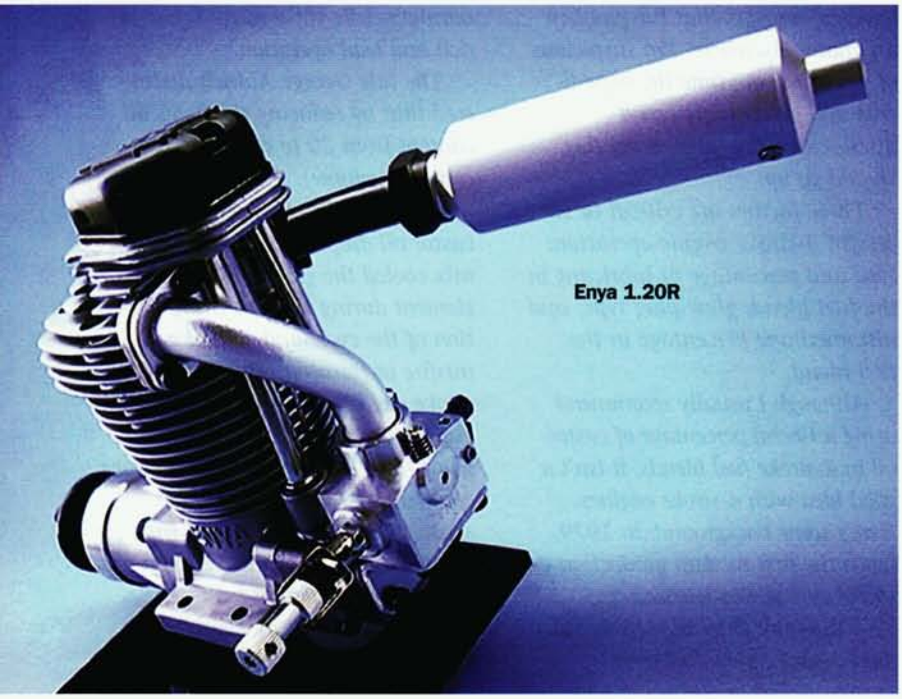
Q I have heard several methods and different advice on 4-stroke break-in procedures. Some say that the manufacturers' directions are not the best way to break in new 4-strokes. Can you help?

A *After reading about break-in procedures for 4-stroke engines in dozens of instruction manuals, I'm also left scratching my head. Without reviewing all of the contradictory information, allow me to detail how I handle the situation: since the vast majority of 4-stroke engines have ringed pistons, I break them in as I break in ringed 2-stroke engines for which the words "cool" and "oily" are most important; "cool" is generated by a rich needle setting, and "oily" is provided by the lube percentage (see the previous letter).*

Since most manufacturers recommend that their engines be run at ½ throttle at the beginning, that's what I do—with a rich primary needle-valve setting; this ensures that the connecting-rod bushings and valve-train components are polished up a bit before break-in is attempted for real. I do this for 10 minutes, 2 minutes at a time, with a recommended flight propeller. Undersize props are not used for 4-stroke break-in as they are with 2-strokes; 4-strokes need some flywheel effect (weight) to carry them through the cycle; plus we don't want to float the valves by over-revving. Finally, use the fuel you intend to use for flying.

Next, operate the engine at WOT for relatively short periods (2 minutes) with a rich needle setting (about 1,000rpm off-peak) while using the same prop and fuel. The idea is to heat the piston/cylinder set and then allow complete cooling, over and over again (full operating temperatures won't develop at ½ throttle). This is called heat cycling; it stress-relieves the components, and that is what break-in is all about in modern engines.

After at least an hour of running in this manner, peak the rpm (adjust the primary needle valve) and use a tachometer to measure the engine's operation; if it holds steady without misfiring or running roughly, it's probably ready for you to set the idle and check the throttle-up characteristics. Don't waste your time trying to fine-tune the idle before the engine



Enya 1.20R

has been completely broken in; in addition to ensuring satisfactory cylinder pressure and torque, a properly seated piston ring controls fuel draw and idling.—DG

THROWN PROPS

Q After carefully reading the instructions, I spent several days trying to get a Thunder Tiger .54 to run. Unfortunately, two out of three times, the engine spits back and throws the prop! Then it runs OK if not provoked (e.g., by a quick throttle-up or nose-high operation). I have changed the fuel lines, the tank, the propeller, the glow plug, etc., but nothing works. I can get it running smoky (rich), but after I let it cool down, the next start-up produces a bang, and the prop is loose again! I estimate that this engine has spent about 20 minutes in the air and 12 hours on the test stand. Do you have any suggestions?

A *It sure sounds as if you aren't having much fun! The kickback that results in loose and thrown propellers is the result of detonation—a combustion defect. Detonation is produced when the original flame front, which is pressurizing the unburned mixture in front of it, progresses at such a rate that this mixture combusts spontaneously when it reaches its auto-ignition temperature. The burn rate within this zone is many times faster during normal operation; this causes a sharp spike in temperature and pressure before the piston reaches top dead center. In automotive engines, this is referred to as "pinging" or "knocking." In addition to mechanically damaging the piston crowns, cylinder-head chambers and other engine components, the piston (primarily in single-cylinder engines) is often forced to reverse direction; we know this as "kickback."*

Causes of detonation include lean air/fuel ratio; elevated compression ratio; unsuitable nitromethane content and atmospheric conditions.

O.S. FS-70II

- ***Air/fuel ratio.*** *Many 4-stroke engines will detonate if the engine is set too lean; trying to squeeze out the last couple of hundred rpm by screwing in the needle valve a bit more will often produce detonation or kickback, and it may loosen or throw the propeller.*

- ***Elevated compression ratio.*** *When a glow engine's compression ratio is increased, the compression pressure and temperature increase, and so does the chance of detonation. To make matters worse, the increased compression forces the ignition process to begin earlier during the compression stroke by adding heat to the plug element. The best fix for an over-compressed, detonating engine is to add head shims to reduce the compression ratio.*

- ***Nitromethane content.*** *Nitro is the power-boosting, heat-generating chemical in a glow engine's fuel blend. Although 4-stroke engines generally tolerate greater heat loads than 2-stroke engines, there are limits to the nitro percentage that can be tolerated before the onset of detonation. Depending on the engine's design, using between 20 and 50 percent nitro often requires reducing the compression ratio from that provided by the factory. Do this by adding head shims.*

- ***Atmospheric conditions.*** *Detonation often occurs when ambient conditions are hot and dry; conversely, cool, humid days reduce its likelihood. Juggling prop load and/or nitro content will help to control detonation to suit the prevailing conditions.*

Never lean the engine to or beyond its maximum rpm. It's very easy to produce a lean, detonation-plagued run; back off a couple of hundred rpm. Before you remove the cylinder head to prepare for the addition of a head shim, try running the engine with less propeller load (diameter and/or pitch); by allowing the engine to speed up, you'll reduce the effective compression ratio and retard the ignition point (both help to *reduce the likelihood of detonation and kickback). In addition to taking heat out of the system, reducing the fuel's nitro content automatically retards ignition, and this also reduces the likelihood of detonation.*

No, I haven't forgotten the glow plug. There are scores of glow plugs on the market, each with a unique wire element that has a heat-retaining capacity. Since a plug's "heat range" influences the engine's ignition point, your choice of plug can help to provide detonation and kickback control. Unfortunately, there is no universal standard for rating glow plugs' heat-retaining capacity; every plug manufacturer has its own standard. The problem can be simplified by saying that the 4-stroke engine usually requires a very hot plug; the O.S. type F plug has been proven to work well; but don't let this stop you from experimenting with others.—DG

FOULED FOX

Q I have owned a Fox .19 for several years, and it has never been run. I tested the engine the other day and discovered that I could not turn it over. The throttle barrel had also seized. What is the best way to loosen up this engine?

A *Your Fox .19 is probably gummed up; the factory ran all new engines on castor-based fuel before it sent them out. Over a period of years, residual castor oil within the engine thickens, producing the gumminess. To correct this, first attach a propeller securely to the shaft. Next, wearing an old oven mitt for protection, heat the engine a bit with a propane torch; be careful to keep the flame moving. When the castor begins to smoke, stop. Using the prop for leverage, apply a light to moderate twisting force (careful; you don't want to break the connecting rod) to the shaft; the castor-oil gum should have softened. If not, heat it a bit more. When the engine has broken free, it should then be disassembled and cleaned with an engine cleaner such as Demon-Clean. —DG*

NITRO: HOT OR COLD?

Q Does a higher percentage of nitro in fuel make the engine run cooler or hotter? I have heard people argue this issue both ways.

A *Nitro's heating ability—or lack thereof—reminds me of what control-line speed champion Luke Roy said 30 years ago concerning the same controversy: "The continued addition of nitro to a fuel blend will eventually cause the engine to freeze."*

K&B's 2-speed Torpedo .19 engine.

Luke's tongue-in-cheek statement equates freezing with piston seizure—the unfortunate and often catastrophic result of nitro's heating effect on certain engine types.

The truth is, the higher the fuel's nitromethane percentage, the hotter the engine runs. The technical explanation for this phenomenon is a bit complicated, but many readers want to know about fuel, so let's give it a try.

As the percentage of nitromethane within a given fuel is increased, more power and heat are produced within the engine. This happens because increased chemical/thermal energy passes through the engine during a given period of time. Nitro has a very low heating value—pound for pound, about the same as burning firewood (5,000 British thermal units [BTU] per pound)! In contrast, gasoline has a heating value of almost 20,000 BTU per pound—better than nitro by a factor of 4. So why is nitro such a powerful ingredient?

The answer is in the fuel-to-air ratio (F/A). The "A" in the F/A ratio refers to the mass of air that the engine is capable of inducting because of its design and the prevailing atmospheric conditions. Since piston engines are air pumps, fuel must be added in the correct proportions if combustion is expected to occur efficiently. Nitromethane has a peak power F/A ratio of about 1:1 (or higher), while gasoline's peak power F/A ratio is roughly .1:1—1/10 that of nitromethane. Because 10 times the weight of gasoline can be added to engine air in the form of nitromethane, its low heating value is more than offset. Example: if an automotive drag-race engine consumes 10 pounds of nitro per second, this is equal to 50,000 BTU/sec. (5,000 BTU x 10 lb./sec.), while 1 pound of gasoline per second is only 20,000 BTU/sec. (20,000 BTU x 1 lb./sec.). In terms of energy delivered per unit of inducted air, nitro is better than gasoline by a factor of 2½ during the same delivery time period. Of course, we don't use 100 percent nitro in our fuel, so the advantage over gasoline is reduced, but it is still substantial.

There's much more to the story of nitromethane, including its aggravating habit of detonating (combustion defect), which limits the engine's compression ratio, and a real thirst that requires very large tanks. Add its cost (about $35 per gallon), and you can see why some modelers switch to other fuels. —DG

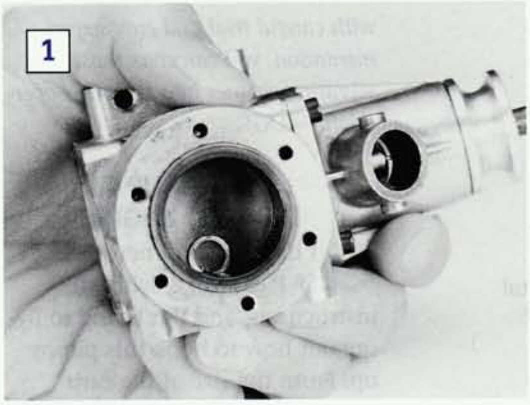


Photo 1. Place the copper glow-plug washer on top of the piston with its edge protruding into the sleeve's exhaust port. 2. Uniformly heat the upper crankcase with a low flame; hold the engine with an insulated glove (I use High Heat gloves). 3. The sleeve as it emerges from the crankcase.

UNCOOPERATIVE FOX

Q Can you tell me how to get the wristpin out of the connecting-rod assembly of a Fox .50? The piston doesn't have any wristpin retainers.

A *It sounds as if you have an early Fox .50 that has a meehanite (fine-grain, cast-iron) compression ring installed on an aluminum piston that runs inside a steel cylinder sleeve. Fox fastened the wristpin to the piston in a unique way; he drilled a hole through the bottom of the piston's wristpin boss and the wristpin. Fox then pressed a roll pin into place. If you have one of these engines, it's probably impossible to disassemble. If you clean the internal parts, leave this subassembly together. If the assembly needs repair, return it to the factory. Newer versions of the Fox .50 secure the wristpin to the piston with the more conventional E-clip.*

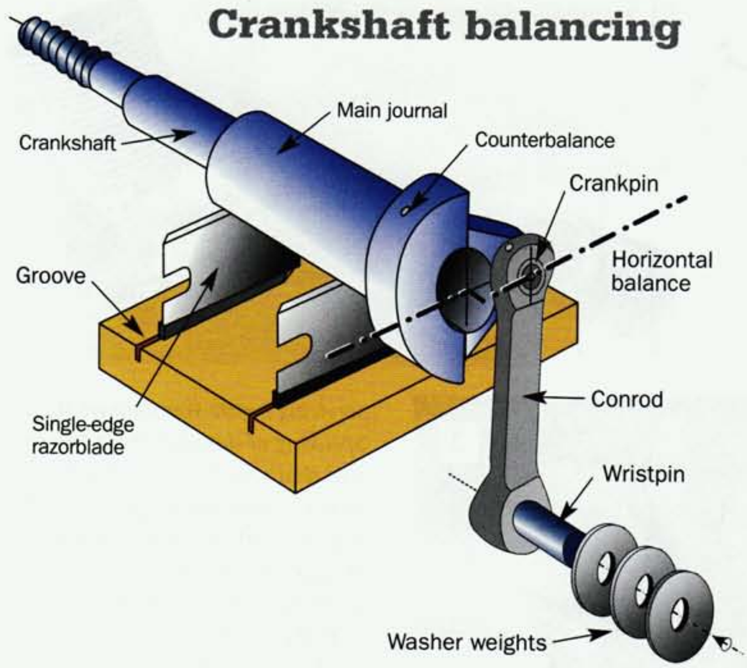
Many modelers become confused when they remove the piston-rod/wristpin subassembly from an engine that has a one-piece crankcase (no removable front housing or upper and lower segments). After the cylinder head and backplate (rear cover) have been taken off, you must first remove the cylinder sleeve and slip the conrod off the crankpin. To dislodge the sleeve, place a soft copper glow-plug washer on top of the piston so that it protrudes less than the thickness of the sleeve into the exhaust port (Photo 1). With a prop securely fastened to the crankshaft, turn the engine over until the washer engages the top of the port; if you lightly turn the prop, the sleeve should lift from the case. If it doesn't, don't force the issue! Instead, apply a few drops of 3-In-One oil (or a similar product) to the piston crown, and a little even heat from a propane torch to the upper crankcase (Photo 2). When the oil begins to smoke, stop heating and try again to turn the prop. In most cases, the sleeve will now slide right out (Photo 3). If it doesn't, send the engine back to the manufacturer for servicing before you damage it. Speaking of damage, never use any tool that's made from a harder material than the engine component you are working on. For example, the copper glow-plug washer is softer than the piston or sleeve material, so if you need to push on the bottom of the sleeve to remove it, a wooden ice-cream stick would be a great tool to use. —DG

BALANCING SINGLE-CYLINDER ENGINES

Q I'm looking for information on how to balance a single-cylinder engine. I believe this involves weighing the big end/small end of the connecting rod [along with] the piston, wristpin, etc., and calculating how much and where to grind material from the crankshaft.

A *Numerous formulas have been developed for balancing the single-cylinder engine, but all contain a flaw: single-cylinder engines can't be perfectly balanced for all rpm ranges. In other words, if the engine runs smoothly at one speed, it will run roughly at another. Balancing is a compromise, at best.*

The most commonly used formula suggests that all of the rotating (internal) engine parts and 50 percent of the reciprocating weight (back and forth motion) should be balanced by the crankshaft counterbalance. Because the conrod both rotates and reciprocates, weighing



individual ends is a difficult and inaccurate process—especially if you don't have a very accurate scale. Over the years, various methods for weighing rod ends have been suggested, but my old friend Clarence Lee has found a way. "If you balance all of the conrod and wristpin weight and 1/4 to 1/3 of the piston weight, you will be pretty darn close to having an engine run as smoothly as is possible." From this point, Clarence suggests that you add or remove weight from the crankshaft counterbalance by trial and error to discover the smoothest run within a given rpm range.

There are many variables associated with balancing an engine: stroke/bore ratio, rod length/stroke ratio, piston weight and the engine's primary operating speed range. Engine designers know that an engine's piston/wristpin weight must be kept as low as is structurally possible to reduce the inertia loads that increase by the square of shaft speed. Stated another way, if you double the engine's shaft speed, the reciprocating inertia forces increase four times (22 = 4). In general, short-stroke engine designs run more smoothly than their long-stroke, low-rpm counterparts.

Balancing can be performed on the crankshaft as it is supported by a homemade razor-blade balancer (see illustration). Hang the conrod on its own crankpin balanced by the wristpin, and decide which percentage of piston weight (slide flat washers onto the wristpin) you will start with.

If you determine that the crank's counterbalance is too light, how can you add weight? If the crank's counterbalance hasn't been hardened, you can drill it and fill the hole with lead or solder. As I've mentioned when discussing propeller balancing, you can also externally balance an under-balanced crank. With the piston at top dead center (TDC), position an unbalanced prop heavy-end down, adding to the counterbalance weight. Another way to achieve the same end is to add weight to the inside of a spinner backplate and fasten a washer/machine-screw combination into a drilled and tapped hole through the backplate in line with the crank's counterbalance.

All of this seems unscientific, but with careful trial and error experimentation, you can coax most vibrating engines into smoother operation. —DG

SETTING UP A PUMPED ENGINE

Q I have a brand-new O.S. .61 SF-P (2-stroke) without instructions, and I'm trying to figure out how to hook this puppy up. From the size of the carb opening, I would say that this machine gulps fuel quickly, so it's unlikely that it will work properly without the pump. I want to install this engine in my new 1/5-scale model. Can you help me?

A *Your O.S. .61 SF-P ringed engine is a side-exhaust, front rotary crankshaft-induction unit with a PA-102 fuel-pump system, which includes the O.S. Type 86 special carburetor.*

Since pumped engines are more expensive than standard suction-feed engines, what advantages do they offer?

- ***Extra power.** Enhanced power delivery throughout the maneuvers, regardless of aircraft attitude or fuel-tank location within the model.*
- ***Reliable operation.** Regulating fuel pressure during throttling (between wide-open and idle) allows better mixture ratios and throttle reliability.*

Although different pump systems have been developed over the years, the O.S. unit operates from positive and negative pressure pulses within the engine's crankcase that act on a diaphragm—similar to the well-known Perry pump system. The O.S. pump is fitted directly into the backplate with components that are sandwiched together. It has aluminum castings, a metal pump diaphragm, a plastic regulator diaphragm, valves, springs and gaskets. It has four inlet and outlet *nipples that are labeled on the pump's rear cover: an inlet (in) through which fuel is drawn from the tank; an outlet (out) to deliver fuel to the carburetor's primary needle valve; a return (R) that flows excess fuel back into the tank; and a nipple (S) that connects the pump-regulator chamber to the carb (below the throttle) to sense manifold pressure.*

The matching Type 86 carburetor has a massive 12mm bore that is only slightly restricted by a butterfly-type throttle valve (95 square millimeters). In addition to the high-speed needle valve, the carb has an automatic mixture-control valve that ultimately releases fuel to the spraybar at the center of the throttle butterfly. This valve is very easy to adjust by means of an eccentric screw head riding within a yoke. When correctly set for best idle performance, it automatically adjusts the air/fuel ratio throughout the throttle range. There aren't any other adjustments. The pump has two adjusting screws, but these are factory set and sealed; the owner is advised not to fiddle with these or disassemble the pump—under penalty of law! Seriously, if you take it apart, you may never get it back together again; it's that complex. Two final thoughts; the tank must be vented to the atmosphere and use an in-line fuel filter. —DG

HOT & COLD

Q When the weather gets warmer, you normally have to open the needle valve due to the temperature. When the weather is colder, do you run leaner because the air is "heavier"? This is a subject for discussion at our flying site. Here in northern Idaho, we fly year-round, even in snow.

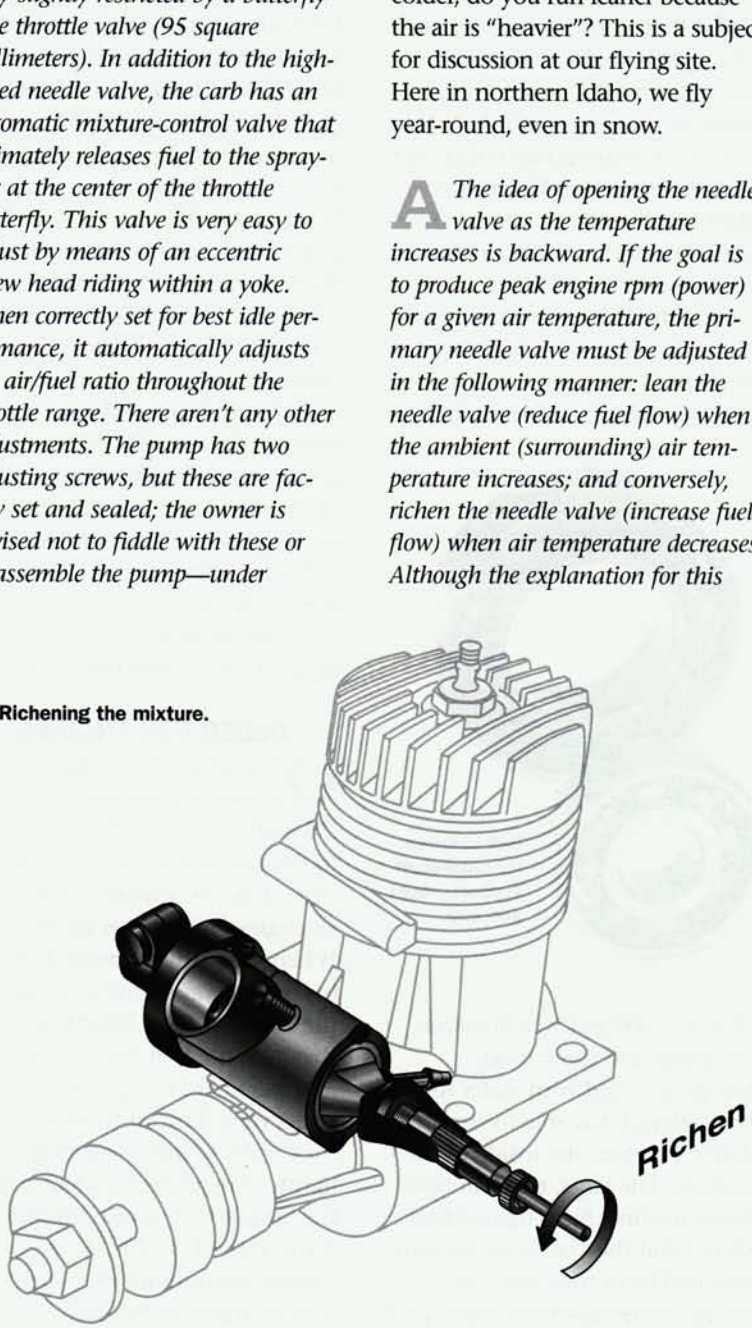
A *The idea of opening the needle valve as the temperature increases is backward. If the goal is to produce peak engine rpm (power) for a given air temperature, the primary needle valve must be adjusted in the following manner: lean the needle valve (reduce fuel flow) when the ambient (surrounding) air temperature increases; and conversely, richen the needle valve (increase fuel flow) when air temperature decreases. Although the explanation for this phenomenon is a bit lengthy, here's what happens:*

When a non-contained gas such as atmospheric air is cooled, its density increases. The opposite is true when it's heated. For our purposes, density may be defined as the quantity of material occupying a given space. The density of heated or cooled air changes due to the relative motion of nitrogen, oxygen and water-vapor molecules—most of what air is made of. Increased motion pushes the molecules farther apart; reduced motion moves them closer together. Increased density means more oxygen is available to the engine. For engines, the most important component of the air is oxygen. When mixed with fuel molecules, oxygen produces power after ignition and combustion. In terms of engine power, cool air is good, and hot air is bad.

The term "heavy air" is often used by modelers referring to hot, humid, summertime air. This has more to do with the physiological effects than with engine performance, which is relatively poor under these conditions. Your reference to wintertime "heavy air" corresponds to high-oxygen-density air.

Atmospheric pressure and humidity also have an effect on needle-valve settings and engine performance, but that's a story for another time. —DG

Richening the mixture.



FUEL-STARVED POWERPLANT

Q I hope you can help me with a problem I'm having with my MDS 1.48. The engine is mounted inverted and powers a Hangar 9 ¼-scale Cub. I originally used the remote needle-valve setup with very poor results. It seemed that no matter how much the engine was turned to the rich side, I could never get it to "four-cycle." At first I thought that I might have an air leak somewhere in the fuel system, so I replaced the [fuel] lines and used wire-ties to cinch down every connection—no luck. I've now eliminated the remote needle valve all together. Using the needle in the carb helped, but not much. Frustrated, I gave up; the Cub has been hanging in my garage ever since! I purchased a test stand, hoping to figure out the problem with the 1.48, but I didn't. Before I ran the engine on the test stand, it had about 20 ounces of fuel through it. I was finally able to get the engine running at a rich four-cycle, but it took seven (!) turns to the rich side on the needle valve. This seems excessive. I've tried the old trick of using a small piece of fuel line around the needle valve to eliminate air leaks, but that didn't work either. When I go from seven to six turns out, the engine runs at peak rpm; there is no adjustability. I've considered replacing the carb but have no idea what to replace it with.

A: It's a shame that you've had all this trouble with the MDS 1.48 2-stroke engine; it seems like a good match for the Cub. The first thing that comes to mind is, what size fu line are you using? You didn't say i. your letter. Is it the large variety or the medium? If the latter, I suggest that you change to the larger size. Fuel-flow rates can exceed 2 ounces per minute at a rich "four-cycling" mode of operation with this engine, and that's a lot of flow for medium size fuel line.

Another possible cause of the problem is a restriction within the carburetor itself. A piece of flashing or a chip from manufacturing processes could be lodged somewhere within the metering jet tube. Remove the carb from the engine and carefully disassemble it, looking closely at the jet and idle-needle assembly/interface. With the primary needle valve removed, blow air or force fuel through the spraybar with a fuel bulb/syringe to see whether it behaves as if it's restricted. Try running a piece of small diameter music wire, or a pipe cleaner, through the spraybar.

Last, make certain that the carb is tightly sealed to the neck of the crankcase; even a small air leak can lean a fuel mixture in a hurry. —DG

NEW BEARINGS FOR A MOKI

Q I have a three-year-old Moki 1.8. It starts very easily, runs very reliably and has plenty of power. In midflight the other day, however, the engine stopped. The front [ball] bearing had failed, and a small piece of steel from the failed bearing had lodged at the very front of the crankcase housing, between it and the crankshaft. This caused only very minor damage to the housing, just behind the front bearing, and didn't damage the crankshaft at all. Using 600-grit wet/dry abrasive paper and some mild detergent mixed with water for lubrication, I was able to completely clean up the inside of the housing. The large, rear ball bearing seems fine, but I figured that while I had the crankcase housing unbolted from the crankcase, I would change out both bearings. I had previously acquired replacement bearings from a local supplier, but unlike the unsealed originals, these are sealed. The new bearings are good-quality units from SKF. Would it be all right to replace the old bearings with the sealed units? Does it make a difference?

Ball bearings for crankshaft support—front and rear.

A *The seals on your replacement bearings won't hurt a thing, so install them as is; the grease will simply wash out during engine operation. You may remove the seals if you don't like the slight frictional drag they produce. Pry them from their seats with a tiny, slot-type screwdriver (such as those used by jewelers), or use a hobby knife with a no. 11 blade. Don't touch (and possibly damage) the balls in the process (unlikely, since you'll be careful!). You can then wash out the grease with a solvent; I like to use lacquer thinner because it doesn't attract rust-producing water from the air (caused by hygroscopic action, as occurs with alcohol). Allow the bearings to dry naturally. Don't use compressed air to hasten drying; dirt in the airstream could contaminate the bearing assembly. Lubricate them with Marvel Mystery Oil and install them in your Moki. —DG*

OLDER FOX ENGINES

Q I purchased four old Fox engines, including an early .78 with an exhaust baffle coupled to the carburetor. Two Fox .36s and a Fox .29 completed my find; all engines are new in the box! When I told my fellow club members that I was going to use one of the .36s in a Balsa USA Stick 40, they told me that Fox .29s and .36s were hard to start, the carburetors were difficult to adjust, and they really vibrate—especially in a lightly constructed model such as the Stick 40. They also informed me that the Fox .29 and .36 require a minimum of 15-percent nitromethane in the fuel. Can you tell me how much of this information is fact and how much is fiction?

A *It sounds as though your Fox .29 and .36s are equipped with cast-iron pistons and steel cylinders. This combination required several hours of patient break-in before the iron and steel were "bedded-in" and heat-cycle stress relief was achieved. The break-in fuel was very important to the "iron Fox"; it required a minimum of 25-percent castor oil (preferably 28 percent, with a low nitromethane percentage—about 5 percent). Although the Fox instructions were clearly written, many modelers ignored them and tried to fly the engine right out of the box; this never worked and gave rise to the problems described by your club members. In my opinion, this was not the fault of the manufacturer or the engine. Properly broken in, Fox engines are great runners.*

In reference to Fox carburetors, I'd like to note that Duke Fox produced more carburetor designs than any other manufacturer during the '60s and '70s. Another prolific producer of carb designs, SuperTigre, had to take a back seat to Fox in this arena. With proper break-in and fuel (5- to 10-percent nitro is plenty), Fox R/C .29s and .36s are easy to start, smooth running and very throttleable—if the owner follows Duke's detailed instructions. As an added benefit, a properly maintained "iron Fox" will run and last forever. —DG

GAS TO GLOW

Q I would like to convert an O.S. BGX-1-3500 from glow to gas, primarily for economy of operation. Would you recommend this conversion?

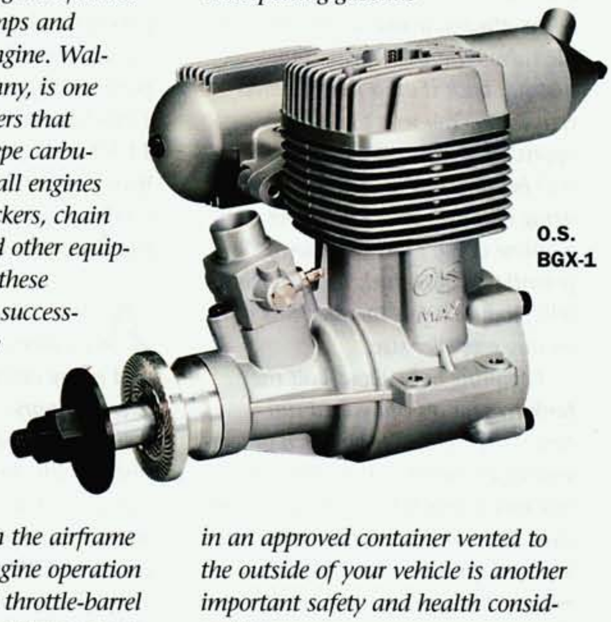
A *Converting the BGX-1 to gasoline is a pretty straightforward procedure, provided you are prepared to invest in a spark-ignition system and, possibly, a new carburetor. One ignition unit that I'm familiar with is produced by CH Ignitions of Riverton, WY. This company markets a capacitive discharge ignition system with Syncro-Spark timing control, which is widely used throughout the modeling community. The Syncro-Spark feature automatically retards the ignition timing when you hand start (no kickbacks here) and during idle. For relatively large engines such as the BGX-1, CH offers a Syncro-Spark unit that completes its spark advance curve by about 4,000rpm, and this ensures that low-rpm torque and horsepower performance aren't compromised.*

A second consideration involves the carburetor. Although the glow carburetor supplied by O.S. will function satisfactorily on gasoline, there are advantages to using an aftermarket unit that both pumps and regulates fuel to the engine. Walbro, a Japanese company, is one of several manufacturers that provides diaphragm-type carburetors intended for small engines that power weed-whackers, chain saws, leaf blowers and other equipment. Over the years, these carburetors have been successfully adapted to many miniature aircraft engines such as the BGX-1.

Fuel-tank positioning (vertical and horizontal) within the airframe is critical for proper engine operation with the O.S.-supplied throttle-barrel carburetor that uses muffler pressure. With a Walbro-equipped engine, the tank can be placed anywhere within the model without affecting the air/fuel mixture. This means that you can place the tank at the model's balance point, if you wish. The standard O.S. carburetor can be made to work more reliably by adding a Cline regulator, which has a diaphragm-type pressure regulator and is driven by timed engine crankcase pressure to pressurize the fuel tank. CH offers a gasoline conversion kit for the BGX-1; it includes a Walbro carb, a carb adapter, bolts, a gasket, an O-ring and a pressure fitting.

You can't run lean gas/oil mixtures (50:1, for example) with this engine because it isn't fitted with needle-bearing-type connecting-rod bearings. Its plain-bearing bushings require about 10-percent lubricating oil in the fuel (9:1). CH suggests using Klotz KL-100 (half synthetic and half castor oil) for this application.

If you have never used gasoline fuel in one of your miniature engines, there are several things to remember. Safety is the first consideration. When using gasoline fuel, I always carry a fire extinguisher to the flightline because the chance of fire is much greater than with glow fuel. Transporting gasoline in an approved container vented to the outside of your vehicle is another important safety and health consideration.



O.S. BGX-1

Relative to glow fuels, gasoline engines run at higher temperatures, so it's important to provide good ducting through engine cowls—especially to the cylinder and head fins. Don't worry about cooling the crankcase; it operates at a reduced temperature because of the fuel vaporization (a physical change during which heat is absorbed) happening there. Although gasoline removes less heat than methanol-

Older-style K&B .48

dominated glow fuel, it's still enough to keep the crankcase cool without external airflow considerations.

As always, avoid setting the needle valve right at its peak rpm; instead, back it off a few hundred rpm (rich). You won't notice an appreciable reduction in performance, and besides, you can't afford a damaging hot, lean run. Remember that gasoline doesn't have the power potential of glow fuel, so the engine will produce a few hundred less rpm on any propeller size.

Requiring only about half the tank size for an equivalent run time—depending on how rich or lean you set the needle valve—the gasoline mix is much less expensive than glow fuel, and it promises improved idle and throttling with less oil residue deposited on your model. Are the benefits worth the additional costs and concerns? Many believe they are. —DG

TIGHT ABC PISTON

Q A while back, K&B sent me one of its new .48s ... a pretty engine. I attempted to use it, but it was so tight I couldn't get it to turn over—no way! So, I set it aside. Recently, I needed an engine, so I loosened the K&B piston by hand lapping it to the cylinder; now it starts normally and runs fine. Anyhow, I wondered if you have had a chance to play with this one? From what I see, it seems to be very, very potent. For my flying, I used a 12x8 Master Airscrew that tached 11,500rpm (like most .60s). I have it in a Jenny which would tear up most pylon courses—too fast for me these days!

A *Yes, I've experienced the same problem with the K&B .48 and many other ABC-type engines over the years. ABC-type piston and cylinders include: ABC (aluminum piston with chrome-plated brass cylinder), AAC (aluminum piston with chrome-plated aluminum cylinder) and ABN (aluminum piston with nickel-plated brass cylinder). These are designed to have a slight interference fit near top dead center; this disappears after the engine heats up because the brass and aluminum cylinders expand faster than the high-silicon-content piston.*

These lapped (ringless) piston engines will leak compression and combustion gasses if the piston is too loose. It's advantageous from the point of peak performance to keep this tight cold fit.

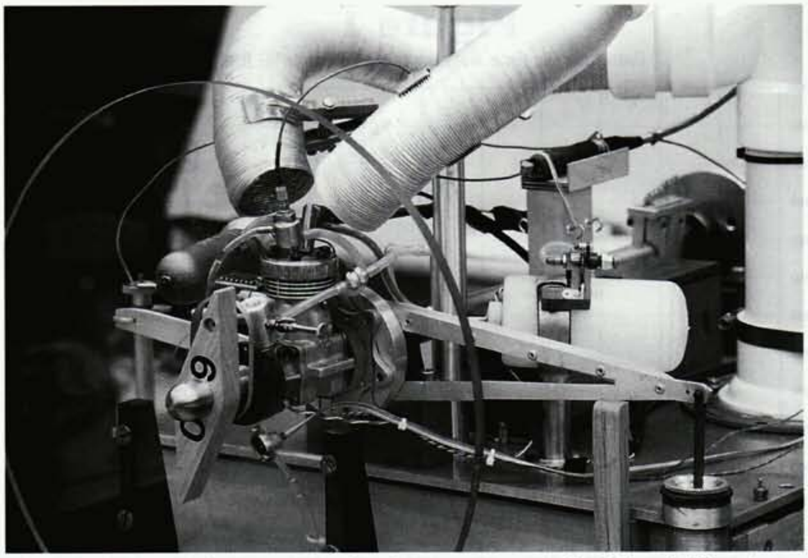
Although your method of loosening the piston worked, there's a much easier way to accomplish the same results. In the future, use a heat gun to warm the cylinder before the first few starts during the break-in period; this will loosen the assembly and permit you to crank it over without breaking the crankpin, connecting rod, or piston. An additional benefit: only the top portion of the piston will wear to the tapered cylinder, thereby ensuring the best possible fit.

Because ABC-type engines were originally designed as wide-open-throttle racing engines, they operated at close to their design temperature for most of their useful lives. Today, these engines are expected to both idle and throttle reliably. Unfortunately, this permits them to cool excessively, which causes the piston to rub away the critical fit near top dead center.

Although there isn't much we can do about the cooling-related wear that the engine experiences during idling and throttling, a few tricks can extend its life:

- *From the beginning, use the highest factory-recommended nitromethane fuel content with a new ABC-type engine. If the instructions say to use 5 to 15 percent nitro, then use the higher 15 percent. This generates the highest combustion temperatures and, therefore, the greatest clearances between the piston and cylinder, when they are the tightest they'll ever be. After running the engine for a season or two, you will probably notice that performance begins to diminish. Performance can be determined by comparing tachometer readings on a standard propeller from when the engine was new to the time of comparison. If rpm drop by several hundred or more, the piston-cylinder clearance is probably excessive ... so you should reduce the nitro content to 5 percent. Less nitro means lower combustion temperatures and less component expansion, and this results in a tighter* *piston-cylinder fit with less blowby and lost power. Experience has shown that reduced nitromethane content is compensated for by the improved piston-to-cylinder fit at running temperatures. That's why some "worn-out" sport pylon racing engines make very acceptable fun-flying engines—less nitro!*

• *Never run an ABC-type engine 4-cycling rich. From the first time the engine is started to the end of its useful life, the relatively cool temperatures generated by firing every other revolution of the crankshaft accelerate piston wear and the onset of reduced performance. —DG*



Basic components of a torque-reaction dynamometer: semi-rotation, ball-bearing-supported engine mount; air-blast deflection disc; forced-air cooling; oil-filled vibration damper; load beam (propeller substitute); and rpm sensor. At the rear of the unit are a pendulum weight attached to the engine-mount shaft and a torque-recording instrument.

A water-cooled piezo-electric pressure transducer (right) has been mounted adjacent to the spark plug in a special cylinder head, which also contains a head temperature probe (foreground).

A tachometer frequency-to-voltage converter (bottom) was required for rpm data retrieval. The unit above the converter is a digital readout for exhaust gas temperature (used to set the needle valve to peak power).

4-CYCLING CONTROVERSY

Q There has been some discussion on the Internet concerning 2-stroke- cycle engines and the term "4-cycling." Some participants have indicated that 2-stroke engines can't 4-cycle, or fire every other revolution of the crankshaft. Have you changed your mind about this controversial issue?

A *Because some readers may not be familiar with the 4-cycling issue, I'll repeat what I said about 4-cycling in a 2-stroke-cycle engine: "If an engine's fuel is richened to just inside the rich limit of the combustion range, it will begin to misfire every other cycle. Why? As the combustion process takes place, not all of the exhaust gases are scavenged (flushed) out of the cylinder. This is normal. However, as the next air/fuel charge is moved into the cylinder from the crankcase through the cylinder's transfer port(s), it mixes with leftover exhaust gases. Waste gases impede the oxygen molecules' access to fuel molecules just enough to move the mixture ratio outside the combustion range. The engine misfires!*

"The unburned mixture does a good job of purging the cylinder, so the next fresh air/fuel charge enters a relatively unpolluted chamber where it again is within the combustible range and ignites. The engine alternately fires and misfires in this fashion, forming the familiar 4-cycling pattern."

Last year, Frank Vassallo and I conducted combustion experiments at Veritay Inc. as part of a contract with the Navy for developing a 2-stroke engine for an unmanned aerial vehicle (UAV) required to operate on

Figure 1

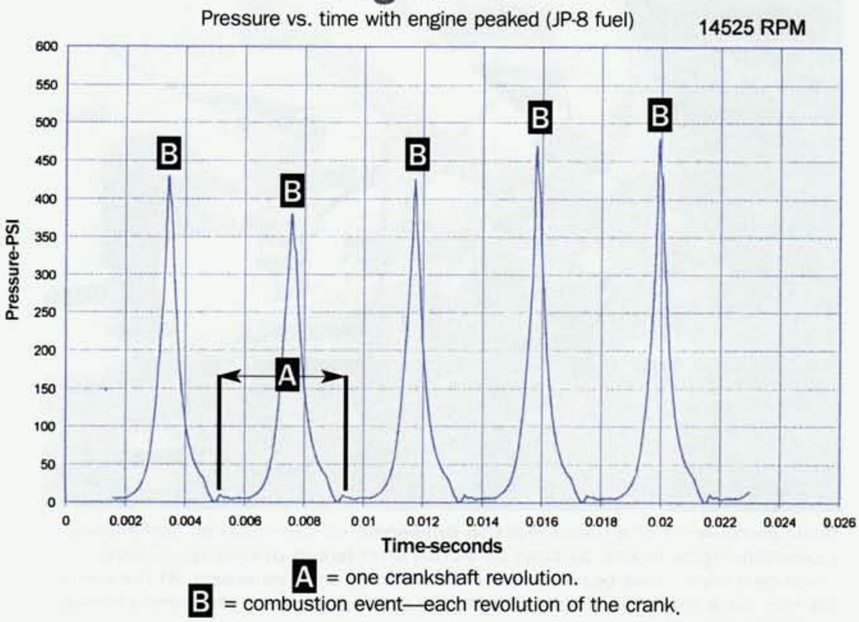
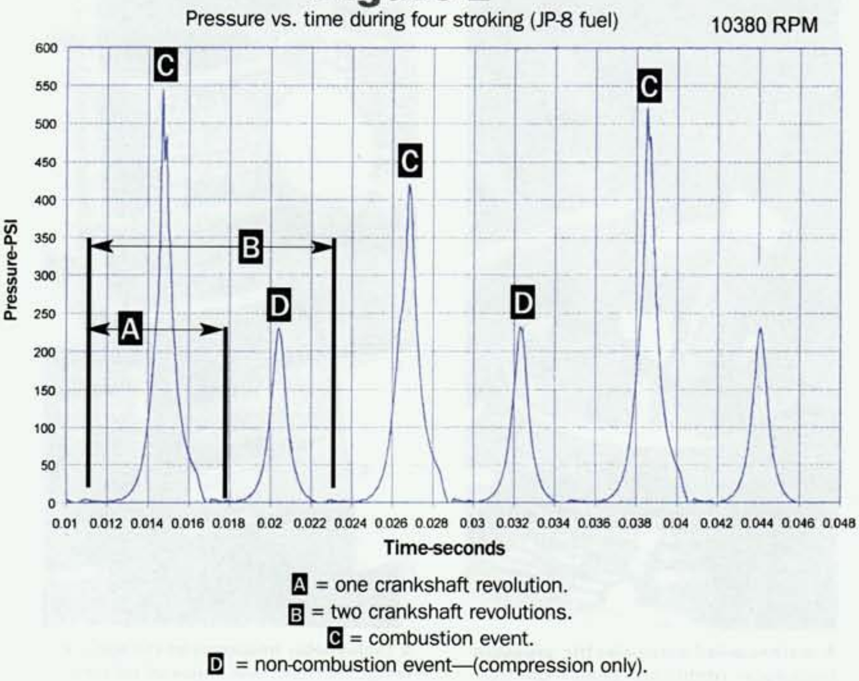


Figure 2



so-called "heavy" fuels (JP-5, 8 and 11). These kerosene-like jet fuels possess special physical and chemical qualities, hence the need for our tests.

To measure cylinder pressure versus time, we outfitted the head of our trusty Enya .61 "mule" with a special water-cooled piezo-electric pressure transducer, while time was measured in terms of rpm using a custom tachometer made by Tony Criscimagna of TNC Electronics. Tony fabricated and calibrated a frequency-to-voltage converter for his standard tach, which allowed us to mate it to our computer data retrieval system. After our project work was completed, I suggested to Frank that we run a 4-cycling test. Notice that with the engine peaked to maximum rpm, it fired every revolution of the crankshaft, or about every 4 milliseconds; this corresponds to 14,525rpm (Figure 1). Notice that the average peak pressure during this sample was approximately 438 pounds per square inch (psi). Now look at the pressure versus time graph (Figure 2) for the very rich air/fuel mixture (four-stroking) mode of operation: the three highest cylinder-pressure spikes represent firing events while the others show compression with no combustion. Again, the time between a firing and non-firing event (approximately 6 milliseconds) corresponds with 10,380rpm; stated another way, the time between firing events is about 12 milliseconds, or once every other revolution of the crankshaft. The engine is 4-cycling.

The three firing peak pressure spikes average about 497psi, or about 59psi greater (13.5 percent higher) than the average firing pressure for the peaked 2-cycling sample. This seems to indicate that a more completely scavenged cylinder—as with the 4-cycle example—produces more work per firing. The 230psi produced by the other non-firing spikes can be accounted for through standard thermodynamic computations for an adiabatic compression with a known effective compression ratio.

Frank has two other proofs that support the 4-cycle theory from a mathematical perspective based on our retrieved data. We think that 4-cycling truly exists and, more important, is very desirous during the running-in of ringed and ferrous lapped piston engine designs. Reducing the number of firing operations by half through 4-cycling drastically reduces the engine's temperature. Heat is removed by conduction to the unburned liquid fuel, and more is taken away by its vaporization. The rich needle-valve setting coupled with firing on every other revolution *ensures that an abundant supply of lubrication passes through the engine at all times. As I've said many times, "Cool and oily; that's the secret to breaking in non-ABC-type engines."*

Last, 4-cycling is detrimental to the longevity of ABC-type engines, which include ABC, AAC and ABN units. Very rich 4-cycling cools the normally tight-fitting piston and cylinder to the point where they contact (at the piston crown) when passing top dead center in the tapered cylinder. In a relatively short time, the very top circumference of the piston wears to a point where it no longer seals properly when the engine heats up after being peaked (needled) for maximum performance, since the cylinder is designed to expand faster than the piston. ABC-type engines should be broken in at a rich 2-cycle mode with occasional short peaked periods such as those produced by momentarily pinching the fuel line. —DG

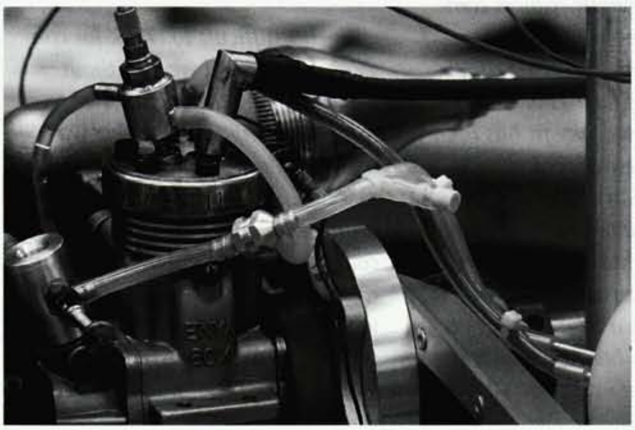
POLISHING FOR PERFORMANCE

Q If I polish the internal parts of my .40 to .46 2-stroke engines, will I gain some power? These parts include the crankshaft (internal channel), crankcase (including both transfer and boost bypasses), filing and polishing all cylinder ports, exhaust outlet in the crankcase, and inside the muffler.

A *This question has been asked in various forms since the first model airplane engines were mass-produced more than 65 years ago. Generally, what you're trying to improve is the engine's ability to induct fresh air/fuel mixture into the crankcase, transfer it into the combustion chamber where it is burned, then clear the cylinder of exhaust gases. Mechanical engineers have terms related to these processes that include: induction efficiency, crankcase scavenging, delivery ratio, combustion efficiency and cylinder scavenging, but the goal is always the same: to improve the cylinder pressure throughout the cycle, providing gains for torque and horsepower or improved fuel economy.*

Although polishing may actually improve air/fuel mixture flow in some engines, other design factors are generally more important; some of these include: carburetor design, induction timing, induction and bypass channel geometry, port timing, compression ratio and exhaust system design. Experimenters such as Gordon Blair, professor of mechanical engineering at the Queen's University of Belfast, Ireland, have devoted a lifetime to attempting to isolate and understand the effects and influences of these factors on the performance of the 2-stroke-cycle engine. Although a great deal has been learned, much more remains to be discovered; I believe the effects of component polishing fall into the latter category.

Over the years, most engine modification specialists found (through trial and error) that polishing was a waste of time. However, removing burrs and chips from induction channels, crankcase and cylinder port surfaces ensures that they won't break loose and possibly ruin vital engine components such as the piston-cylinder interface and a crankshaft ball bearing. Spend your time in those areas; it'll be a lot more productive!—DG



The Enya .60 engine with water-cooled pressure transducer and spark ignition. A special air-induction venturi was used to measure air consumption in other tests.

ENGINE EFFICIENCY

Q I have your book, "2-Stroke Glow Engines for R/C Aircraft." It says a lot about speed but little about economy. Is there a formula or guideline concerning timing, etc., for attaining fuel efficiency?

A *Although I don't know of any formulas for reaching this goal, there are some guidelines that should lead you in the right direction.*

The best way to extract the maximum mechanical energy from any chemical fuel in a heat engine is to raise its operating temperature. In the case of a piston engine, this is accomplished by raising the compression ratio. There are limits in terms of combustion defects such as "knock" (detonation) and pre-ignition. Some fuels are better suited than others in terms of their ability to tolerate increased compression. Methanol (methyl alcohol), for instance, allows higher compression than straight-run gasoline under ideal conditions. Of course, high compression ratios require sturdy, heavier, engine construction to withstand elevated cylinder pressures.

Although gasoline has compression ratio limits that are significantly lower than certain other fuels, its air/fuel ratio for chemically correct economical burning is about 15 parts of air to 1 part gasoline (15:1). Because lean air/fuel ratios are necessary for economical engine operation, gasoline is hard to beat. Compared to gasoline, methanol is about 9:1, and *nitromethane is 4:1. On the negative side, gasoline engines run hotter than methanol-burning engines and are more likely to produce accidental fires.*

Lower shaft speeds, smaller transfer and exhaust ports, a longer expansion (power) period and the reed-valve induction system all contribute to more efficient engine design. However, efficiency and power are mutually exclusive; economical engines aren't powerful engines.

If all this sounds like "back to the future," it is! Our earliest production engines from the 1930s were designed very similarly. Unfortunately, engineers couldn't use high compression ratios because metal alloys for pistons, lightweight castings and other critical construction components were inferior; they couldn't withstand the temperatures and pressures. —DG

HOT RESTARTS, ROD WEAR & BEARING RUST

Q What causes the connecting rod on my Fox .40 ABC engine to wear when it's run very rich [4-cycling] for long periods? I thought the extra oil I use in the fuel would help, not cause harm.

A *The worst thing you can do to an ABC-type engine—other than running it lean—is to run it 4-cycling rich for long periods. When new, most ABC (aluminum-alloy piston with chrome-plated brass cylinder) engines exhibit an interference fit (components that actually touch) as the piston crown passes top dead center (TDC) when turned over by hand. In many cases, you can actually hear the piston squeak; this is normal. Originally designed for fast, 2-cycle operation, the piston and cylinder expand similarly (slightly more for the cylinder), maintaining a good gas seal without enduring the mechanical drag of a piston ring. Unfortunately, when operated at a rich 4-cycle (engine firing once every other revolution), the piston and cylinder never reach design temperature and the piston rubs at TDC, causing great wearing loads (pounding) on the piston wristpin bosses and both connecting-rod holes. The piston fit also is worn away at its crown, further degrading the engine's mechanical condition. In the future, always try to run ABC-type engines (including the AAC and ABN types) in the 2-cycling mode, especially when they're new. —DG*

Fox .40 Schnuerle with Fox Quiet muffler.

Q What causes an engine not to start when it's hot? The Fox .40 starts fine when it's cold, but it won't even 'pop' when it's hot!

A *When hot, most ABC-type engines are relatively difficult to start. The hot clearance between the piston and cylinder reduces compression to a point at which combustion chamber start-up conditions are questionable. This is magnified if the squeaky fit has been worn away because of cold, 4-cycle operation. You didn't mention whether you are attempting to hand-start or are using an electric starter. By richening the carburetor's high-speed needle valve a bit and using an electric starter, the hot ABC engine can often be coaxed into starting. —DG*

Q I am having rust problems with the crankshaft ball bearings in all of my engines. Any suggestions?

A *You aren't the only one with bearing rust problems. Here are a few suggestions:*

- *At the end of a running session (bench or flying), run the engine completely dry of fuel from a wide-open throttle setting (pinch the fuel line or run the tank dry).*
- *Load the engine crankcase with after-run oil (I use Marvel Mystery Oil). For a .40-size engine, I squirt at least ½ ounce into the venturi while turning the propeller over slowly. Rotate the induction valve to the closed position so the oil won't run out.*
- *When not in use, set the engine on its nose to ensure that oil floods the bearings. Place a rag under the nose because some of the oil will probably escape through the front crankshaft seal. Note: never use WD-40 on rusty bearings. My good friend Clarence Lee discovered that it breaks the rust loose, but then the rust runs through the engine the next time it's fired up, and iron oxide (rust) is very abrasive. —DG*

Q How can I check for connecting-rod wear without disassembling the engine?

A *It's difficult to check for connecting-rod wear without disassembling the engine. I've seen experts attempt to do it this way: with the glow plug and propeller in place, slowly turn the engine over until the piston is at TDC (with compression gases above it). Gently rock the crankshaft from side to side without allowing the piston to move. The relative movement on either side of TDC indicates how*

Left: measuring the crankpin diameter with a 0- to 1-inch outside micrometer. Right: measuring the connecting-rod-hole diameter (crankpin end) with a small hole gauge.

much play, or clearance, there is between the crankpin and the bottom hole in the connecting rod. This technique is very subjective, though; one person may find the amount of play acceptable, while another will conclude that the rod is badly worn. Also, it's difficult to accurately tell whether a connecting rod is worn out by wiggling it back and forth after removing the engine's backplate. In my opinion, the engine must be disassembled to the point at which the rod can be removed from the crankpin. Before measuring, both components must be cleaned and dried. The crankpin can be measured with a 0- to 1-inch outside micrometer or a vernier caliper. With a small hole gauge (or vernier caliper), take a few measurements of the rod-hole diameter. Don't be surprised if it's oblong; this is how rod wear usually shows up.

Accumulated clearance data show that the range of acceptable tolerances for a connecting rod is between 0.0015 and 0.002 inch. If the crankpin end of the rod measures 0.0025 inch or more, it's considered to be too loose. Generally speaking, if the hole is more than 0.0005 inch oblong, there's a problem, and the connecting rod should be replaced. —DG

The actual size of the connecting-rod hole is being measured by the 0- to 1-inch outside micrometer, from the small hole gauge.

ENGINE MODIFICATIONS

Q I have an idea to improve the operation for two of my engines: the O.S. 40FP and the Thunder Tiger 40 GP. They each have cylinders where the transfer and boost ports are machined squarely through [90 degrees to the cylinder centerline] the cylinder wall. Can I file these ports at an upward angle to gain a smoother running, more powerful engine? Can you tell me some tricks for increasing power?

A *By angling the transfer and boost ports toward the head, you will change the transfer timing of the engine. As a result, these ports will remain open longer, as measured in terms of degrees of crankshaft rotation. By performing this modification, you will reduce the exhaust lead (the period between the exhaust opening and the transfer opening), which affects the blowdown event (exhausting prior to the transfer port opening). This increases the likeli-*


Checking connecting-rod play.

hood that fresh air/fuel mixture will be contaminated by exhaust gases, resulting in reduced engine power and efficiency.

Engine designers and engineers have spent considerable time and effort developing successful production engines for the modeling community. If there were helpful modifications, they would have been incorporated into the final product. Of course, certain changes can be made to improve power, but these are almost always compromises made at the expense of other attributes, such as reduced fuel efficiency, engine life and the possibility of catastrophic failure due to an overloaded component.

My suggestions for improved engine operation are:

- *Read and follow all written instructions supplied by the engine manufacturer.*

- *Thoroughly break in your new engine according to accepted operational practice.*

- *Use fuel that contains adequate percentages of lubricant (as suggested by the engine manufacturer).*

- *Only use fuel from a manufacturer who clearly states the lubricant components and percentages on the label.*

- *Never adjust the high-speed needle valve for maximum rpm and fly with the engine that way. Always back off (rich) several hundred rpm because most engines lean out in the air.*

- *Run the engine dry of fuel at the end of the operating session and use generous quantities of after-run oil to prevent bearing rust.*

If you desire improved engine power, investigate commercially available engines with a greater displacement (size). —DG

SURGING MAGNUM

Q I recently purchased my first 4-stroke engine—a Magnum .52. I followed the engine's break-in instructions exactly, but at full power, it surges, and if I make any attempt to adjust the needle valve in either direction, the engine instantly quits. It has had two to three hours of run time, and I use Byron 15-percent-nitro/16-percent synthetic/castor-blend fuel and a Fox 4-cycle glow plug. Please let me know what might be causing the problem.

A *First, put an O.S.-F plug in the engine. Second, check the fuel-delivery plumbing for pinhole-size air leaks. Third, bring the engine up onto compression manually. After three to four hours of break-in, the engine should hold a good compression seal. If it doesn't, it won't have proper fuel draw and will run erratically. There are several possible causes of poor compression in a new engine: one of the valve clearances might have been set too tight, so the valve doen't rest completely on the valve seat. In a few Magnum engines, it took a very long time for the piston ring to fully seat on the cylinder sleeve. Check that the valve clearances are set according to the instructions (cold), and run the engine for another hour or so. If this doesn't help, it's time to send the engine back to Global for servicing. —CC*

TIME TO REPLACE THE PLUG?

Q Last summer, I purchased an ARF Hirobo Shuttle helicopter with an Enya .35 engine, and I greatly enjoyed learning to fly it. I use PowerMaster fuel; the first gallon was 15-percent-nitro RC aircraft fuel; the second and third gallons were 20 percent nitro, and the last two gallons were 25 percent nitro. The engine has a very smooth idle that is slow enough to disengage the clutch. The top-end power seems very good for hovering and flying circuits. I still use the original glow plug. In your opinion, how often should I change the glow plug and how long can I expect the engine to last?

A *It's hard to say how long a plug will last; plugs in sport 2-stroke and 4-stroke engines can last a very long time. Plugs in ducted-fan use have far shorter lives; helis fall somewhere in between, but closer to sport use. Being run often in hot, humid weather can shorten the life of a plug—and of an engine,* *especially if you tune it for all-out max power all the time instead of going for a slightly richer mixture.*

Because helis are more sensitive to engine misfiring, which can cause drive-train vibration, the RC heli community considers plug replacement smart preventive maintenance, and I suggest you adopt the same view. Don't skimp on a fresh plug supply; the costs of replacing bent heli parts that result from an engine flame-out and consequent crash can add up really quickly!

Enya engines have some of the best metallurgy in the industry and, again, if you tune for a slightly rich mixture that supplies more oil and more expelled unburned alcohol (both of which carry away heat and yield cooler running), you will have that engine for a very long time. And, of course, don't forget proper after-run care. —CC

INVERTED OK?

Q Please discuss the disadvantages or possible complications of installing an O.S. 70 inverted. The instructions don't list a contact for technical help.

A *I've run O.S., Saito and Magnum 4-stroke engines inverted with no problems at all. Four-stroke engines don't seem to suffer from inverted operation as 2-stroke engines sometimes do. The 4-stroke's higher combustion-chamber temperatures and more efficient fuel consumption characteristics probably have something to do with this. On some brands of 4-strokes, the glow plug has been moved closer to the exhaust valve—a hot area that helps keep the plug's filament glowing. Such a move also takes the plug farther away from the intake valve and its incoming cool fuel/air mixture. The only thing you must be aware of is not to flood the engine while it's inverted. If a 4-stroke engine becomes seriously flooded to the point of hydra-lock, damage to the engine's internal parts can result if a strong electric starter is applied under such condition. No matter which brand of 4-stroke you are running, make sure it is equipped with an O.S.-F glow plug. It is simply the best. —CC*

WATCH OUT FOR THOSE "EXPERTS"

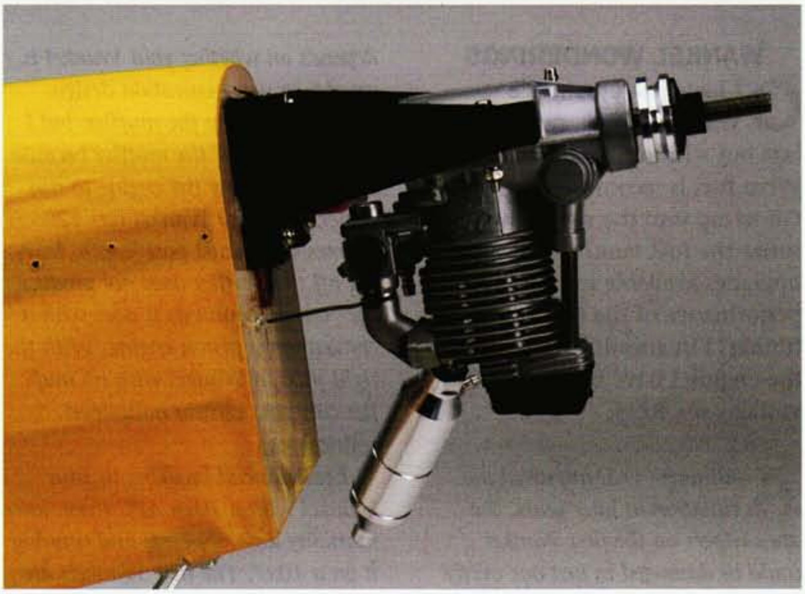
Q I have just bought my first four-banger, an O.S. Surpass .91 FS engine, and I am a little concerned about the manufacturer's recommendations: "At least 18% oil content" in the fuel to be used. I am concerned because at the field, we can only get 16 percent oil with 10 to 15 percent nitro Byron fuel, which is very good for our 2-cycle engines, right?

My friend has a 4-cycle 1.20; he bought castor oil from a lab and added a measured quantity to a brand-new gallon of 16-percent-oil-content fuel to increase the oil/fuel ratio. Is this practice adequate, or should I get the correct fuel?

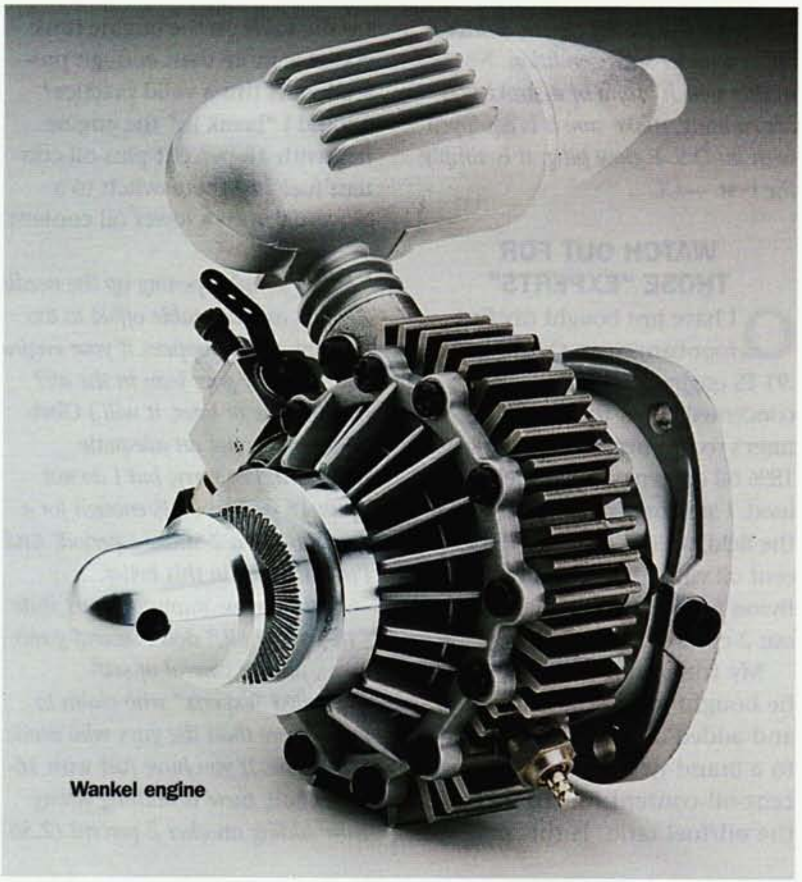
The "experts" at the field have always recommended using the same 2-cycle 16-percent-oil-content fuel, but they say opening the needle valve so the engine runs cooler is more than enough protection. Is this a valid practice? Should I "break in" the engine first with 18-percent-plus-oil-content fuel and then switch to a glow fuel with a lower oil content?

A *If simply opening up the needle is an acceptable offset to too little oil, what happens if your engine inadvertently goes lean in the air? (And sooner or later, it will.) Obviously, this is not an adequate safeguard. I'm sorry, but I do not think 16 percent oil is enough for a 4-stroke—or a 2-stroke—period! And I'm not alone in this belief.*

If the engine manufacturers state "18-percent oil," don't second-guess them; and be careful of self-appointed "experts" who claim to know more than the guys who made the engine. If you have fuel with 16-percent oil, there is nothing wrong with adding another 2 percent (2.56 fluid ounces per gallon) of castor. Lots of guys add extra oil all the time, and none of them have hurt their engines doing so. Just make sure the castor is of degummed, premium-grade quality. —CC



This O.S. .52 Surpass has fantastic idle and throttle response characteristics even when mounted in the inverted position. This is true of other brands of 4-strokes as well.


Wankel engine

WANKEL WONDERINGS

Q I have just obtained a Wankel engine, new in the box but with no instructions. What fuel is recommended? Is it OK to tap into the muffler to pressurize the fuel tank? Are any upgrades available to improve the performance of the exhaust-port timing? I'm guessing, but I believe the engine I have is about a 1973 vintage: no. B211.

A *Although O.S. improved the situation in later years, the apex wipers on the first Wankel could be damaged in just one overly lean run. I used to add an extra 3 or 4 percent Klotz synthetic oil to my fuel as a "special blend" for the Wankel. Mind you, this was in the days when 20 percent lubricant was normal in model aircraft glow fuel. You might want to try adding at least 3 to 7 percent Klotz to today's fuels. The amount, of course, depends on whether your Wankel is an old- or new-generation design.*

It's fine to tap the muffler, but I used to leave off the muffler because this would allow the engine to run cooler. Since the Wankel has 120 degrees of exhaust-port length, leaving off the muffler does not produce the "crack" sound as it does with a conventional piston engine. With the right prop, a Wankel with no muffler can pass certain noise-level restrictions.

I recommend breaking in your Wankel with a 10x6 APC (cool, low-humidity days are best) and running it on a 10x7. The new Wankels are lighter and don't seem to be quite as sensitive to lean runs, but generally, I feel all Wankels need more oil than piston glow engines. —CC

HOW MUCH TO ADD?

Q I am about to break in a Saito 150. Saito's instructions simply say to use a good-quality 2-cycle oil; too simplistic for my engine. Most people recommend that break-in oil be straight castor, at least in the 20 percent range. My problem is that I was given a gallon of racing fuel with only 10 percent synthetic/castor blend. How much castor and/or synthetic do I add to bring this up to 18-percent oil content? Is it even wise to use this fuel? I can buy all the ingredients, but what do I do with a whole gallon of break-in castor?

A *For my 4-strokes, I like about 3 to 4 percent of my total oil mix to be castor. You don't want the entire oil content to be castor. The collateral benefit of some castor oil is as an anti-corrosive. If you run all castor, you're going to have to perform varnish clean-off sessions much more frequently. If you have access to fuel with only 10-percent lubricant, for break-in, I would add another 10-percent oil: 6-percent synthetic (7.7 fluid ounces) and 4-percent castor (5 fluid ounces). For running after break-in, I would change to adding 4 percent each of both synthetic and castor. I use Klotz for the synthetic and a premium grade of degummed castor. —CC*

source guide

A&A Engineering (714) 952-2114; a-aengineering.com.
ABC Radio Control Hobbies (956) 722-2845.
Ace Hobby Distributors (949) 833-0088; acehobby.com.
Aerospace Composite Products; acp-composites.com.
AeroWorks (303) 366-4205; aero-works.net.
AirBorne Models (925) 371-0922; airborne-models.com.
Airfoil Aviation Inc. (217) 938-4473; airfoilaviation.com.
Airplane Factory Inc. (800) 264-7840.
Airtronics (714) 978-1895; airtronics.net.
America's Hobby Center; ahc1931.com.
Amondo Tech (408) 747-1123; amondotech.com.
APC Props; dist. by Landing Products (530) 661-0399; apcprop.com.
AstroFlight Inc. (310) 821-6242; astroflight.com.
Autogyro Company of Arizona (888) 783-0101; autogyro-rc.com.
Batteries America (608) 831-3443; batteriesamerica.com.
Berg receiver; dist. by DeeTee Enterprises (503) 692-6953; deeteeenterprises.com; and by RC Direct (858) 277-4531; rc-direct.com.
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Bluejay Airplane Kits (308) 276-2322; bridiairplanes.com.
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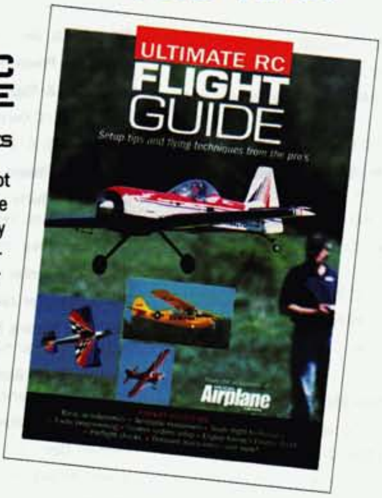

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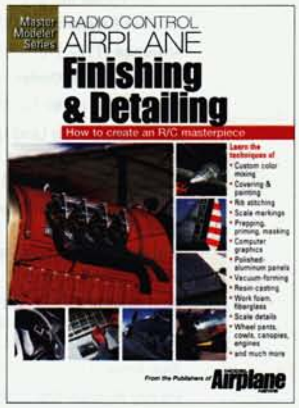

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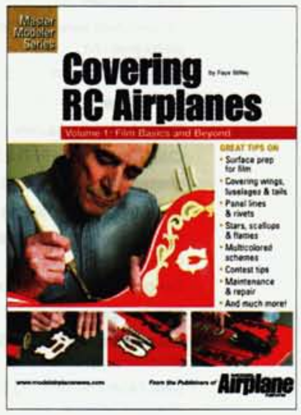

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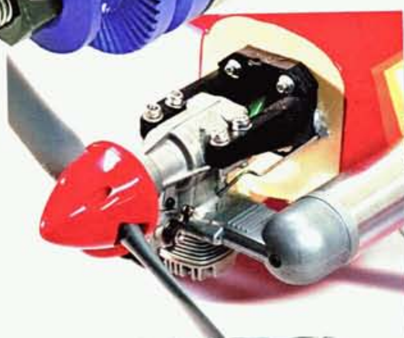

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