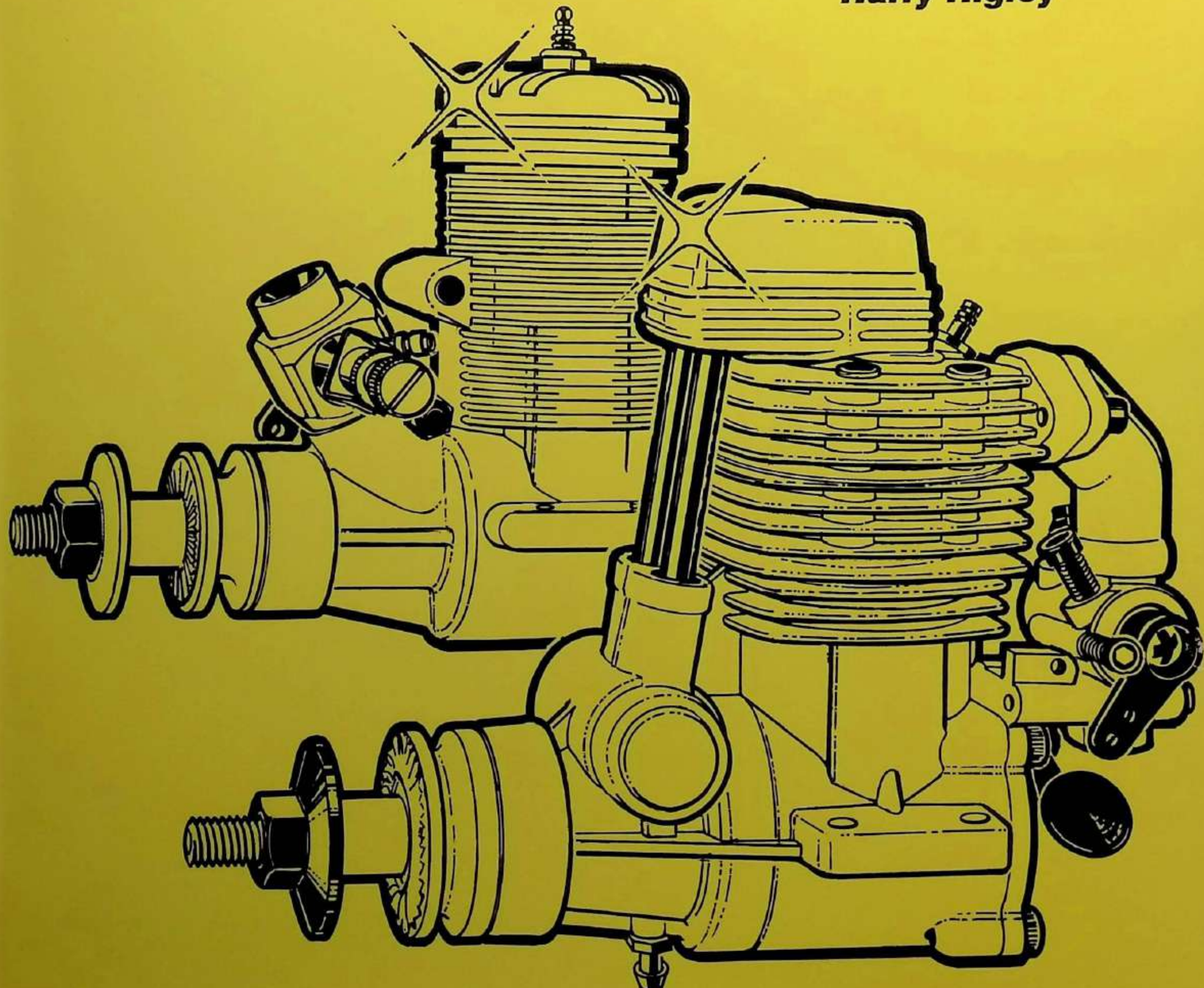
ALL ABOUT ENGINES

By
Harry Higley



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CHAPTER ONE
AN INTRODUCTION

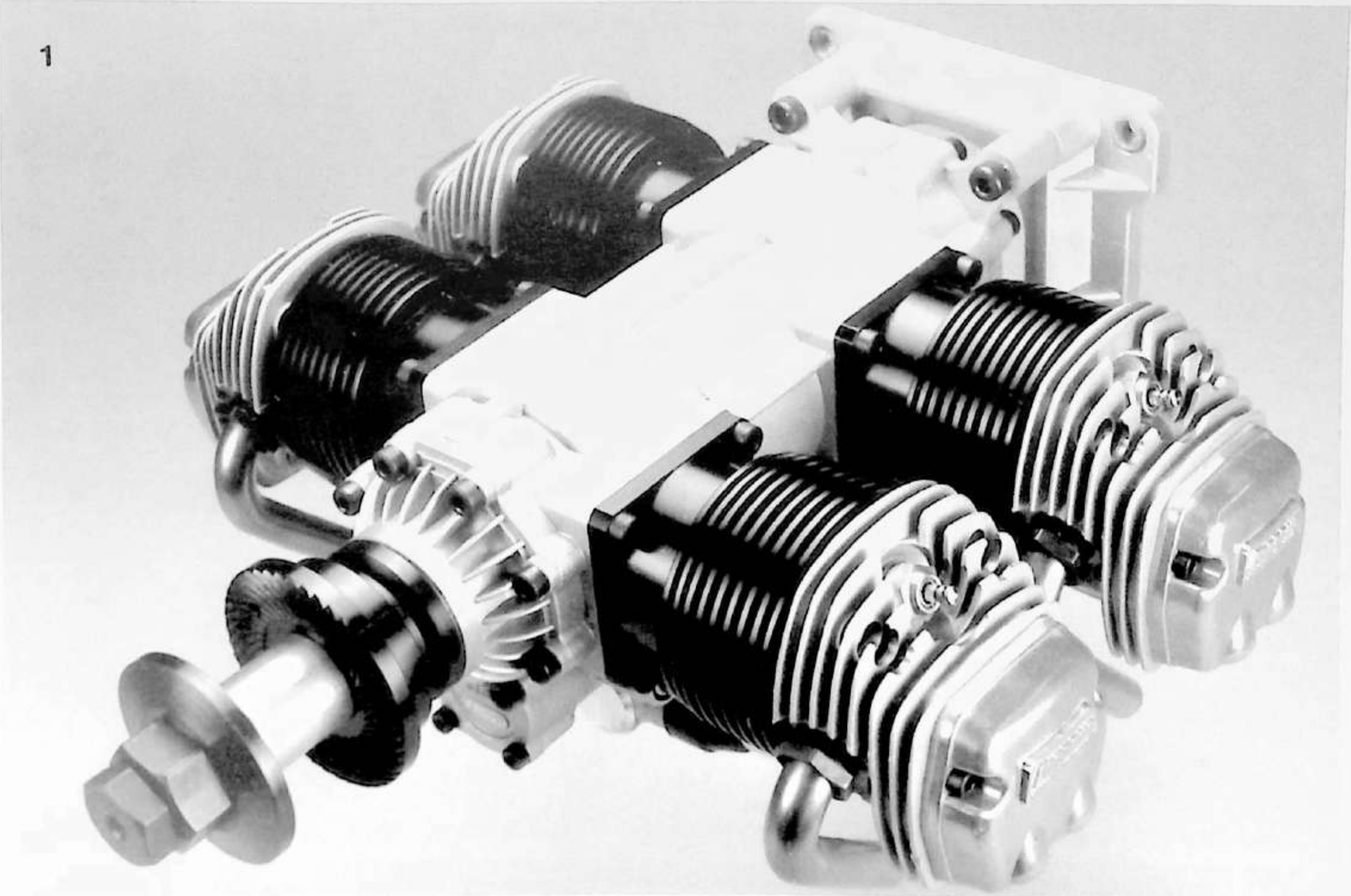
Chapter One explains a little about us and what you can expect to find in All About Engines. Most hobbyists are familiar with our yellow covered how-to-do-it manuals, and you may already have several. The first two were hand written and typed years before personal computers made writing the pleasant task it is today. This shows that we have been helping people like you enjoy modeling for a long, long time. If experience counts, All About Engines should do its intended job well because eleven books preceded it, and they all enjoy increasing sales every year.

The formula for producing books you continue to support is no secret, and appears shortly. While we are serious modelers, no one can know everything. So, we draw on the considerable expertise offered by a group of knowledgeable modelers, engine experts, and industry members. This group continues to grow every year, and we are grateful for their contributions. Getting the information is only half the formula, presenting it clearly is the other half, because the best ideas mean little unless you, our reader, understand them. Nothing makes understanding easier than carefully taken photographs that need only brief written explanations. Clear, complete presentations in All About Engines required more than 900 photographs. Each is numbered and referenced in the written material by that number. We're sure you'll have no trouble reading text laced with photograph numbers. Try the following two sentences. Photograph (1) shows a four cylinder OS four-stroke engine, while (4,11-14) were included because the subjects are interesting and required enlargements to appreciate fully. The text and numbered photographs were tested on average modelers for easy understanding. If they didn't think a presentation was clear, we revised it until they did. The simple formula used in all our books is [expert information + clear presentation].

With that short introduction to our publications, let's explain a little about the subject of this book - model engines. Fox manufactures the oldest engine in production; their legendary "35" has a place in modeling even after nearly fifty years. The one in (2) still makes an occasional flight and runs well though I bought it in 1953; photograph (3) features a current one. Fox's "35" is a unique exception, not the general rule, and time has not stood still. When we wrote our first engine book many years ago, engine variety was barely adequate. Now the selection of manufacturers, size, and complexity is, to quote my youngest son, awesome. Examples pictured in (5-10) provide only a partial list of countries engines come from. You can buy them small enough to use on cuff links and almost large enough to fly an ultra-light man carrying airplane. Photo (12) suggests the vast size range available. Some examples shown in this chapter are complex, other engines have only a few moving parts. As you will see shortly, quality ranges from great to ho-hum, but they all run well in the hands of a knowledgeable person. This book shows how to become such a person.

All About Engines is informally organized into several major sections that may be a single chapter or several chapters long. Depending on your experience, some sections may be temporarily skipped and read later. For example, Chapters Eight and Nine provide information about how to get an engine adjusted and running well enough for its initial flights, if nothing goes wrong. Beginners, anxious to fly, may start with that section. Chapters Two through Four put you inside different engines so you can see how they operate, and then, a survey of popular designs will be helpful in selecting an engine for the application you have in mind. Chapters Five, Six, and Seven approach the combustion process in a practical way that will help you get all the reliability and performance an engine can provide. An engine, tank, and controls must be properly installed, so we included Chapters Ten and Eleven to be sure you understand the characteristics of a good installation and how to do one. Carburetor adjustments and maintenance are the most important part of operating an engine and Chapter Twelve assures you can handle nearly all types. Eventually, every modeler needs to clean, disassemble and work with engines and their sub-assemblies. These subjects can be found in Chapters Thirteen through Sixteen. The next section, Chapters Seventeen through Twenty, extends the ideas of the last section to include four-stroke engines. Late in the development of All About Engines, I put a short but important section, Chapter Twenty-One, on some tough maintenance tasks and repairs. Finally, a one chapter section about tuned pipes concludes this book.

In a prologue or introduction like this, a writer acknowledges the people without whom the book would never be produced. I'd like to thank them all now and tell you who some of them are. Todd Smith, Jim Higley, LeRoy Cordes, and Lynn Engel proofread the manuscript and offered many important suggestions. We strive for consistency from book to book and Jim Harris' striking covers contribute to that and have become our trademark. All photographers depend heavily on photography's other half, the darkroom. Dave Anderson printed every picture seen on these pages and many that were not used. My wife Cora endured uncountable hours under hot lights holding all the engines and performing the task shown in the photographs. Those people contributed to the presentation and layout, while others provided solid ideas about engines. A list of these model engine experts would be too long for anyone to read, so I will credit and thank them in later chapters when the subject being discussed involves help they gave.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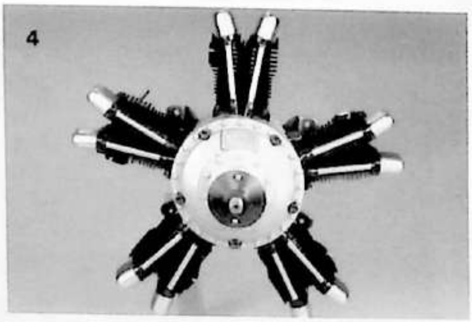
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SERIES
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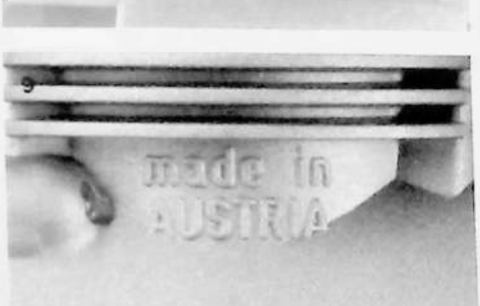
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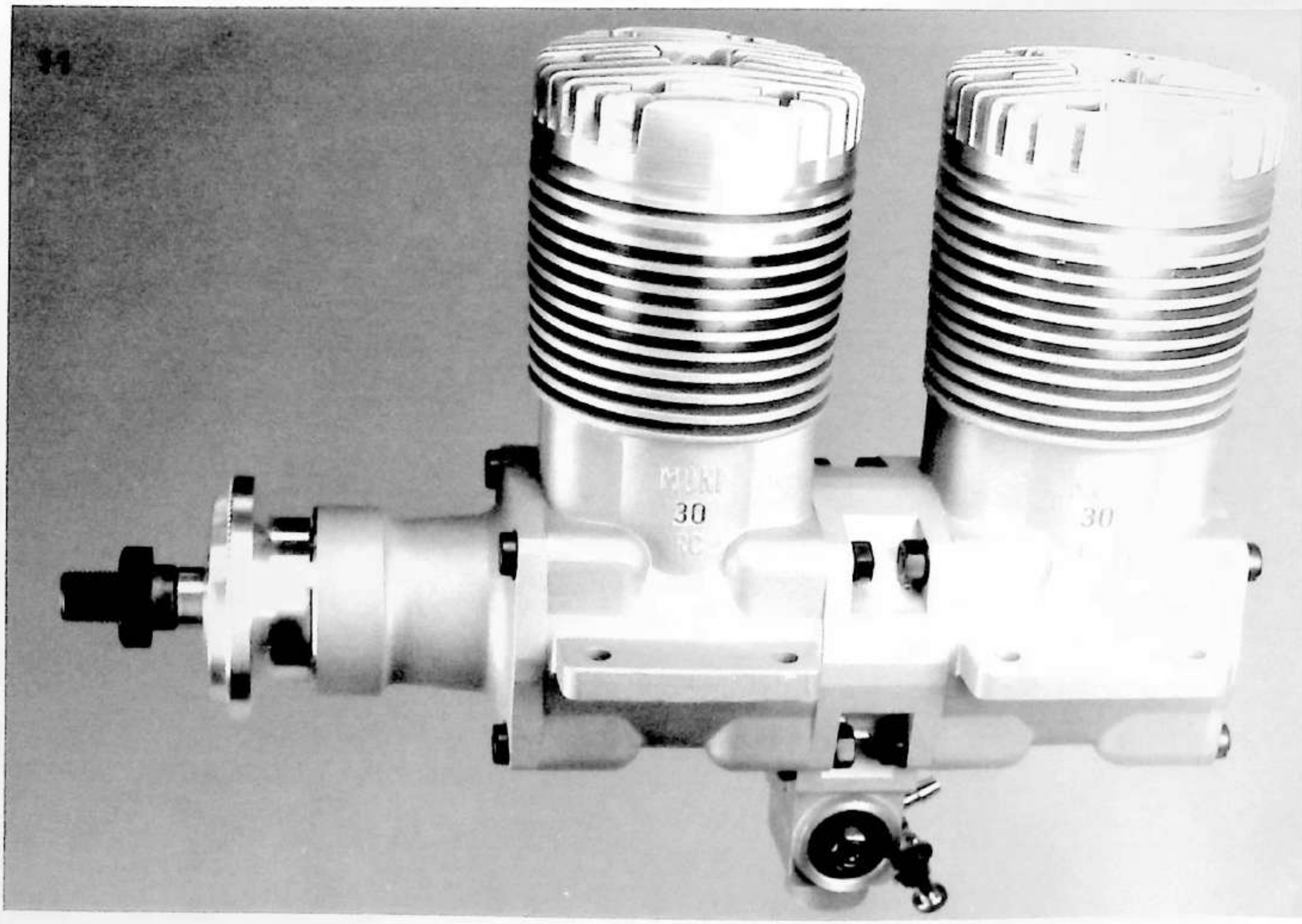

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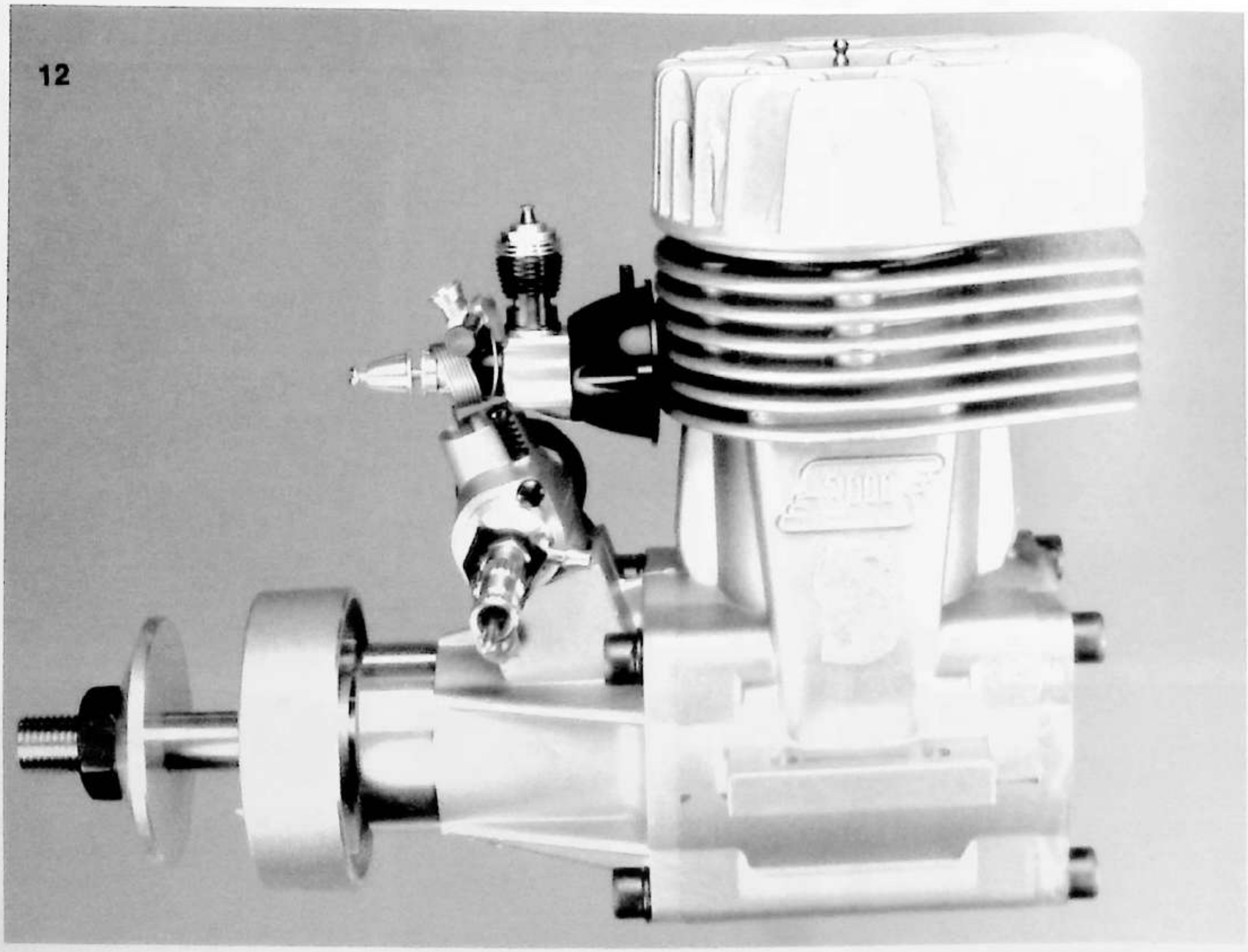

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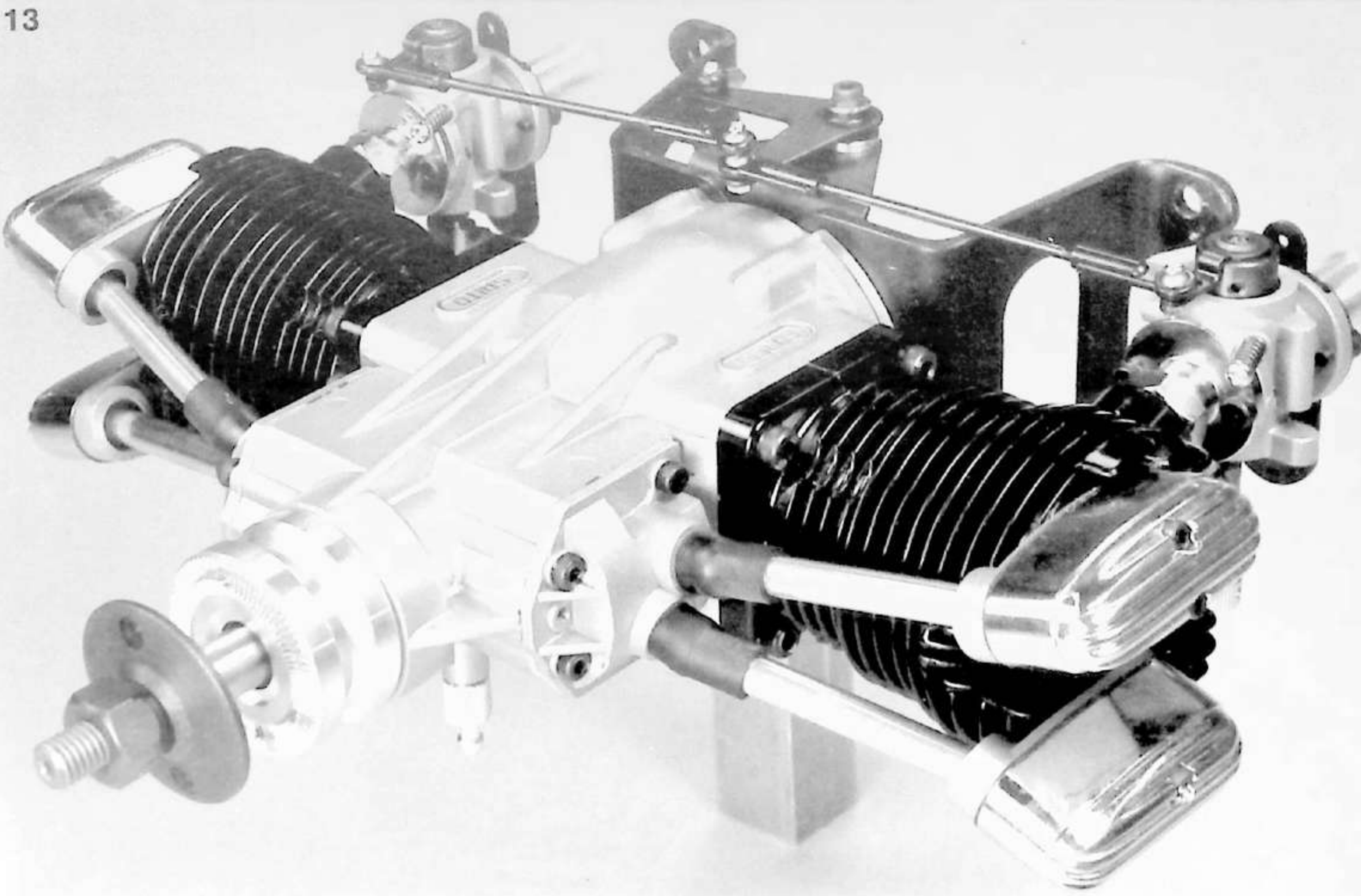

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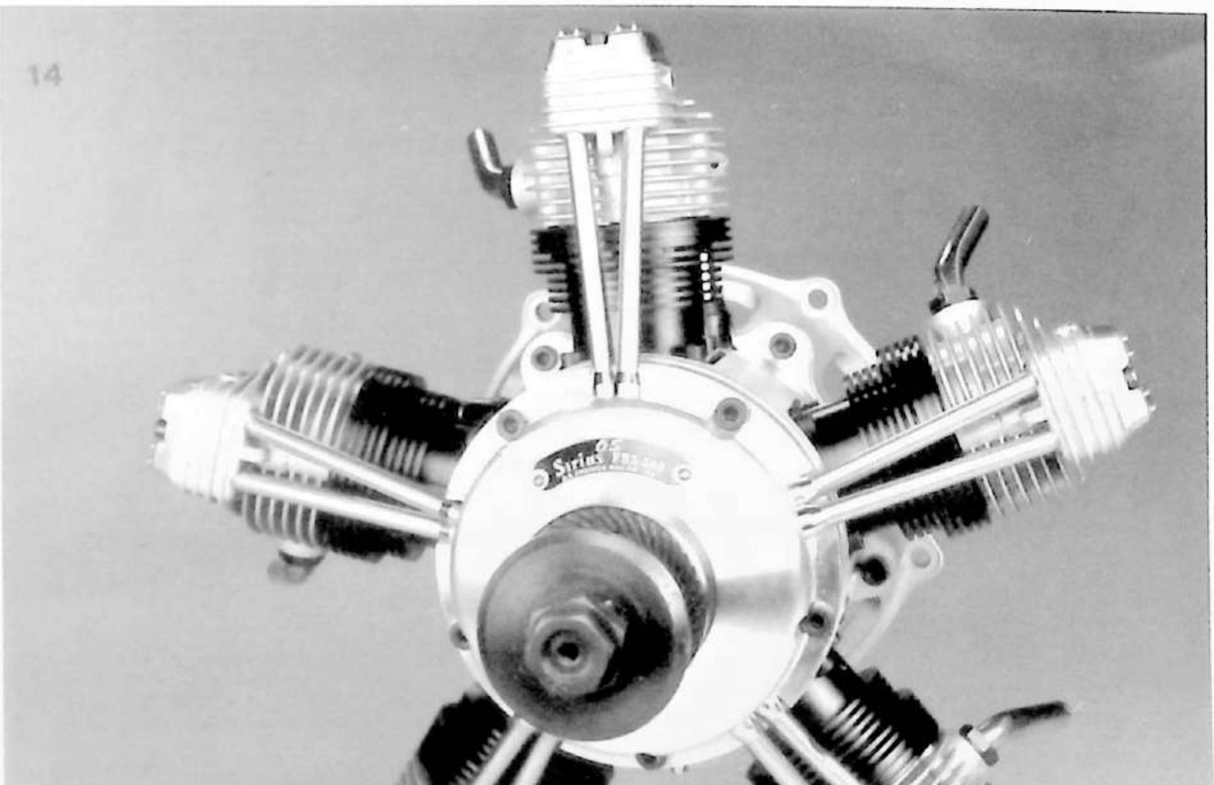
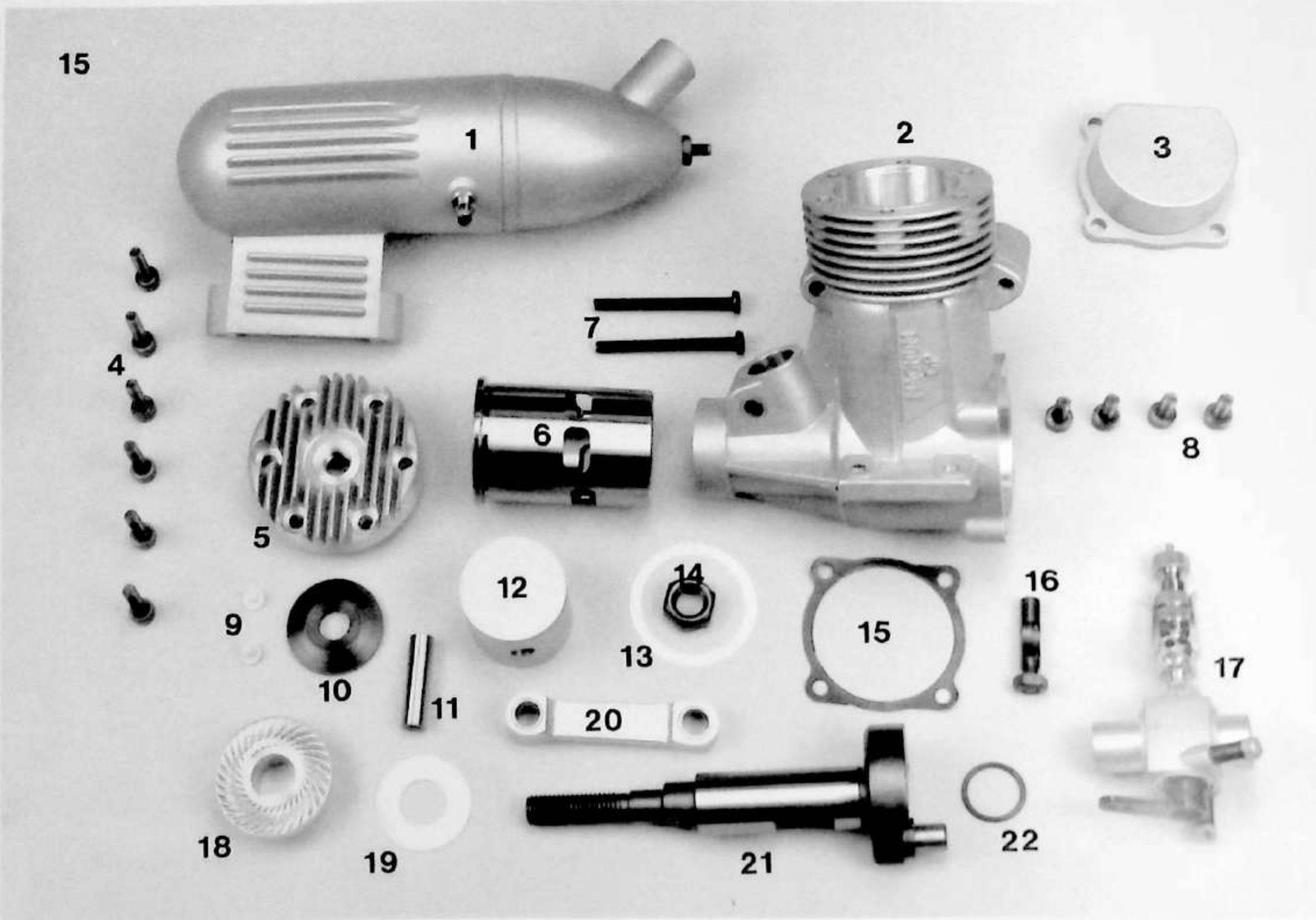


TWO-STROKE ENGINE PARTS



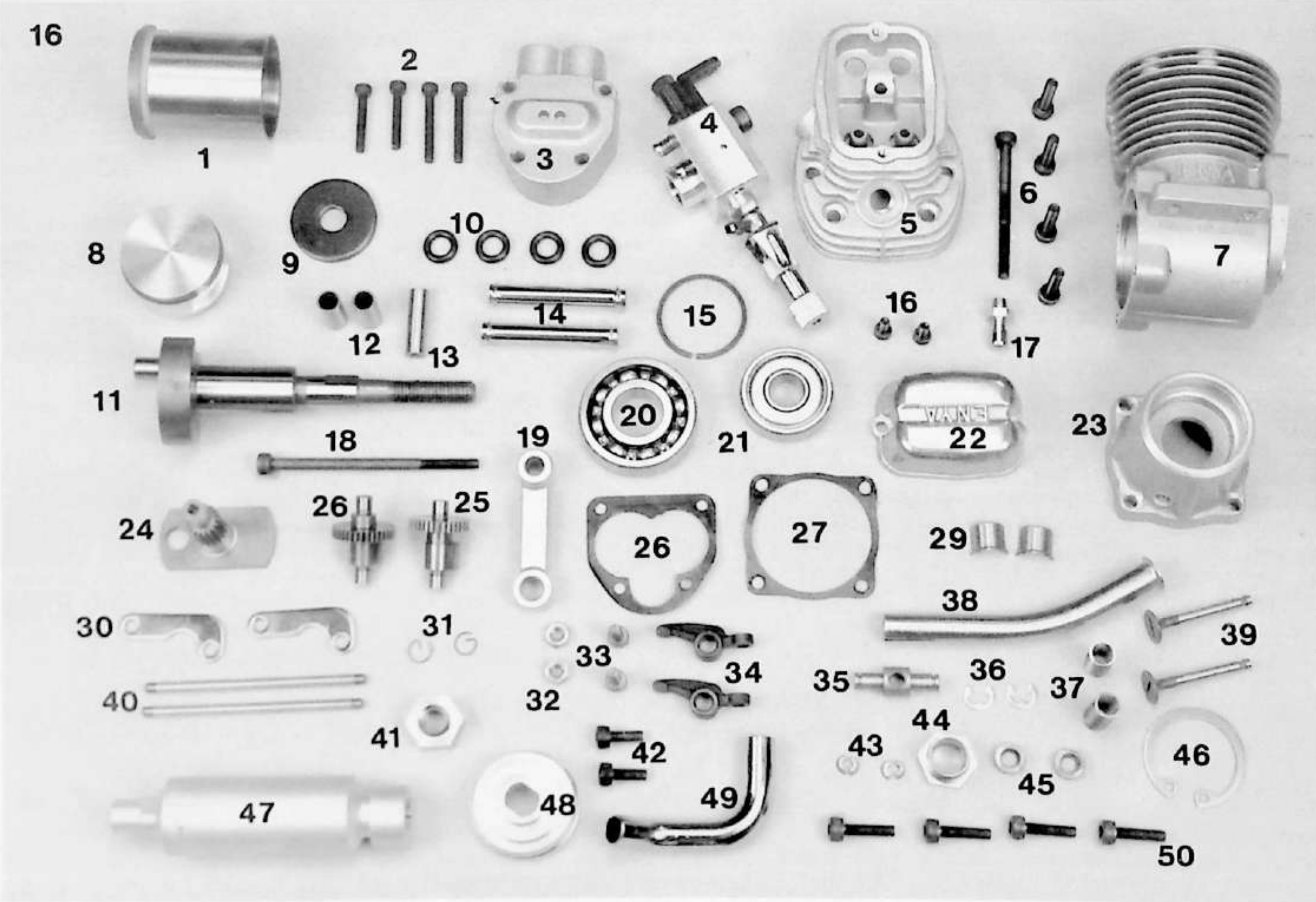
SORTED BY NUMBER

1 Muffler	12 Piston
2 Block	13 Head Gasget
3 Back Plate	14 Propeller Nut
4 Cylinder Head Screws	15 Backplate Gasket
5 Cylinder Head	16 Carburetor Clamp Screw
6 Cylinder Liner	17 Carburetor
7 Muffler Screws	18 Propeller Drive Washer
8 Back Plate Screws	19 Wear Washer
9 Wrist Pin Pads	20 Connecting Rod
10 Front Propeller Washer	21 Crankshaft
11 Wrist Pin	22 Carburetor "O" Ring.

SORTED BY NAME

3 Back Plate	6 Cylinder Liner
8 Back Plate Screws	10 Front Propeller Washer
15 Backplate Gasket	13 Head Gasket
2 Block	1 Muffler
17 Carburetor	7 Muffler Screws
22 Carburetor "O" Ring.	12 Piston
16 Carburetor Clamp Screw	14 Propeller Nut
20 Connecting Rod	18 Propeller Drive Washer
21 Crankshaft	19 Wear Washer
5 Cylinder Head	11 Wrist Pin
4 Cylinder Head Screws	9 Wrist Pin Pads

FOUR-STROKE ENGINE PARTS



SORTED BY NUMBER

1 Cylinder Liner
2 Timing Gear Cover Screws
3 Timing Gear Cover
4 Carburetor
5 Cylinder Head
6 Cylinder Head Screws
7 Block
8 Piston
9 Front Propeller Washer
10 Pushrod Tube "O" Rings
11 Crankshaft
12 Lifters
13 Wrist Pin
14 Pushrod Tubes
15 Piston Ring
16 Rocker Cover Screws
17 Crankcase Vent Nipple
18 Choke Extension Screw
19 Connecting Rod
20 Rear Shaft Bearing
21 Front Shaft Bearing
22 Rocker Arm Cover
23 Crankcase
24 Timing Gear Shaft
25 Intake Cam Shaft
26 Exhaust Cam Shaft
27 Timing Gear Cover Gasket
28 Crankcase Gasket
29 Exhaust Manifold Clamps
30 Carburetor Mounts
31 Wrist Pin Keepers
32 Rocker Arm Lock Nuts
33 Rocker Arm Adjusting Screws
34 Rocker Arms
35 Rocker Shaft
36 Rocker Arm Retainers
37 Rocker Arm Springs
38 Exhaust Manifold
39 Valves
40 Pushrods
41 Propeller Nut
42 Carburetor Screws
43 Valve Keepers
44 Exhaust Manifold Nut
45 Valve Keeper Seats
46 Front Bearing Retainer
47 Muffler
48 Propeller Drive Washer
49 Intake Manifold
50 Crankcase Screws

SORTED BY NAME

7 Block
42 Carburetor Screws
4 Carburetor
30 Carburetor Mounts
18 Choke Extension Screw
19 Connecting Rod
23 Crankcase
28 Crankcase Gasket
50 Crankcase Screws
17 Crankcase Vent Nipple
11 Crankshaft
5 Cylinder Head
6 Cylinder Head Screws
1 Cylinder Liner
26 Exhaust Cam Shaft
38 Exhaust Manifold
29 Exhaust Manifold Clamps
44 Exhaust Manifold Nut
46 Front Bearing Retainer
9 Front Propeller Washer
21 Front Shaft Bearing
25 Intake Cam Shaft
49 Intake Manifold
12 Lifters
47 Muffler
8 Piston
15 Piston Ring
48 Propeller Drive Washer
41 Propeller Nut
10 Pushrod Tube "O" Rings
14 Pushrod Tubes
40 Pushrods
20 Rear Shaft Bearing
22 Rocker Arm Cover
32 Rocker Arm Lock Nuts
36 Rocker Arm Retainers
33 Rocker Arm Screws
37 Rocker Arm Springs
34 Rocker Arms
16 Rocker Cover Screws
35 Rocker Shaft
3 Timing Gear Cover
27 Timing Gear Cover Gasket
2 Timing Gear Cover Screws
24 Timing Gear Shaft
45 Valve Keeper Seats
43 Valve Keepers
39 Valves
13 Wrist Pin
31 Wrist Pin Keepers

CHAPTER TWO
ENGINE ESSENTIALS
IGNITION, STROKES, AND CYCLES

INTRODUCTION

Most families have at least one automobile, and perhaps a gas engine powered weed whacker and lawn mower. Experience with these everyday items is a good basis for the specialized knowledge needed to operate and maintain a model airplane engine, but we will not assume you know much more. Chapters Two and Three explain basic piston engine ideas as they pertain to our small model engines.

PARTS

Photographs (15) and (16) show a simple and moderately complex engine disassembled. Our purpose in doing that is only to provide a reference for your early reading. If we mention an unfamiliar part name, look for it here. The parts lie mostly in rows, and numbers increase going from left to right. Two tables appear for each photograph, one sorted by part number and the other by name. That should make it easy to find any part. Carburetors are complex and a subject unto themselves, so their parts appear in Chapter Twelve.

IGNITION AND COMBUSTION

K&B Manufacturing supplied some engines that we cut apart to reveal their inner workings. Look ahead to photos (31-34). They show how the area immediately above the piston, the combustion chamber, decreases in volume during the piston's upward movement. The temperature of a gas increases as it becomes compressed during the piston's up stroke. The combustion mixture contains a fuel, usually alcohol, that starts burning as the piston nears the top of the cylinder. When a confined gas burns and heats up, its pressure against whatever contains it increases, so the hot, burning combustion mixture forces the piston down. All model piston engines use these principles, though in different ways. For now, let's begin our study of model engine basics by discussing three ways to ignite the mixture. They are pure diesel, semi-diesel, and spark ignition.

Diesel ignition, the simplest kind, relies totally on the heat caused by compression to ignite the fuel. Diesels run beautifully on a wide range of propellers, idle well, start without problems, and are generally easy to adjust and operate. Despite this, diesels have never been very popular in the U.S, partially because of their unusual fuel. Model diesels derive their power from kerosene just like semi-trailer truck diesels. Kerosene and diesel fuel sold at truck stops are similar chemically, but the other ingredients that help model diesel fuel vaporize are difficult to find. Photo (17) shows a modern Irvine diesel engine. Notice the thumb screw protruding from the head. Photos (18) and (19) show a Davis Diesel head both assembled and disassembled to illustrate an adjustable combustion chamber. Compression sensitive diesels need that feature for two reasons. A different amount of compression ignites the fuel during a cold start than during normal running. And, the amount of compression also controls at what piston location the ignition occurs. With too much compression, ignition takes place long before the piston reaches its uppermost position. A preigniting engine may continue running but wastes power fighting the piston's upward travel, and overheating also occurs. *Preignition and detonation mean the same thing and can happen with any type of ignition.*

Most model engines are semi-diesels which means the compressed gasses need a little help to ignite. Modelers don't use the term semi-diesel and call them glow ignition engines. Their ignition assist comes from a glow plug containing a platinum wire coil (20). While starting, a low voltage battery (21) heats the filament red hot. After starting, burning gasses maintain the high coil temperature between firings without a battery. If you run a semi-diesel at night, the glowing coil may be seen reflected in the exhaust port, even after removing the battery. Platinum and gold cost about the same, so you might wonder why glow plug manufacturers choose platinum when a material like nichrome could be heated red hot and costs much less. Glow plugs provide more than additional heat. A few substances, platinum is one, cause a chemical reaction like combustion to occur under less than ideal conditions. Scientists call such a substance a catalyst. Actually, nichrome has catalytic characteristics, though not as pronounced as platinum. A platinum catalyst works exceptionally well with methyl alcohol, so common glow fuels contain mostly methanol.

Before glow plugs became available in the late 1940's, all model engines were spark ignition. Now, many large model engines like the Zenoah in (22) use spark ignition. A spark jumps between spark plug points in the combustion chamber at just the right instant to ignite the fuel, just like in cars and lawn mowers. Model spark ignition engines are little different than any other size and run on a gasoline based fuel, too.

A LITTLE TERMINOLOGY

Common usage has clouded the accurate meanings of a few important piston engine terms, and we need to clear up their definitions before continuing. By stroke we mean a single, complete upward or downward piston movement. Photos (23-25) show the piston at the start, middle, and end of an upward stroke. If that doesn't seem obvious, notice how the lower connecting rod end can move no lower in (23) nor higher in (25). The piston's position in (23) is called bottom dead center "BDC", and top dead center "TDC" in (25). A two-stroke engine receives its name because everything between consecutive ignitions occurs in a downward piston stroke followed by an upward one. Since cycle refers to the period between ignitions, we have a two-stroke cycle engine. These are nearly always called two-cycle engines by mistake instead of two-stroke engines. This book reads better if we use the words correctly.

Any model engine is two airtight regions, separated by the piston. We call these regions the combustion and crankcase chambers. There is also a part called the crankcase, but I'll take some liberty and use the words crankcase chamber, crankcase, and case interchangeably. You will be able to easily tell whether we are discussing the chamber or the part. Photos (23-25) show the crankcase chamber with the piston in various positions.

BASIC CONSIDERATIONS - TWO-STROKE

In a two-stroke engine, the combustion mixture travels from the case to the combustion chamber through passages, called "bypasses", that are cast in the block or cylinder (26). An engine normally has one, three, or five bypasses. Combustion mixture leaves the bypasses and enters the combustion chamber through holes in the cylinder wall called "intake ports". Exhaust leaves the combustion chamber through an "exhaust port" in the cylinder wall. Both kinds of ports appear in (31), and you can tell them apart because exhaust ports must extend farther up the cylinder than intake ports.

Now, let's explain about ports, bypasses, and strokes as they pertain to the combustion chamber. In photo (27) the piston reaches its highest point and ignition occurs. Hot combustion gasses force the piston down (28). At the piston location shown in that shot, the exhaust has a much higher pressure than the charge waiting to enter through the intake ports. The exhaust port, extending higher up the cylinder, opens first (29), letting most exhaust exit and reducing its pressure before the intake ports open (30). Fresh combustion mixture entering the chamber then forces the remaining low pressure exhaust gasses out. When the piston reaches its lowest point (31) nearly all the exhaust has left, and combustion mixture continues entering until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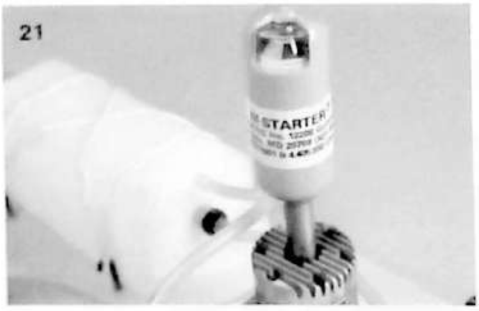

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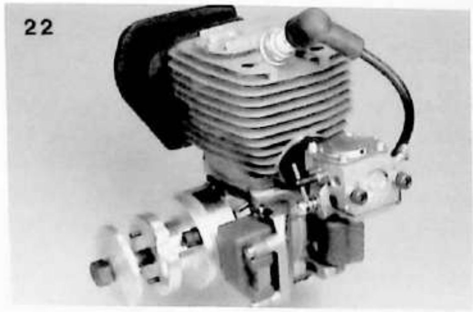
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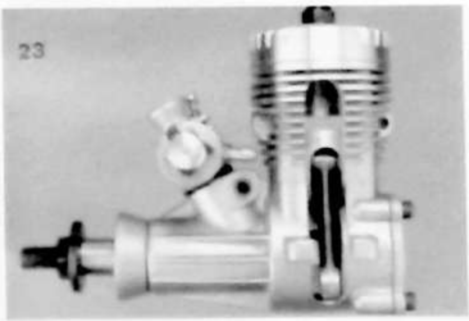
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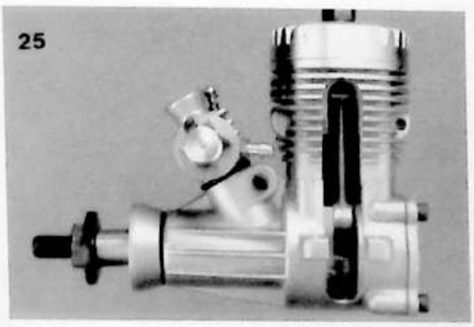
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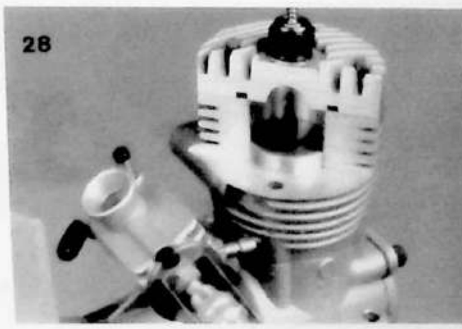
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the intake ports close (32). A slight amount of incoming mixture escapes through the exhaust port, which remains open a little longer. The piston continues moving up (33) to its highest position (34) and the process repeats itself. Because power and most exhausting occur during the downward stroke, we call it the power/exhaust stroke. Similarly, the piston's upward motion is called the intake/compression stroke.

The two-stroker's crankcase chamber acts as a pump, drawing air and fuel through the carburetor and pushing this mixture into the combustion chamber. Like any other pump, this one has inlet and outlet valves. The intake valve, usually a hole in the crankshaft directly under the carburetor, admits combustion mixture into the crankcase. The engine in (39) has its carburetor mount milled away and the crankshaft hole is visible. For now, disregard the protractor. The piston and intake ports work like an outlet valve by blocking the bypasses part of the time.

While intake, compression, power, and exhaust take place in the combustion chamber, the crankcase draws combustion mixture through the carburetor and pumps it into the combustion chamber. After ignition, the piston starts down, and the crankshaft hole rotates out of alignment with the carburetor and seals the crankcase chamber. Photo (40) shows an engine about in this condition. Delaying the crankshaft closing until after the piston moves past its highest position allows mixture already started down the carburetor throat to finish moving into the case. Continued downward piston motion compresses the crankcase gasses, since they have nowhere to go. When the intake ports open (30), pressure built up in the crankcase forces a new fuel/air charge into the combustion chamber. Shortly after the piston starts up, the intake and exhaust ports close and the upward moving piston creates a vacuum in the case. When the piston has traveled up about like in (33), the crankshaft hole aligns with the carburetor. Outside air, having more pressure than exists in the case, travels through the carburetor where it mixes with fuel and then into the crankcase. This continues until the hole in the crankshaft moves totally out of alignment with the carburetor, shortly after the piston finishes its upward travel. Then the process repeats itself.

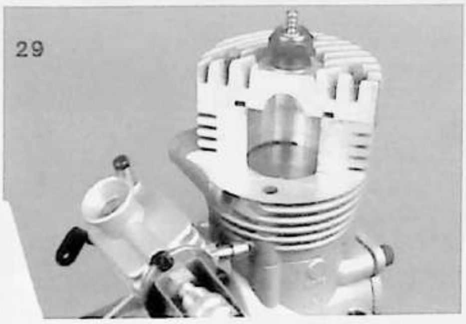
Engine people devised simple ways of measuring when a valve opens, closes, and the open period duration. Our examples illustrate these measurements and make understanding engine articles and later reading in this book more meaningful. We bolted a protractor and pointer to the engine in (35) so the pointer and protractor's zero aligned at BDC. In (36) the intake closes at 62 degrees after bottom dead center "ABDC". It also opens at 62 degrees before bottom dead center "BBDC". The intake remains open for a total of 62 + 62 = 124 degrees of crankshaft rotation. Photo (37) indicates a 144 degree exhaust duration. Looking to (38) you'll see the crankshaft opens at 48 degrees ABDC and closes (40) 224 degrees ABDC giving a 224 - 48 = 196 degree period. These measurements are called port and intake valve timings. An engine's performance is, to some extent, determined by the valve and port timings. Through trial and error, engine manufacturers find the best combination for the engine's application.

To conclude the two-stroke section, I'd like to show three experiments we conducted many years ago that were related to two-stroke crankcase functions. You might think decreasing the crankcase volume would increase power because the downward moving piston compresses the smaller crankcase more. That should increase fuel-air mixture entering the combustion chamber. When we flew control line speed in the 1940's and 50's, engine modifications that reduced crankcase volume were thought to be a good hop-up. Photos (41) and (42) show changes to a backplate and crankshaft of an old speed engine that decreased the crankcase volume. Those engine modifications never produced any improvement significant enough to increase the model's speed. For the second, related experiment, a tube and plunger (43) replaced the engine backplate as shown in (44). The apparatus could dramatically increase case volume while the engine ran. To the surprise of many, the plunger location had only a slight effect on performance. A third, more predictable experiment involved finding a relation between carburetor bore diameter and power. Cox carburetors for their TD engines are tubular with no obstructions. I made adapters for small, medium, and large carburetors (45). The same engine was test run with each one. Predictably, a several thousand RPM increase occurred every time a larger carburetor was used. Experimenting with engines can produce interesting results, sometime they are predictable, sometimes not. Nearly all modelers experiment by at least trying different propellers, plugs, and fuels. We'll say much more on these subjects later.

BASIC CONSIDERATIONS - FOUR-STROKE

These engines use four complete strokes in a cycle, one each for power, exhaust, intake, and compression. That takes two complete crankshaft rotations. Intake and exhaust valves are located in the upper combustion chamber. Since they must open and close precisely, gear timing mechanisms connect the valves and crankshaft. Mike Giger and Mike Shaw from Great Planes Distributors provided a four-stroke engine that OS cut apart so its inside, including the valve driving mechanism, are visible (46). Some additional shots appear in (47) and (48).

Two and four-stroke engines seem similar by having two chambers separated by a piston. We learned that two-stroke engines use the crankcase as a pump to draw in combustion mixture and then move it into the combustion chamber. In four-stroke engines, varying case pressure serves an entirely different purpose. A four-stroke engine relies on oil in the fuel that leaks by the piston for lubrication. Engine people call this leakage blow-by. To prevent waste oil from accumulating, the crankcase has a vent hole (49), and as the piston moves down, oil accumulation is blown out the vent. Flexible tubing attaches to a nipple, screwed in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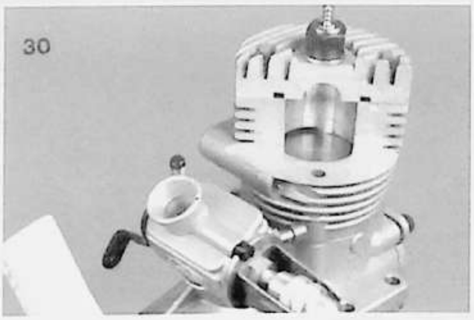
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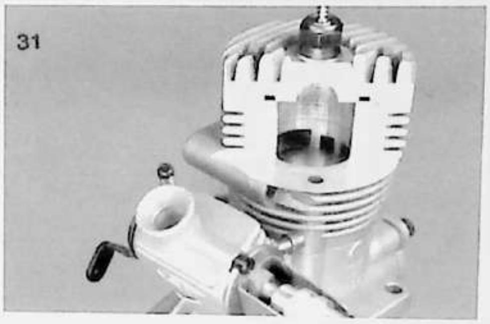
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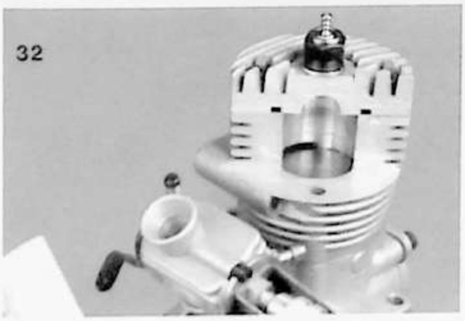
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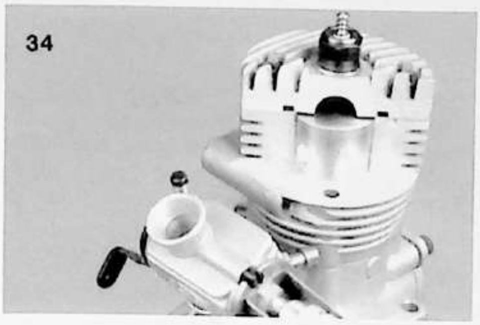
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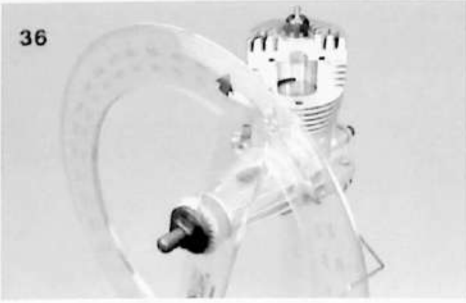
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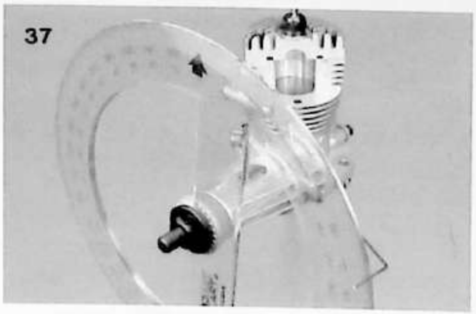
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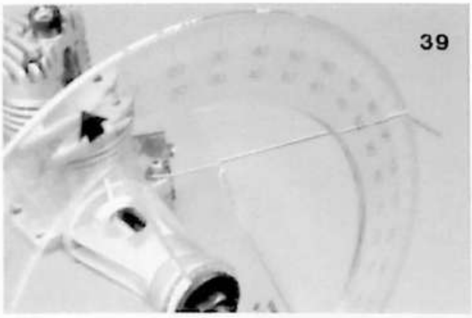
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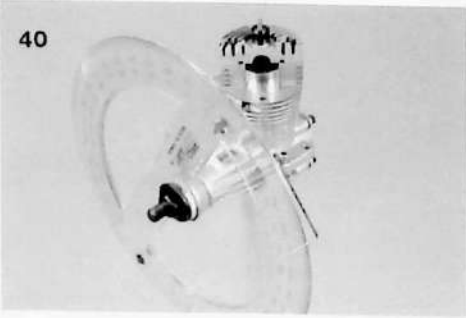
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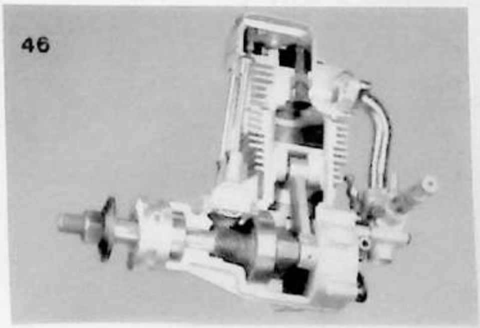
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the vent, so waste oil can be routed from the airplane's engine compartment. The quantity of oil expelled from the vent and messing up an airplane has reassured many modelers who were skeptical of this lubrication system. Crankcase venting also eliminates unnecessarily compressing the crankcase chamber, because that would cause some power loss.

Let's switch our focus to the combustion chamber. Photos (50-55) illustrate four-stroke operations in the same sequence as our earlier two-stroke development. Ignition takes place in (50). Hot expanding gasses push the piston down during the power stroke (51). Notice both valves remain closed. Next, the piston moves up, the exhaust valve opens, and the exhaust stroke commences (52). As the piston moves through TDC (53), the exhaust valve closes, the intake valve opens, and the intake stroke continues in (54). The piston then passes BDC, the intake valve closes followed by the compression stroke (55).

FOUR-STROKES VERSUS TWO-STROKES

We'll be comparing two and four-stroke engines in this section. To be consistent, assume they are the same size or else the comparisons won't mean much. As you'll see later in this section, two-stroke engines produce more power and are also less expensive. You need only look at (15) and (16) to see why - An engine manufacturer makes half as many parts to produce a two-stroke power plant. Two-stroke engines are also much easier to maintain and disassemble. There are no rocker arms to adjust or valves to lap. Many experienced modelers never bother with complicated, expensive four-stroke engines for these reasons. Yet, four-stroke engines offer many advantages that earned them a permanent place in modeling. Most flyers own one, and a typical modeler has several four-stroke engines.

A four-stroke engine looses some power to a complicated valve mechanism and has one power stroke in two shaft revolutions, while a two-stroke engine has a power stroke every revolution. A little arithmetic and common sense might lead you to think a four-stroke engine should deliver less than half the power of a two-stroker. Actually, even driving a valve mechanism, a four-stroke engine is sixty to seventy-five percent as powerful as a two-stroker. Let's see why. A two-stroke's power production ends when exhausting starts (29), long before BDC (31), so power generation lasts only about 3/4 of the power/exhaust stroke. In contrast, four stroke engines generate power for the full power stroke (51). Consider the mixture volume as compression begins. A four-stroke piston will be at BDC with the entire combustion chamber (55) full of combustion mixture. A two-stroke engine begins compression after the exhaust port closes (33); only about 3/4 of the combustion chamber contains fuel/air mixture. Thus, the four-stroke has a greater combustion mixture volume. The four-stroke's superiority in power duration and combustion mixture volume during a single power stroke explains the unexpectedly favorable comparison between four-stroke and two-stroke power.

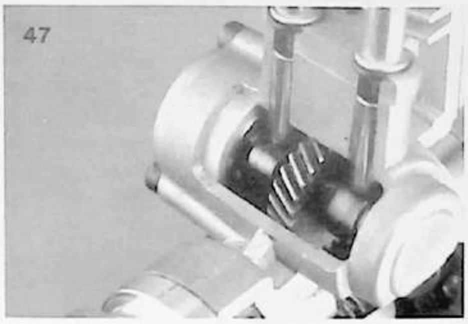
Four-stroke engines have another, subtle power related advantage. One aspect of good flying airplanes is their ability to accelerate quickly to maximum speed after slowing down. A large diameter propeller accelerates an airplane faster than a smaller prop. Man carrying airplanes like the P-51 and Skyraider had huge props for that reason. An engine's horsepower depends on many factors including propeller size and engine RPM. Engineers who study these things make the following observation. At some definite RPM an engine produces its maximum horsepower, and changing propeller size only lessens power. Two-stroke engines develop their maximum horsepower at a higher RPM than four-stroke engines. The greater RPM needed for peak two-stroke horsepower often requires too small a prop for good acceleration. So, modelers are forced to run a larger prop anyway. An over propped two-stroke engine pulls the model with much less than its greatest horsepower. A four-stroke engine with its low RPM for peak horsepower will turn a large prop and still be near its maximum capability. To say this another way, four-stroke engines use a greater percentage of their available horsepower in many modeling applications.

For several reasons, four-stroke engines run quieter than two-strokes. At a given RPM, a four-stroke fires only half as often. That means less noise and at a lower pitch. Four-stroke engines have a greater exhaust period, and that dissipates the sound over a longer time. A four-stroke engine running quietly and a large propeller's noise, sound like a man carrying piston engine ship, and many flyers like this realistic sound.

SUMMARY AND SOME EXTRAS

We can summarize this chapter by noting that there are three kinds of ignition: diesel, glow [semi-diesel], and spark. Four piston engine functions, [power, exhaust, intake, and compression], take place in two or four strokes of the piston. I'm not familiar with any attempts to use diesel ignition on a four-stroke engine. With that one exception, any ignition system can be found on both two and four-stroke engines. Two-stroke engines are more powerful and less expensive, though not as realistic and noisier than four-stroke engines.

A chapter does not always end exactly on a page break, and when that happens, we use the space for interesting photographs that may be only slightly related to the chapter. The first of these follow. While it may be a little early to consider superchargers, we thought you might want pause a few minutes and would enjoy looking at the cutaway OS unit (56-57). Photos (58-59) show the front end of some large models powered by spark ignition gasoline engines.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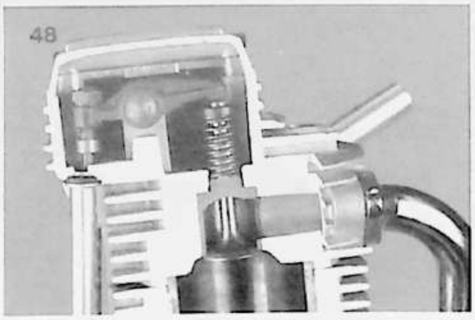
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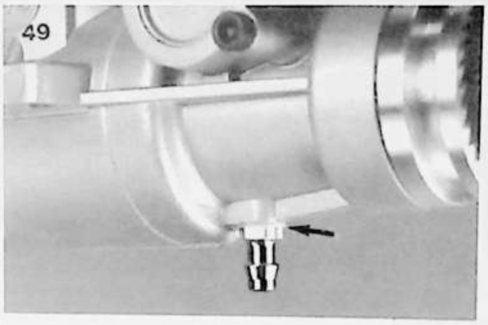
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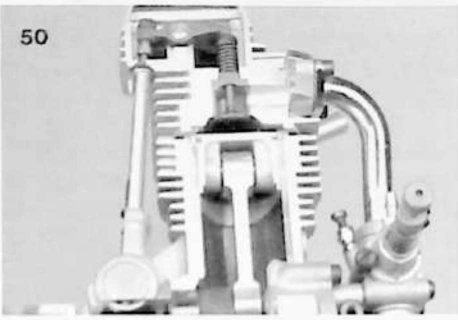
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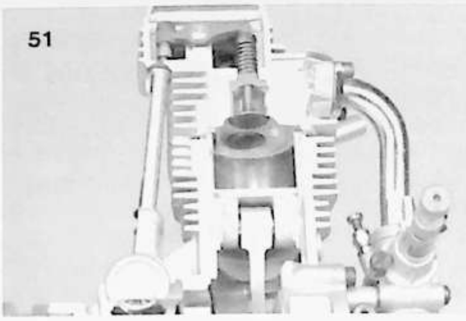
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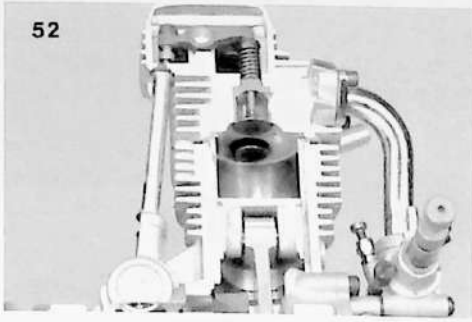
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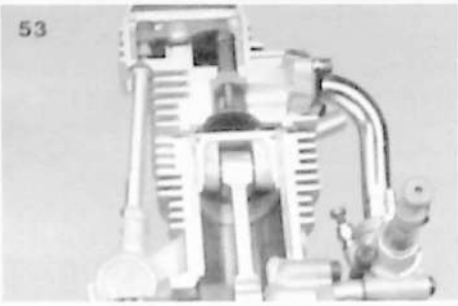
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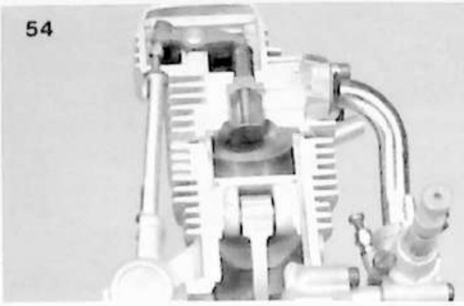
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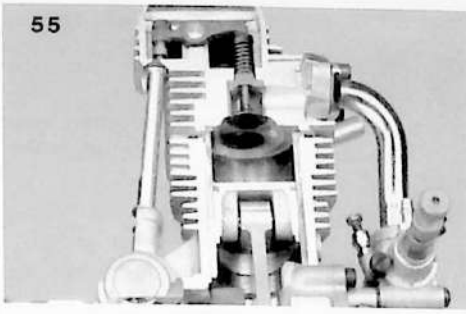
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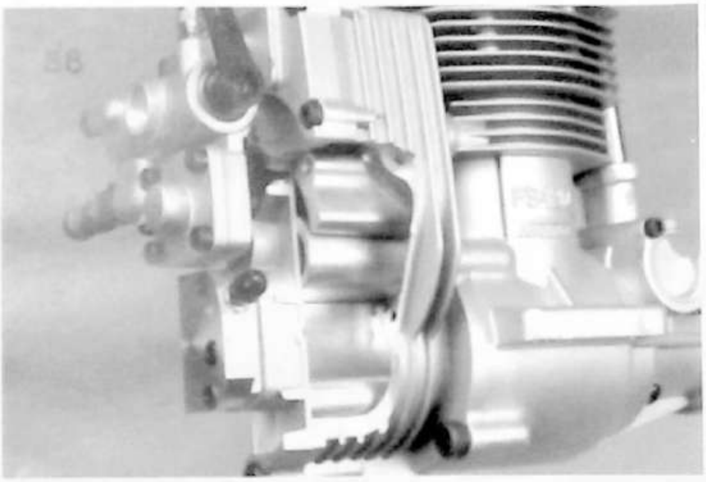
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CHAPTER THREE
MORE ESSENTIALS

INTRODUCTION

Chapter Two stated all model engines considered in All About Engines have two or four strokes and feature diesel, glow, or spark ignition. Other equally important engine characteristics discussed now help new modelers select a first engine, and experienced flyers find these essentials are necessary for easy engine operation and maintenance.

ENGINE SIZE

Model engine size can be expressed in many ways including horsepower. Since we try matching an engine's power to a particular airplane, horsepower might seem like a good measurement, but it isn't. Even a single engine gives a wide horsepower range that depends on propeller size, fuel, and some less obvious things. Besides, measuring horsepower takes special instruments. We need a measuring method that indicates power without the variability and expense of determining horsepower.

Chapter Two introduced ideas about combustion that can be expanded into a sensible size measurement. The amount of combustion mixture burned in a single piston downstroke largely determines an engine's power. More mixture yields more power, so all other things being equal, an engine with the largest combustion chamber will be the most powerful. Let's discuss an easily measured indicator of combustion mixture volume. A piston in (60) rests at its lowest position and at its highest in (61). The top of the piston moves through a cylinder while traveling between these two extremes. To make that clear, we put a brass cylinder the same size on the exhaust passage in (62). Piston engine designers define an engine's size as the volume of that cylinder and express it in cubic inches or cubic centimeters.

The piston displaces this volume into the top of the combustion chamber during each compression stroke, so we call that volume displacement. Displacements range from .010 to 3 cubic inches and larger. Photo (12) on page three shows two engines about those sizes. Cox's novel .010 flies only a micro small airplane when conditions are ideal. A large Super Tigre 3000 effortlessly pulls a ten or twelve foot model. Modelers often omit the decimal point and unit of measure when they specify size. They refer to a .46 cubic inch displacement engine simply as a forty-six.

COMPRESSION RATIO

A tiny diesel (65) has a much higher compression ratio than a giant engine (12), so compression ratio measures something other than size. However, both size and compression ratio involve combustion chamber volumes, and for that reason their discussions appear together. If you want to know about compression ratio, the idea of a ratio may need a little clarification. Ratio simply means one number divided by another. Sometimes a "/" or a "to" appears in a ratio. For example: "7 divided by 3", "7/3", and "7 to 3" express the same ratio. Piston engine people use a "to" when expressing compression ratio. We'll first look at two cycle engines. Consider the liquid volume that can be dispensed into the engine pictured in (63). That fluid volume equals the combustion chamber volume above the exhaust port. Empty the engine, remove its glow plug, and move the piston to TDC. We measure the volume between the piston at TDC and the lower glow plug hole in (64) and call that region the upper combustion chamber or "upper cylinder". The liquid volume dispensed in (63) divided by liquid volume in (64) measurers compression ratio. Stated another way, two-stroke compression ratio is the combustion chamber volume above the exhaust port divided by the upper combustion chamber volume. Glow engine compression ratios usually measure about 8 to 1. Diesels may be as high as 20 to 1, since they need extra heat given by this greater compression. Because it lacks a glow plug hole, you'll need to remove a diesel's head to find its compression ratio. We won't go to that trouble in this introductory section.

A four-stroke's compression ratio is determined in a similar way. Remove the glow plug, set the piston at BDC and measure the fluid volume needed to fill the entire combustion chamber. Empty the engine, move the piston to TDC, and measure the upper combustion chamber volume the same way. Four-stroke compression ratio is the first volume divided by the second.

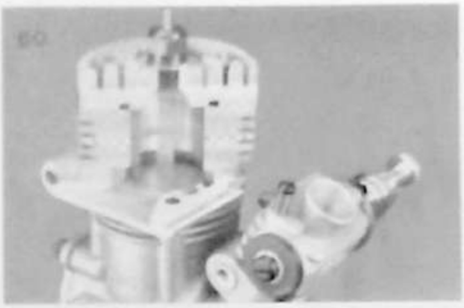
SEALING THE TWO CHAMBERS

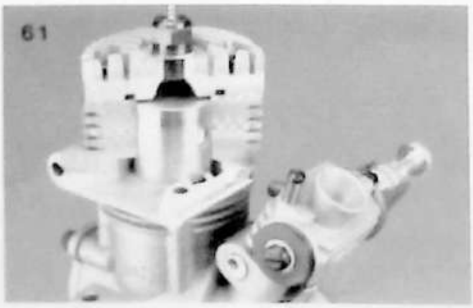
A poor piston to cylinder fit causes overheating in more than one way, and an overheated engine will never run reliably or at its maximum power. Cool running four-stroke engines have the finest piston to cylinder seal manufacturers can get, but in spite of the good fit, enough fuel blows by the piston to lubricate the crank-case. This shows that every piston and cylinder leaks a little, including a two-stroker's, but excess leakage brings on serious problems. Physicists tell us gasses that move fast through a narrow passage, like the one between a piston and cylinder, produce heat from fluid friction. Gases moving through a bad fit give off heat faster than the engine can get rid of it. Hot exhaust, now in the crankcase, contributes additional heat. Besides heat caused by exhaust gas movement, mechanical friction between the piston and cylinder wall also generates heat. *The seal with the least leakage and mechanical friction helps any engine run cool,* but many engines initially have a poor seal with too much friction. Later chapters explain how to improve this by a process we call a break-in. The remainder of this section covers different piston and cylinder types any of which would be satisfactory for a new modeler.

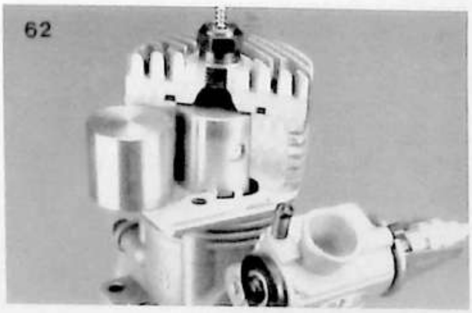
One seal uses a cast iron piston carefully fitted in a steel sleeve or vice versa. Metal parts sliding against each other wear better and have less friction when made from dissimilar metals such as cast iron and steel. These metals expand about the same during normal running, so their seal remains almost unaffected by temperature increases. Fine polishing stones accurately hone the cylinder diameter to size. Engine manufacturers bring the piston to size by lapping, a name for removing metal with a fine abrasive paste. So, we sometimes call an engine with this kind of piston and cylinder a lapped engine. Modelers have abbreviations for various piston and cylinder combinations. I'm not familiar with one for cast iron and steel, so let's use CIS. Photo (66) shows a CIS piston and cylinder liner. A long break-in burnishes a CIS piston and sleeve to a high luster, near perfect fit. Once broken-in, a CIS engine gives hours and hours of trouble-free service. Our forty plus year old Fox 35 in (2) with untold use runs better and better. While that long engine life may not be typical, most sensibly run engines will die in a crash rather than from wearing out.

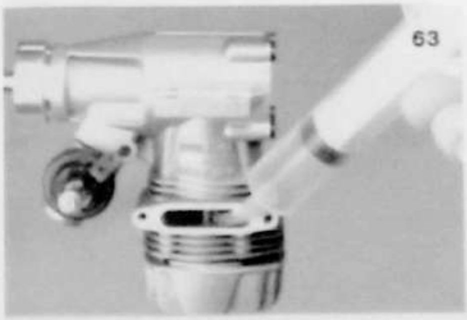
The heavy iron piston in a CIS engine produces some vibration and absorbs power as it reverses direction at TDC and BDC. A lapped engine with a light aluminum piston reduces these tendencies, but an aluminum piston requires a cylinder that expands the same when heated so the piston and cylinder maintain a good seal between the engine's two chambers at any operating temperature. Super Tigre introduced new materials for the piston and sleeve about 1968. Their engineers chose a high silicon aluminum piston which resists wear and expands just slightly less than some brass alloys when heated. Super Tigre made cylinder liners from chrome plated brass and named the combination ABC. Now, most manufacturers offer ABC engines. Aluminum is another choice of material for the cylinder, but aluminum rubbing against aluminum wears quickly and has too much friction. So, either the piston or cylinder wall receives a chrome plating. The entire cylinder may be one aluminum piece like Saito's 50 in (67). Some engines have an aluminum liner that looks like the parts in (66) and (68), though those are steel not aluminum. The abbreviation AAC means aluminum piston, aluminum cylinder or liner, and chrome plating. Both AAC and ABC survive a hot run better than other piston and cylinder combinations because the two parts expand similar amounts and won't seize. An overheated brass cylinder actually expands more than the aluminum piston. AAC and ABC engines require careful disassembly since these softer metals can't be subjected to as much force as steel. OS plates their brass cylinder liners inside and out with a dull nickel, but they still call the combination ABC instead of something like ABN. One OS I repaired came with the cylinder ruined because the owner didn't realize the part was soft brass and gouged it during disassembly.

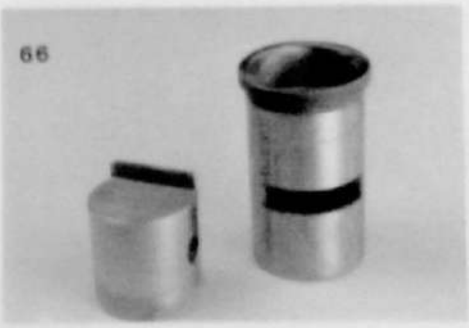
Early model engines had steel cylinders and aluminum pistons, but they relied on steel or cast iron piston rings (68) to maintain the seal between the combustion and crankcase chambers. We call these ringed engines. This combination works well and remains popular to this day. An aluminum piston must be smaller than a steel cylinder because aluminum expands more than steel when heated. A piston ring seals the chambers in the











following way. Combustion gasses force the ring downward. The ring's bottom surface contacts the piston, and that makes part of the seal between the crankcase and combustion chambers. The exposed top of the ring lets gasses flow into the narrow vertical gap between the ring and piston. These gasses force the ring out against the cylinder wall completing a tight seal. Ringed engines break-in easily and withstand some abuse better than more modern kinds, but, they don't take excessive heat well because the ring warps. Ringed engines sometimes have a chrome plated cylinder bore which increases ring and cylinder life.

Model engines have two types of rings. A conventional ring appears in (68). We pictured the second type, called a Dykes ring, in (69). A Dykes ring has an "L" shaped cross section; a conventional ring cross section is rectangular. Dykes rings eliminate some outward spring. When everything works correctly, a Dykes ring seals better with less friction than a conventional one. At very high RPM a ring wants to continue upward when passing TDC, and that breaks the seal. Lighter Dykes rings exhibit this tendency less. Some hand made competition engines had an aluminum piston, chrome plated brass cylinder with a Dykes ring. Their makers called this combination ABCD. Now, Webra's 32 (70) features an ABCD piston and ring.

CARBURETOR LOCATION

Most engines have the carburetor in front (71) and an intake valve machined in the shaft (72). Fuel mixture travels through these machined holes into the crankcase chamber. This popular arrangement, called front induction, gives a short engine and allows the shaft valve to remain open long enough for a good mixture volume to enter. Other engines have the crankcase intake valve on the backplate (73). Rear induction mechanisms most used are a disk (74) or drum valve (75). The crankshaft drives the disk or drum so it opens and closes the crankcase chamber. Rear induction doesn't weaken the crankshaft with holes, and its rear mounted carburetor contributes to a streamlined cowl, but modelers find few airplane kits with an engine compartment long enough to accommodate an engine like this. High performance, high cost rear induction engines work well for some marine applications, streamlined racing aircraft, and ducted fan jets.

BUSHINGS OR BEARINGS

A bushing is a hollow cylinder with no moving parts. Bushed engine makers produce their low cost engines by casting a compact crankcase around an inexpensive bronze bushing or simply using the aluminum crankcase as a bushing (76). Since fuel enters most engines through the shaft, the well oiled bushing can last a long time, if they're kept clean. Then, they hold up well except for failures caused by insufficient oil. These small, light-weight, bushed engines are inexpensive. Sometimes an unacceptable amount of fuel leaks through a worn bushing, and it cannot be changed.

You can look back to (72) and see a ball bearing assembly on the shaft and another in the front of the crankcase. For convenience these are called bearings rather than ball bearing assemblies. Bearings are replaceable and contain the shaft with balls or rollers (77). More costly engines have bearings instead of bronze sleeve bushings, but bearings have a shortcoming bushings do not - bearings rust. Many fuels encourage rust so this shortcoming can ruin an engine's bearings. After that, an inexperienced model engine mechanic may destroy this slightly damaged engine trying to remove its bearings, and that does not need to happen. A good oiling after every flying session eliminates rust. Later, more will be said about that and about replacing ball bearings, should that become necessary. Like bushings, clean, well lubricated bearings rarely wear out.

TWO-STROKE PORTING AND SCAVENGING

The last chapter explained the way bypass and intake ports are used in two-cycle engines. A closely related term, scavenging means clearing exhaust gas from the combustion chamber. Until after 1960, most two-stroke engines had one bypass located directly across from the exhaust. A piston baffle (68) and (69) directs incoming gasses up into the combustion chamber which helps force out the remaining exhaust gasses. Engines like this are often called cross scavenged, loop scavenged, or baffled. In the early 1960s, model engine designers applied porting methods long the standard on motorcycles. Their new creations featured three or more bypasses and a baffleless piston in ways originally patented by a gentleman named Schnuerle. The many articles written about Schnuerle's and other porting methods place an undue emphasis on the subject. Multiple bypasses produce a moderate power increase when everything else is perfect. No porting method adds enough power to compensate for even a slightly bad piston to cylinder seal, so *a beginner should not be concerned about porting when choosing an engine.*

SOME MORE EXTRAS

Again we have a few spaces for photographs before starting the next chapter so (78-81) were added. The first three feature an OS 26 Surpass four-stroke in a Goldberg Eaglet. This combination provides the least expensive way to fly a four-stroker. The 26, having about the power of a 17 two-stroke [.65 x .26 = .17] makes the take-off just a little tricky, but the ship flies great once it becomes airborne. Mark Spencer's Saito 50 powered Midwest Mustang looks and sounds like the real thing.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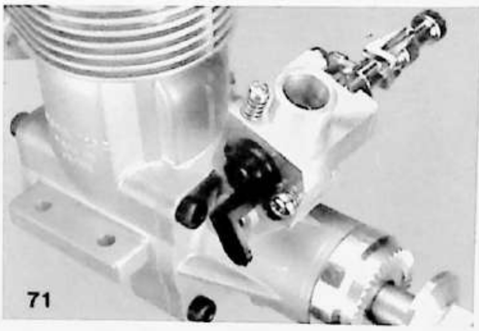
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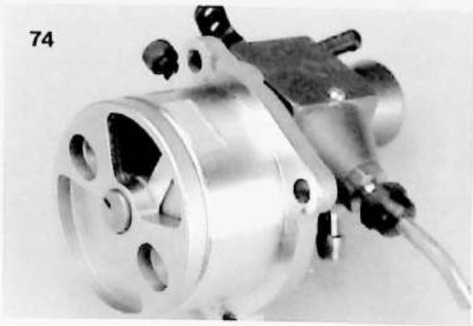
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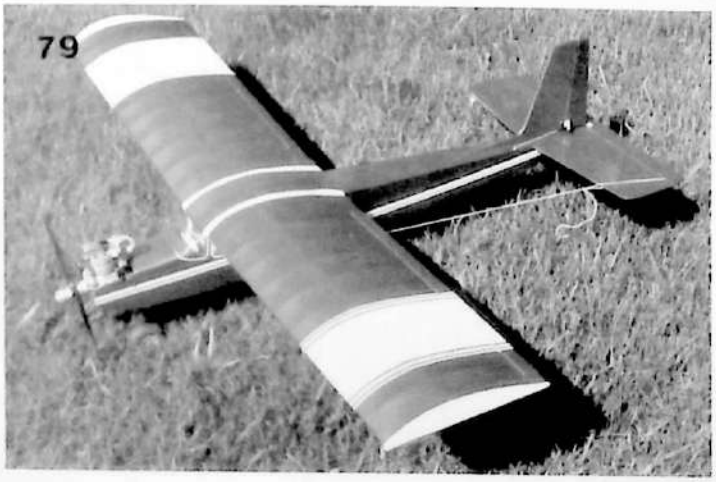
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CHAPTER FOUR
WHAT'S AVAILABLE

ENGINES NOVICE FOR THE NOVICE

Now we can make a suggestion for a novice's first engine. Size should be the most important consideration and sometimes the only one. Large airplanes fly easier and penetrate the wind better than small ones. Most beginners choose a 40 to 50 two-cycle glow engine because it has enough power to fly a big, easily controlled training airplane. Seventy-five percent of all engines sold are in that range, so every engine manufacturer makes them. Photos (82) through (93) show twelve different engines by eleven manufacturers in those sizes. While everybody may have a favorite, no one engine dominates the new flyer's market. The more expensive engines pictured often break-in easier, start better, run more reliably, last longer, and produce more power than inexpensive ones. For these reasons I would recommend a higher priced engine, if you can afford it. If not, with just a little work and patience, any engine can be made to run acceptably. We're just a few short chapters away from showing how.

FOUR-STROKE ENGINES

While 40 to 50 glow two-strokers dominate, other sizes and types offer unlimited variety. For reasons explained in the last chapter, four-stroke engines enjoy a surprising popularity. Photo (94) pictures an old OS four-stroke 60, the first commercially successful one. More modern designs appear in (95) through (102). The Enya 120's enormous size isn't apparent in (95). In (96), (97), and (98) you see an OS 48 Surpass, Enya 53, and a Saito 50. Later, we'll show how tq disassemble, reassemble, and service them. OS, Saito, and Enya each has their own approach, but most four-strokes from one manufacturer differ in little except size. By learning on the three engines pictured, you'll also be comfortable with most other four-stroke engine they make. I've included photos (99) through (102) just to show the fine engineering and workmanship available for those willing to pay for it.

SPECIALIZED ENGINES

Less common engine designs find applications in specialized modeling activities. A K&B ducted fan 45 and 80 appear in (103) and (104). These find use in scale jet models. Ducted fans demand the highest RPM an engine can turn without destroying itself. K&B's full blown racing ducted fan engines achieve that performance level. Airplane engines always have the propeller blowing air over themselves; cars and helicopters do not cool an engine as well. Car and helicopter power plants appearing in (105) and (108) all have oversize heads for extra cooling. Model car engines most often measure about .20 cu. in. Those pictured in (105-106) are a Royal and an OS. Helicopter engines come in all sizes including a Royal 28 (107) and OS 61 (108). The aerobatic event for radio controlled airplanes is called pattern. Its rules restrict engine displacement, so pattern flyers need all the power an engine can develop. Only 60s and 61s enjoy much popularity. High quality pattern engines have every racing feature money can buy. Photos (109) and (110) show examples by YS and Enya.

Giant models, one fourth the size of man carrying airplanes, steal the show wherever they fly, but bigness offers a special engine consideration. Glow fuel costs more than gasoline, and big engines inhale large amounts. Even so, many quarter scale model builders still choose glow ignition engines like the Super Tigre 3000 (111) and OS 3500 (112). Incidentally, I showed the Super Tigre next to a 45 so you could appreciate its size, and the OS 3500 is even a bit bigger. Other people with an interest in large models choose spark ignition engines, like the Zenoah (113) and Tartan Twin (114), and run less expensive gasoline. Whatever a modeler's large engine preference, someone surely makes it.

Boat engines are normally airplane engines with some modifications and additions. They include a flywheel and universal joint that attaches to the drive shaft; these appear nicely in (115). No significant air volume flows over the engine, so the modified cylinder and head accept a water jacket (116). Larger engines, like the OS 61 in (121), sometimes force water around the exhaust port too. Boaters choose their engines from a selection second only to that offered for airplanes. An inexpensive ASP 12 (116) and beautifully made Austrian Webra 20 (117) bracket the price range for small engines. Photo (119) illustrates a midsize British made Merco 30. The huge, Tartan (120) air cools itself with a fan located under the shroud. Every group of modelers includes some who want to compete, and boaters are no exception. The OS 61 (121) and K&B 45 (122) lack nothing that would help performance. The last engine mentioned in this overview comes from K&B (118). They cleverly made an aircraft racing engine into a practical outboard.

WHAT'S NOT AVAILABLE

Chapter Four ended with a few photograph positions open, so we thought you might like to see some specialized engines from long ago. They belong to my engine collector friend Fred Linde. The early glow O&R marine in (123) ended production in the mid 1950s. The "O" of O&R stands for Irwin Ohlsson whose company still produces glow plugs for K&B, Saito, and Hobby Shack. The next engine is a cutaway OK Super 60 car engine (124) Fred bought from an estate. Our best guess dates it about 1947. The third engine, a Hornet 60 (125), comes from the same period. The Hornet is my all time favorite engine. While no one claims these old timers could begin to compete with the modern engines just shown, engine collecting becomes bigger every year.


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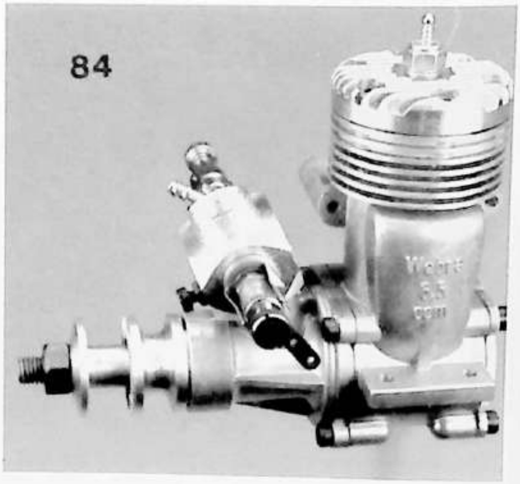
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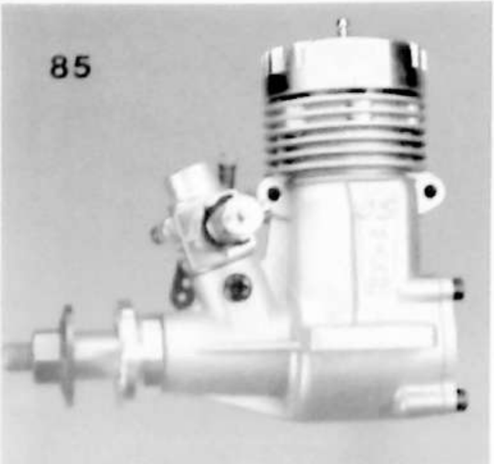
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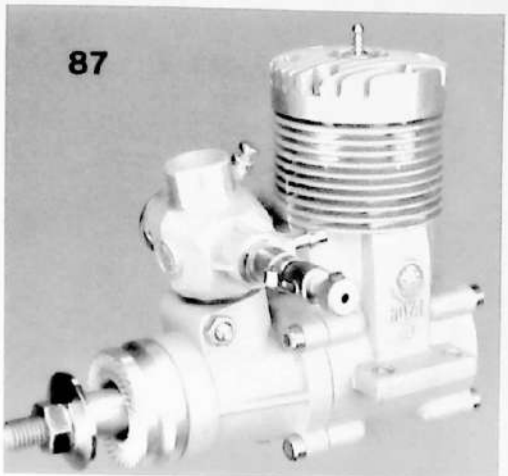
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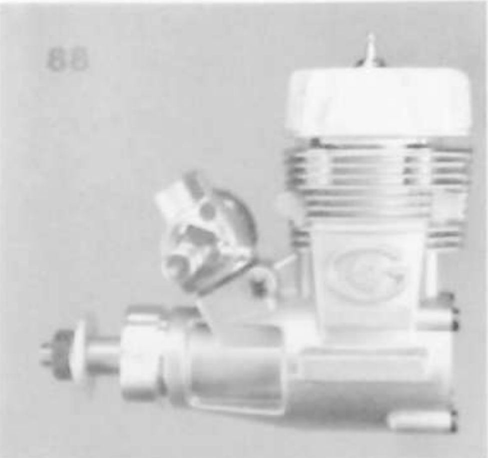
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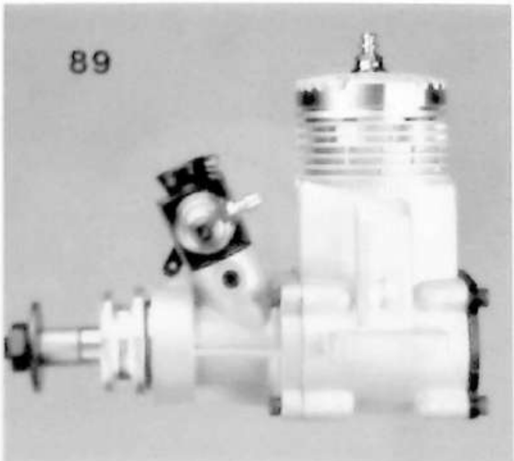
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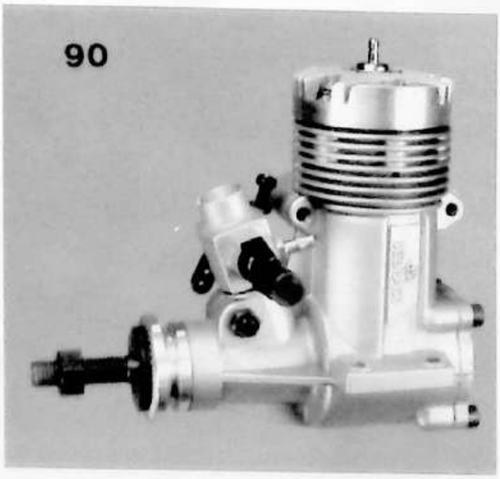
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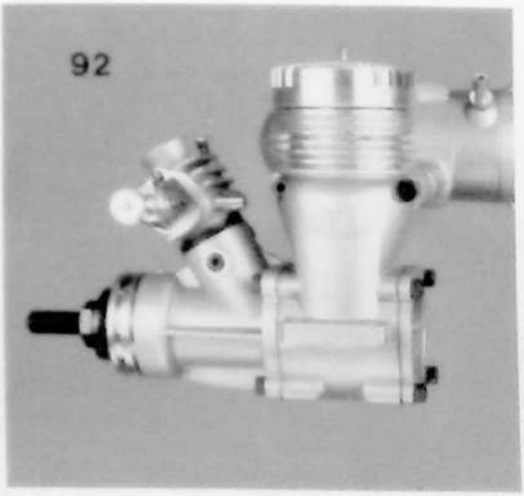
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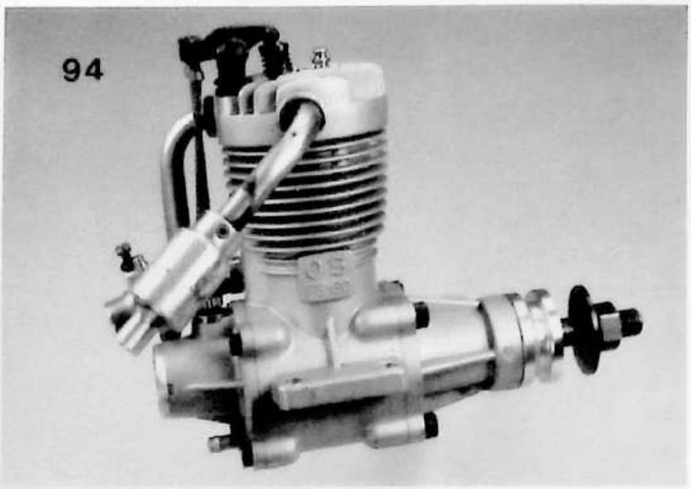

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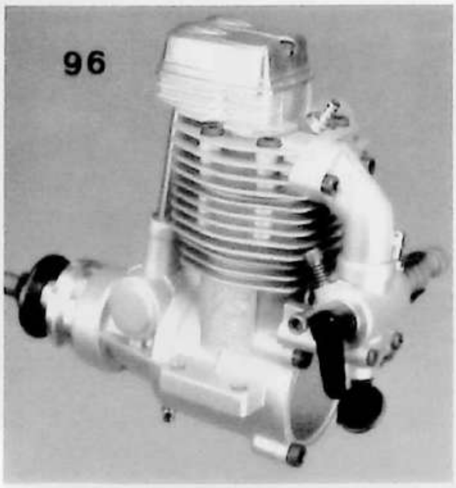

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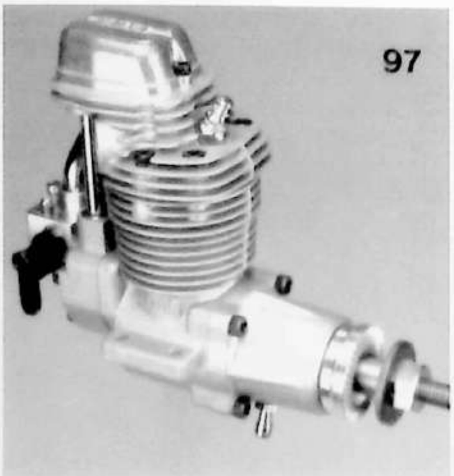

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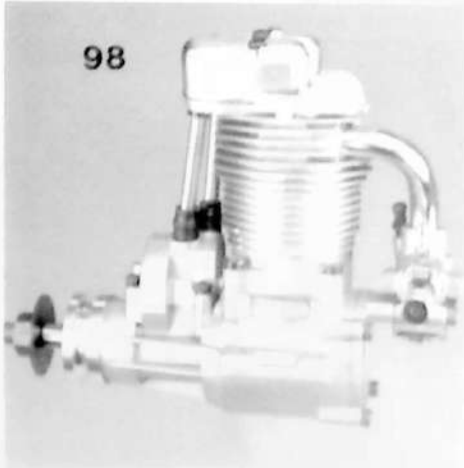

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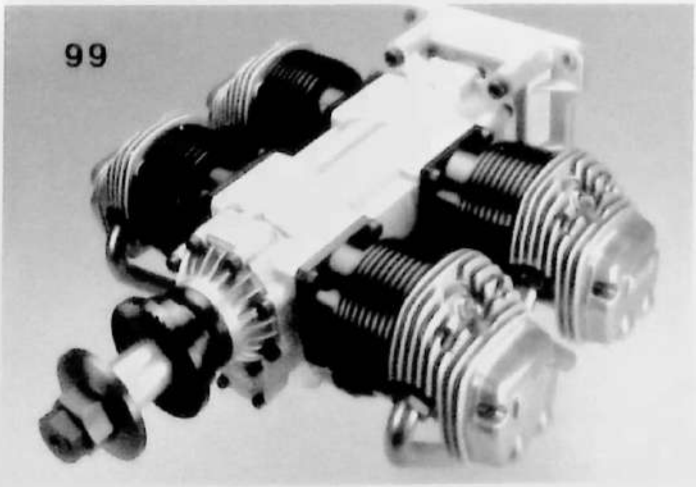

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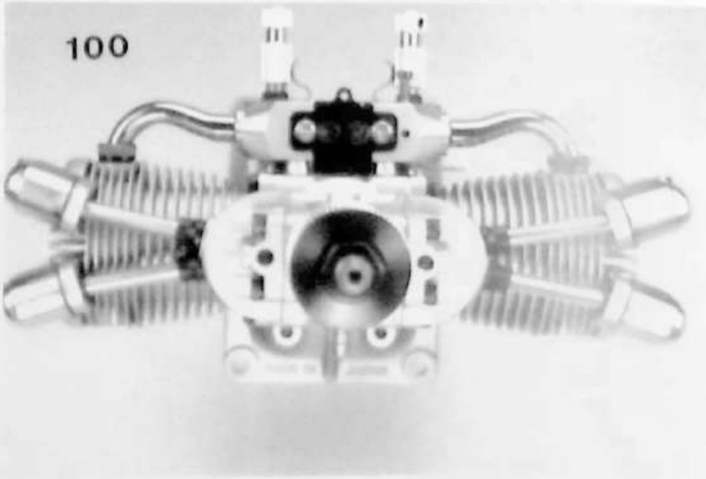

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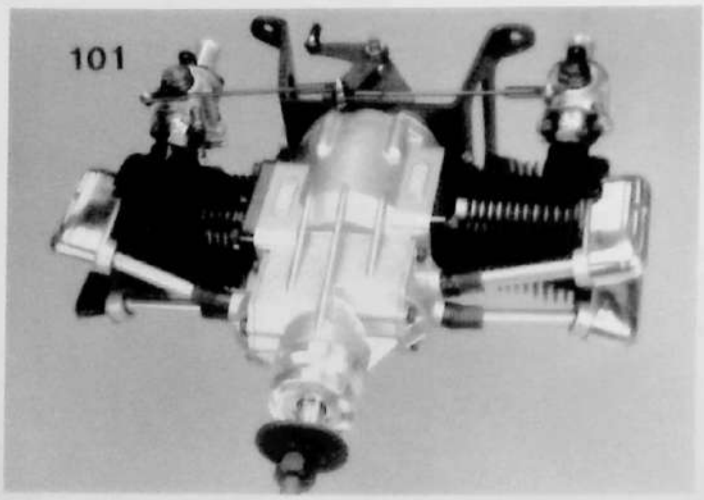

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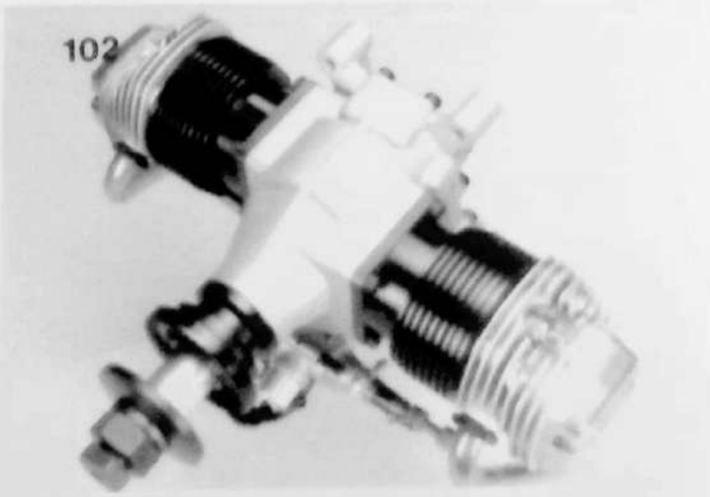

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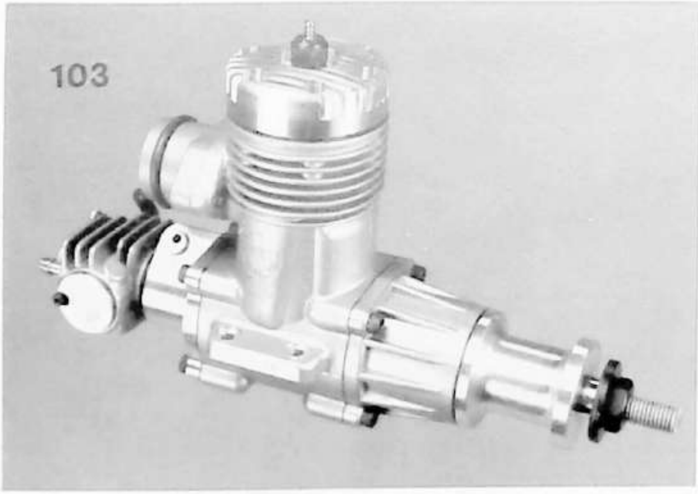
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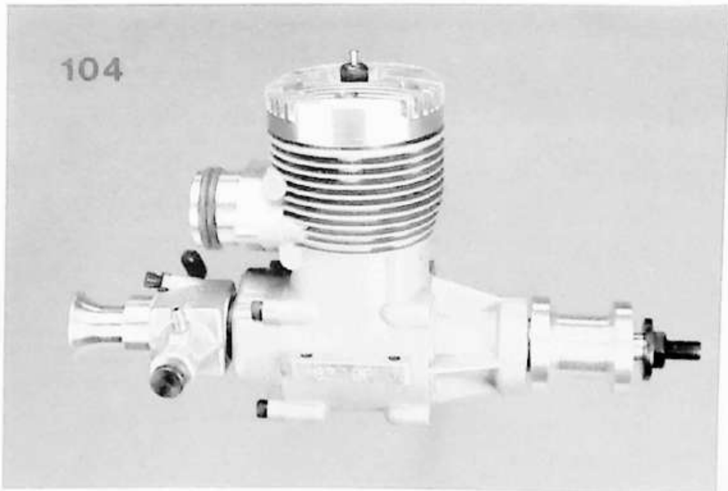
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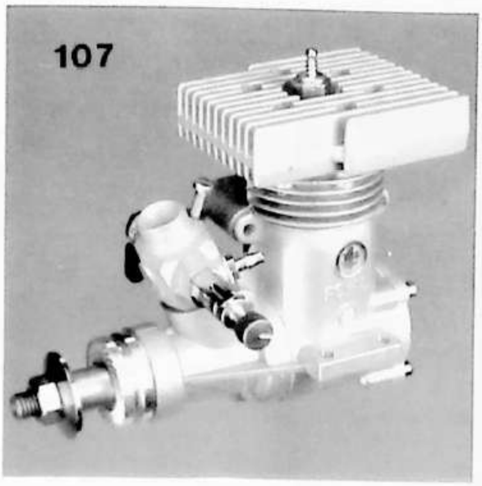
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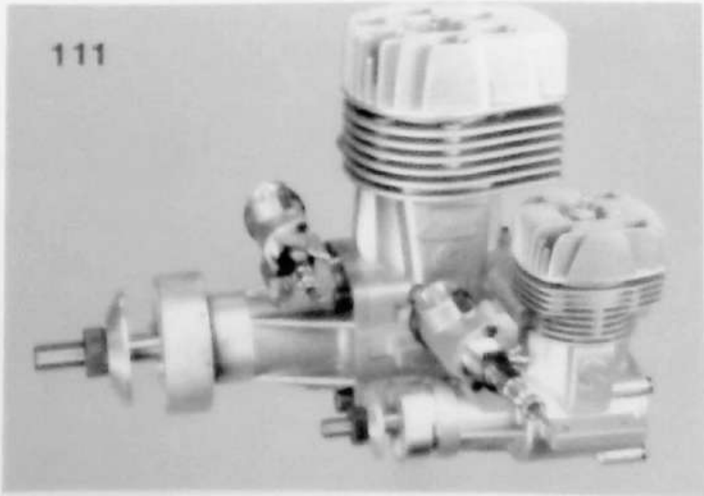
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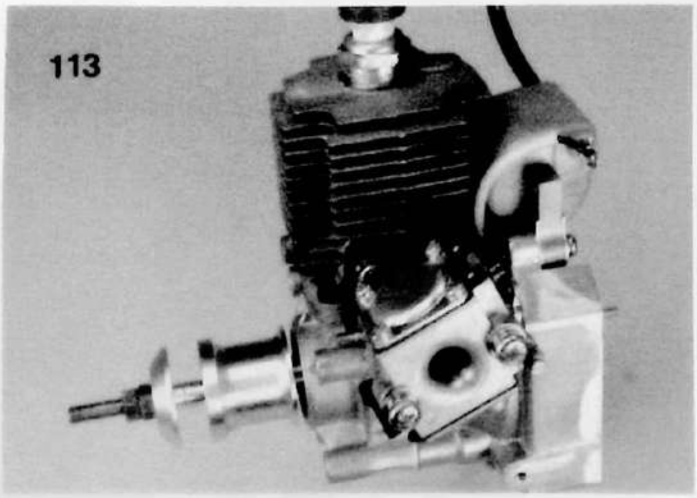
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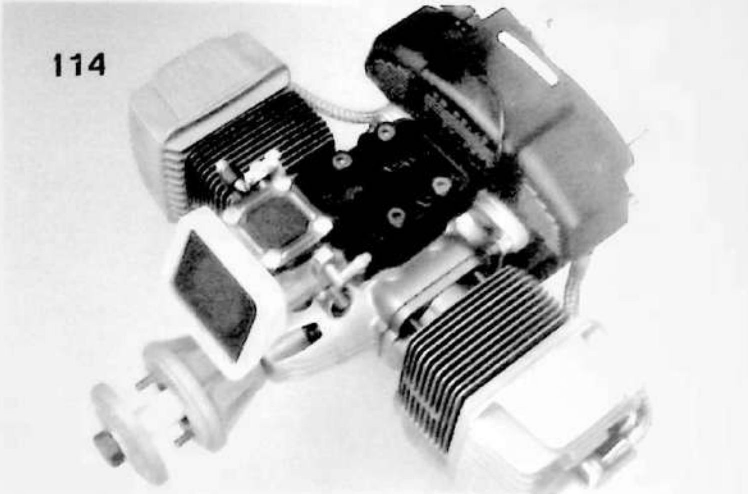
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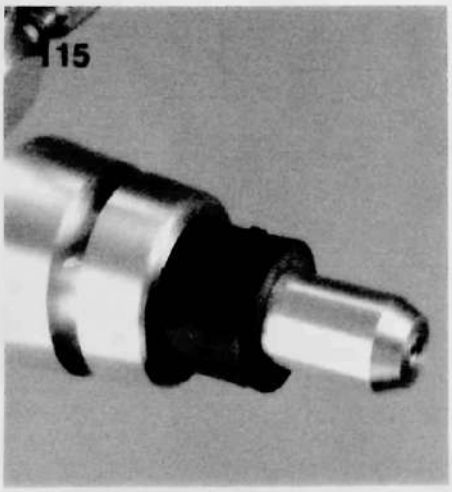
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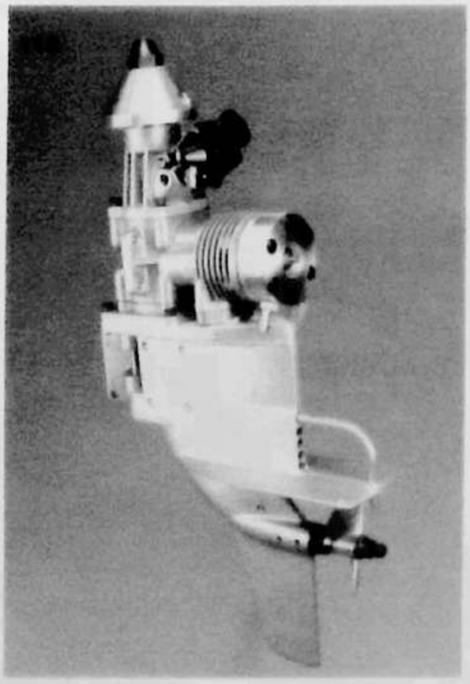

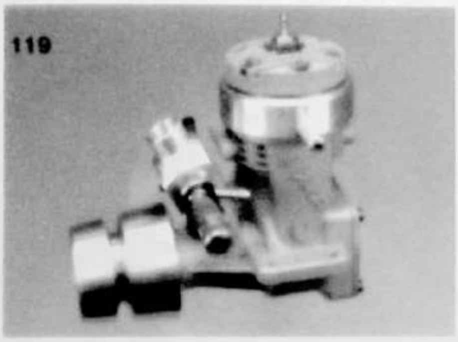
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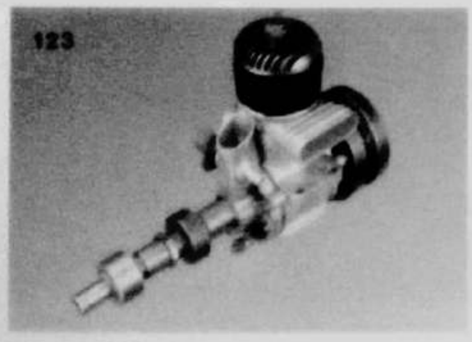
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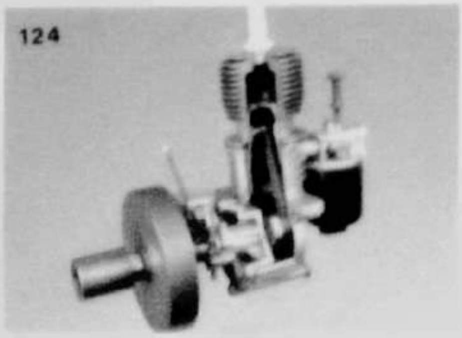
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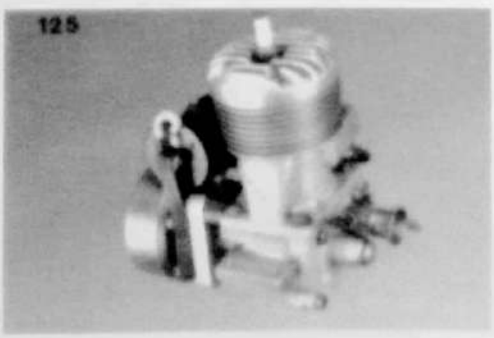
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CHAPTER FIVE
GLOW PLUGS

INTRODUCTION

All automobiles, weed whackers, chain saws, and many other powered devices run on gasoline engines with spark ignition. So, nearly everyone knows, at least in a general way, how a spark plug works. On the other hand, most model engines burn alcohol on glow ignition, and almost no other engines do. So, except modelers, few people have ever heard of a glow plug or know how one works. Because information about glow plugs isn't available outside of modeling, we'll give the subject some special attention.

HOW THEY'RE MADE

An examination of right glow plug in (126) shows a central stem that attaches to the inner end of the filament deep in the plug. The other filament end is welded to the body. An electrical insulator separates the stem from the body and seals the plug against leakage. Modelers call the insulator a "seal" for that reason. Electric current passes from the stem, through the coil, and to the body. As we learned in Chapter Two, the coil, heated incandescent with a 1.2-1.5 volt battery, ignites fuel during starting and the plug remains hot without the battery once the engine starts.

GLOW PLUG CHARACTERISTICS

Hobby shops sell a variety of plugs, but some have special applications and cannot be put in every engine. Examples include the OS Wankel plug, which extends farther into the head than standard plugs. OS recommends a type F plug for their four-strokes, and those engines run noticeable better with an F. A similar comment applies to our Enya 53 and its Enya number three plug. In these cases you're better off following the manufacturer's recommendation.

Less specialized engines run on many different plug types. Let's consider some. The left plug in (126) has a shield over the filament that keeps combustion mixture from flowing into the coil and cooling it. Since that helps an engine keep running at low speeds, modelers call the shield an "idle bar". Engines often idle acceptably with plugs lacking an idle bar, so a variable speed carburetor doesn't necessarily restrict you to idle bar plugs. Racing engines are not expected to idle well and run with unshielded plugs like the right one in (126). The threaded body comes in two lengths called "short reach" and "long reach" (127). Use short reach plugs on small engines of less than .15 cubic inch displacement and the long reach for larger engines.


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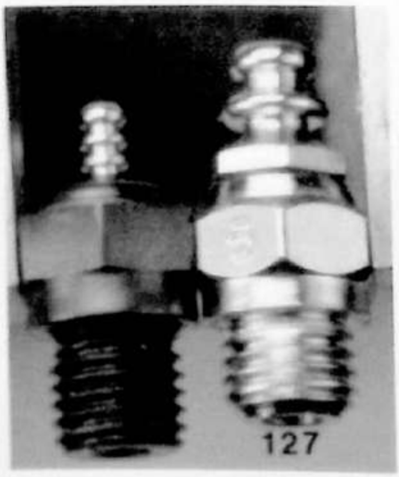
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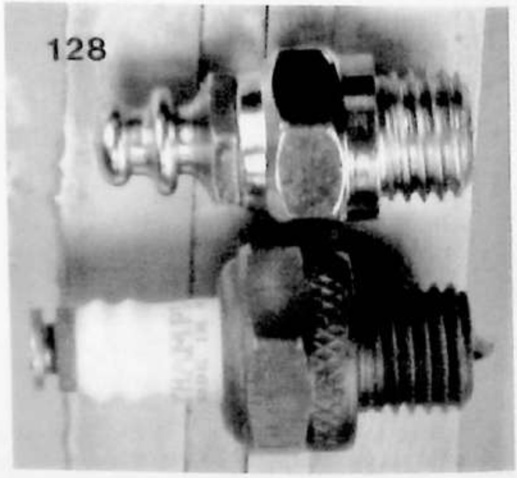
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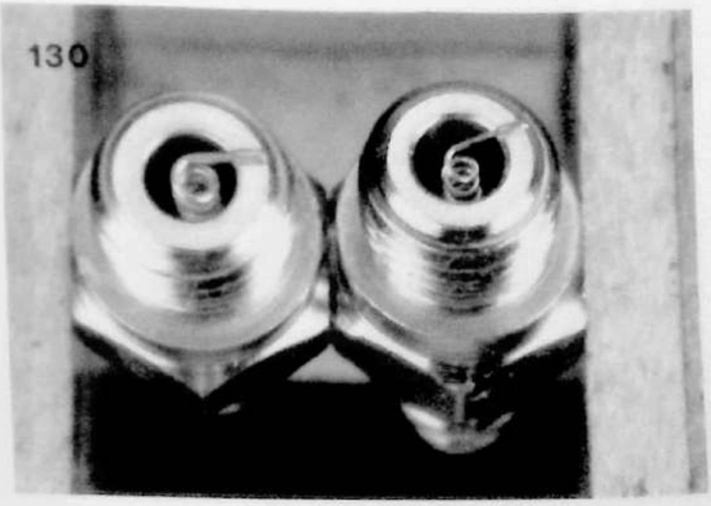
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Plugs glow at different temperatures, and we call plugs that operate at a low temperature "cold plugs" while higher temperature plugs are called "hot plugs". Several things account for these heat differences. Some seals conduct heat better than others and keep the stems at different temperatures. The plug's surface area and mass also influence how the coil cools. Perhaps the most massive and coldest plugs ever made were those by the Champion Spark Plug Company (128). The one in that photo lies next to an Enya, a large plug by today's standards. During the Champion's production life, most modelers flew Fox 35's (129) that ran nicely on the cold plug. You might like a Champion to add realism to an engine on a scale ship, but they were discontinued in 1956 and bring a premium price from engine collectors. Besides, today's engines need much hotter plugs. The coil's wire diameter and length affect plug temperature more than other factors. The left example in (130) has a much heavier coil than the right one. The higher resistance plug with the smaller diameter wire in (130) glows hotter. We screwed these two plugs into a Six Pack Glow Plug Caddy and tested for current flow. Photos (131) and (132) clearly show a variation between the two plugs. The Champion coil wire diameter is half again as big as any modern plug's (133) and glowed a cold dull red.

Plug heat influences where in the compression stroke ignition occurs; remember that we do not want preignition. Sometimes, though not always, preignition can be cured by changing to a cooler plug. Plug heat also affects the engine's ability to keep running at low speeds. If your engine preignites or has idle problems and you want to experiment with plugs, OS and Enya offer them with heat ranges based on coil diameter and length. These are very high quality and carry a high price tag. A manufacturer varies the plug heat by having different coil dimensions in plugs that are otherwise identical. There are other ways to control preignition and solve idle problems, so some plug makers, including Fox and K&B, supply inexpensive, average-heat plugs and don't bother with ranges. *New modelers who follow our recommendation and buy a two-cycle 40 engine should choose a long reach, idle bar plug by Fox or K&B.*

To complete this glow plug overview look at (134). That radical glow design originally came from Emerson Electric; Twin-K markets these plugs now. Filaments in their GloBee plugs, shaped like an electric stove coil, lie entirely in the combustion chamber. The well made GloBee's have a durable glass seal that some speed and racing flyers like.

PRACTICAL CONSIDERATIONS

We'll continue with glow plugs, but switch to some practical considerations. Modelers have shown me stripped heads and swear they didn't over tighten the plug. I'm sure these heads stripped without excessive force in the following way. A glow plug's threads are sometimes over tolerance and may also be tapered. Normal engine maintenance involves removing the plug occasionally, and repeatedly screwing in an oversize plug enlarges the threads in the head. Later, the modeler strips the enlarged threads when installing a smaller, correctly made plug. Knowledgeable flyers use a die (135) to rethread (136) all replacement plugs they buy. The amount of metal removed surprises even experienced modelers. A glow plug die also cuts the filament whisker when it extends past the plug body (137). Glow plugs have an old and uncommon 1/4-32 thread, which has no other application I know of. Because of this, the die costs a lot, but smart modelers consider the money they spend a good investment.

A completely stripped head has no threads remaining to reform and can only be repaired with an insert or HeliCoil. Sometimes threads in the head become dirty or only damaged but not destroyed. A little finesse with a 1/4-32 glow plug tap can reform them to a usable, though less than perfect condition. Thread restoration takes a delicate touch and requires a sensitive method of turning the tap. A one quarter inch wheel collar or short length of one inch dowel rod makes a tap handle that gives the feel and control we require (138-140). Always remove the head (141) before cleaning its threads (142-143). If you don't, metal shavings will enter the combustion chamber and score the piston and liner or damage the delicate valve seats in a four-stroke engine's head. Replacing a plug correctly after this repair or for any other reason also takes some sensitive feel. Start the plug by hand (144) to get it correctly aligned. Forcing it in crooked with a wrench recuts or cross threads the hole. Later, the displaced threads strip completely. After starting the plug, continue hand threading and only use the wrench for final tightening.

Many things can happen to a glow plug. A broken weld or filament is easily diagnosed when a charged battery fails to light the plug. Carbon deposits (145) and erosion renders the plug useless. A leaky seal allows combustion gasses to escape and nothing overheats an engine more effectively. The plug in (146) has oil between the stem and body. Because the seal leaks, small bubbles appear in the oil as we turn over the engine. When these things happen, we pitch the plug, but you can repair one fault yourself. The coil sometimes moves against the body and shorts the plug. You can move the coil to its correct position with a straight pin (147) and a little luck.

This chapter ends with a related subject. Enya's fine four-stroke engines have the glow plug pointed toward the prop. The battery connector cannot be safely removed after the engine starts. Model Products and McDaniel make easily installed adapters (148) that allow the plug to be attached at a more remote location. These devices also find favor among scale model builders who don't want a glow plug sticking through their airplane's cowl.


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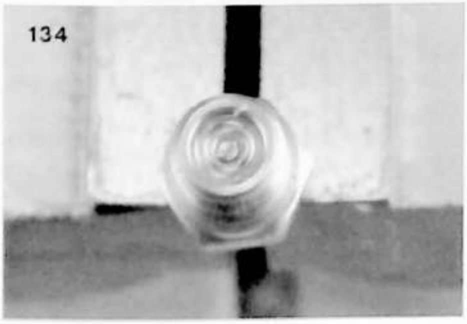
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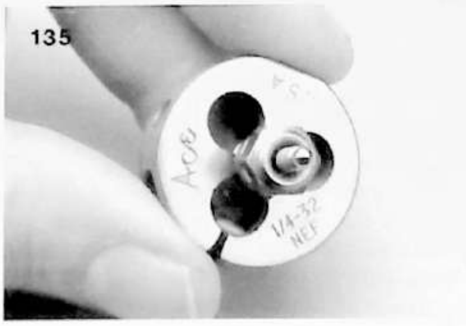
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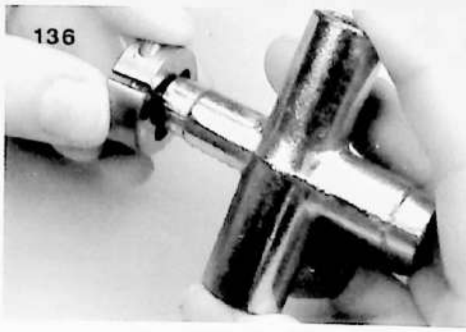
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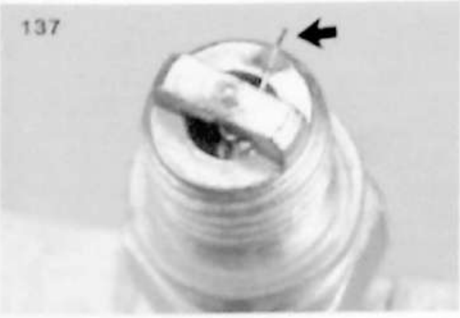
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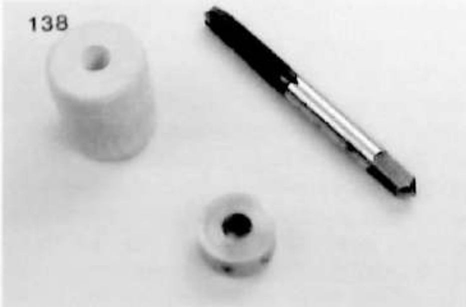
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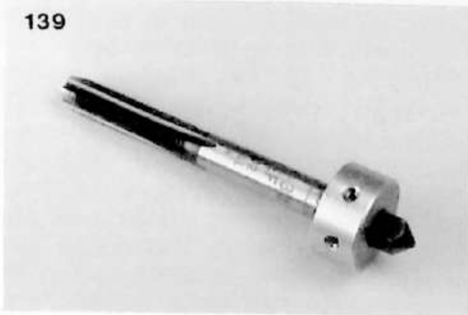
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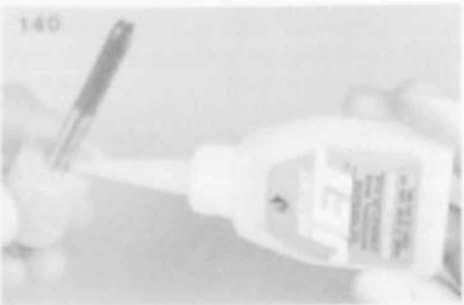
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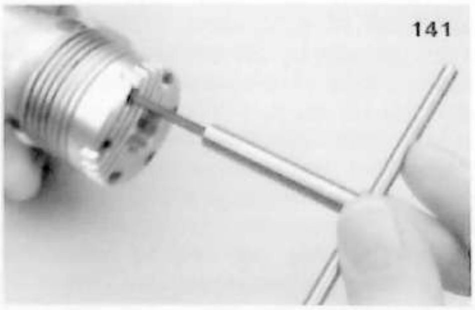
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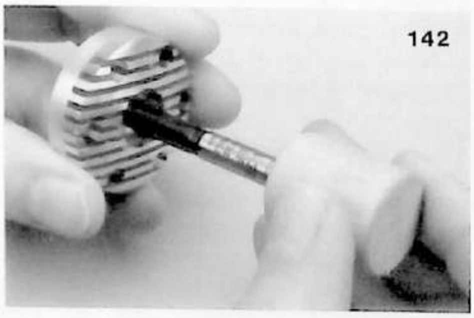
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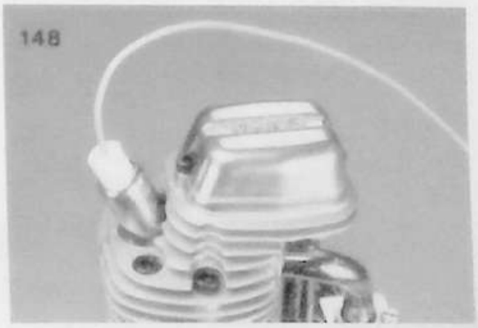
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CHAPTER SIX
FUEL, LUBRICATION, COMBUSTION AND COOLING

INTRODUCTION

Model engine fuels are mixtures of power producing ingredients and lubricants. There are many possibilities. The power producers, methyl alcohol [sometimes called methanol or alcohol], gasoline, and kerosene start burning by diesel, glow, or spark ignition. Diesels only run on kerosene based fuels, and with that exception any other fuel can work with any type of ignition, though some combinations are better than others. When many combinations are discussed, a chart conveys information better than text.

FUEL	IGNITION		
	GLOW	SPARK	DIESEL
ALCOHOL	COMMON	POSSIBLE	NOT DONE
GASOLINE	RARELY DONE	COMMON	NOT DONE
KEROSENE	NOT DONE	NOT DONE	COMMON

We begin this chapter with a general discussion of each power producer and lubricant, then consider them with respect to the various ignition methods shown in the table.

PRIMARY POWER PRODUCERS

Combustion is a complex process so we will only present a gross overview, but it gives more than enough information for the practical understanding of fuels you will need to run an engine. Heat from burning fuel expands the combustion mixture. During the power stroke, the expanding combustion mixture pushes the piston down the cylinder, and a greater force in the combustion chamber translates directly to more horsepower driving the propeller. If nothing else is considered, fundamental physical laws tell us that the more heat our fuel liberates, the greater the engine's horsepower, or more simply stated - more heat more power. A fuel's ability to give off heat is measured by units like BTUs per pound and calories per gram. Other than noting that alcohol burns with much less heat than kerosene or gasoline, we won't use BTUs or calories directly, because another factor, fuel to air ratio, affects power in our engines to a greater extent. To burn alcohol efficiently, carburetors mix about one part alcohol to seven or eight parts of air. Gasoline and kerosene need about a one to fourteen or one to fifteen mix to burn well. A combustion chamber full of alcohol base mixture contains more fuel than an equivalent volume of a gasoline mixture, so an engine run on alcohol has more power than one run on gasoline. Kerosene is only used with diesel ignition and its burning characteristics appear in the Kerosene On Diesel Ignition section.

The idea of more heat more power has some serious limitations. The engine must get rid of left over combustion heat and still run at a constant temperature. Increasing engine temperature during a flight ultimately causes the engine to quit and may even damage it. The cool burning alcohol makes less heat for the engine to dissipate than either gasoline or kerosene. A second aspect of cooling also favors methanol. Fuel in the combustion mixture contributes significantly to cooling as it travels through the crankcase and into the combustion chamber. An alcohol mixture, rich in liquids, cools the engine's inside better than an air rich gasoline mixture. So, an engine not only has more horsepower, it also runs cooler on alcohol than gasoline.

LUBRICANTS

Besides power and cooling, model engine fuel has another equally important job, lubrication. The amount of lubricant in model engine fuel depends mainly on the type of engine and how fast it runs. We'll get into more detail on fuel formulation in the later sections. For now, we are only interested in the types of oils found in our fuel. Two-stroke oils like those used for chain saws, weed whackers, and other small gas engine powered appliances are petroleum products that mix with gasoline. Two-stroke oil, not surprising, is also soluble in kerosene and can be used as a diesel lubricant, though there are better choices. Petroleum lubricants like these will not dissolve in methanol, so oil pressed from castor beans has lubricated alcohol powered engines since their beginning. Specifically, Bakers AA Degummed Castor Oil became the standard vegetable oil lubricant. More recently, synthetic oils supplemented castor oil in alcohol fuels. Castor oil and most synthetics also mix in kerosene and also can be used for a diesel fuel lubricant. Synthetics packaged by Klotz and others manufactured by Union Carbide have been successful for both applications.

A wide disparity of opinion exists about whether castor oil or a synthetic is the best lubricant for alcohol and kerosene diesel fuels. I know respected modelers who use only synthetic oil, others swear by castor oil. Castor oil has a higher film strength and does not burn during the combustion process like a synthetic does, so caster oil retains its lubricating properties better at higher temperatures than synthetics. If you set your needle valve too lean and the engine overheats, castor oil will continue lubricating longer than a synthetic. Some important factors favor synthetic oil. Its viscosity stays workable in cold weather when castor turns to a molasses like consistency. Hot castor bakes into a varnish on the piston, cylinder wall, and elsewhere. It cannot be removed with solvents, and the engine must be disassembled for cleaning. Castor residue left on an airplane doesn't clean off easily while synthetic residue cleans nicely. By using both oils you realize some advantages from each type. The ratio doesn't seem to make much difference and popular choices range from one part castor to five parts synthetic through one part castor to one part synthetic. *A beginner using glow or diesel ignition should have at least some castor oil in his fuel.*

Let's complete this section by listing which lubricants work with each power producer in a simple table.

	GASOLINE	ALCOHOL	KEROSENE
CASTOR	NOT SOLUBLE	SOLUBLE	SOLUBLE
SYNTHETIC	MOST ARE SOLUBLE	MOST ARE SOLUBLE	MOST ARE SOLUBLE
PETROLEUM	SOLUBLE	NOT SOLUBLE	SOLUBLE

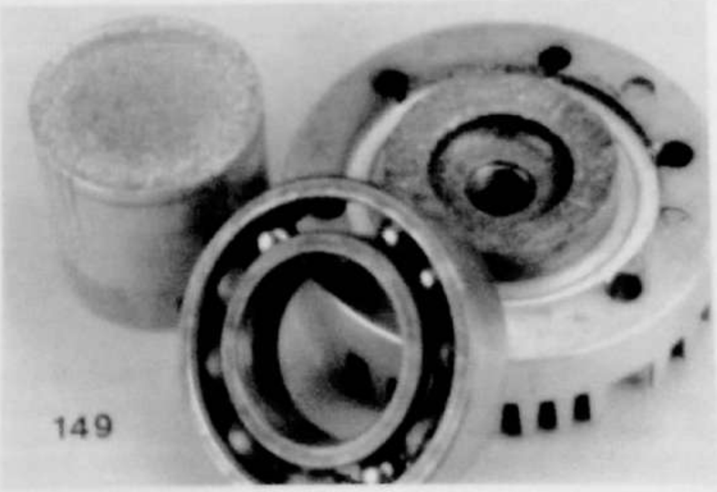
METHYL ALCOHOL ON GLOW IGNITION

Methanol ignites at too high a temperature for pure diesel operation; yet with the platinum catalyst in a glow plug present, burning starts easily. As you already know, alcohol burns at a low temperature, puts out ample power, and runs with a manageable heat level. Glow ignition and alcohol fuels work on all size model engines from the smallest to the largest. Many modelers convert weed whacker engines originally intended for gasoline on spark ignition to alcohol on glow. That involves using an adapter so the glow plug fits in the large spark plug hole. Because of the difference in fuel to air ratios between gas and alcohol combustion mixture, the carburetor often needs to be replaced or modified to pass more fuel. A modeler goes to these extremes because he realizes the advantages offered by using alcohol fuel on glow ignition.

One property of alcohol bears special consideration. Alcohol and water mix easily in any proportion, and alcohol soaks up water vapor like a sponge. Alcohol left in the engine after a flying session attracts water and rusts the steel parts - especially ball bearings. Photo (149) shows a bearing that got rusty and disintegrated. The steel balls moving through the engine ruined it. The head and piston look like someone hit them with a shotgun blast. Having castor oil in the fuel helps because castor coats the inner parts with a rust preventing film, but that isn't the entire answer. A rust preventing precaution should be taken no matter what oil the fuel contains. After every flying session, always remove the fuel line and run the engine with a fully open throttle until it quits. That clears out any residual fuel. Then, treat the engine with a light penetrating oil. We explain how to do these things in the chapter on running engines.

If you use a quality grade of synthetic or castor oil in a glow ignition engine, the amount is much more important than which type. I don't think a two-stroke glow engine should run on fuel containing less than twenty percent oil and twenty-two percent is better. Four-stroke glow engine fuel differs only a little. Because these engines operate at a lower RPM and normally run cooler, a four-stroker can run with less oil. Any special "four-stroke" fuels contain a few percent less oil. Except for that one point, most four-stroke and two-stroke glow fuels are identical. Many modelers like a little extra oil and run their four-strokers on two-stroke fuel. The only exception to these suggestions are gas fueled spark ignition weed whackers converted to glow ignition and run on alcohol. That fuel should have the same oil content the manufacturer originally recommended, usually about 25 to 1 or 4 percent.

If the weather isn't cold, a mixture of eighty percent methanol and twenty percent castor oil makes a satisfactory fuel, though the oil may settle. An ounce of Amyl Acetate to a gallon of mix reduces this tendency, but by stirring the fuel before a flying session, the addition will not be necessary. The low cost 80 to 20 mix is used extensively everywhere except the United States where an additive called nitromethane can be found in nearly every glow fuel. Moderate nitro additions to alcohol fuel give off oxygen, burn hot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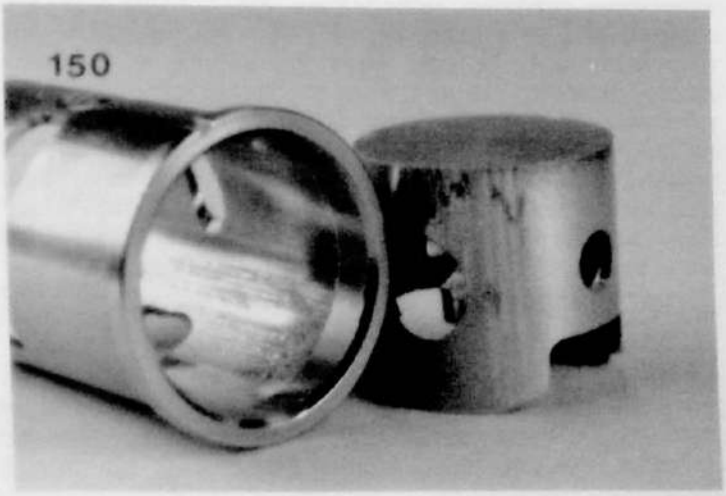
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themselves, and make the alcohol burn faster allowing more alcohol in the combustion mixture. These things give more power. Nitro also aids ignition. The combination of higher temperature and easier ignition helps keep the engine running at idle. Nitromethane also acts like amyl acetate and prevents castor oil from settling. Popular fuels contain five to fifteen percent nitromethane by volume. Higher nitro content fuels give a little more power and idle somewhat better. They are also more expensive because nitromethane is ten times more costly than alcohol. Most engines can handle the extra heat a twenty-five percent nitro mix puts out. Beyond that amount, cooling becomes a problem, engine runs must be shortened, and fuel prices become unrealistic. *New modelers should stick with a five to fifteen percent nitro mix.* Different blends falling within that range all run satisfactorily.

After reading this discussion you would conclude glow fuel formulas hold no secrets. They never really have. The basic formula for common production glow engines is:

BASIC ALCOHOL GLOW FUEL	
20 To 22 Percent	Oil
5 To 15 Percent	Nitromethane
The Balance	Methanol

There are reasons why you shouldn't mix your own fuel. Handling flammable liquids in open containers asks for trouble. The easily breathed toxic vapors are also a fire hazard. Some people ignore safety suggestions, so let's also examine fuel mixing economics. An average modeler cannot store large enough quantities of the ingredients to realize any savings. For those few who want large amounts of fuel, manufacturers offer sizeable discounts. Either way, you lose money mixing your fuel. I used to mix racing fuels to be sure everything was fresh, but quit doing this when my fastest flight in Class II Navy Carrier was flown with two year old fuel discarded by another competitor. Besides, fuel mixing makes a mess and takes time that could be better spent building and flying.

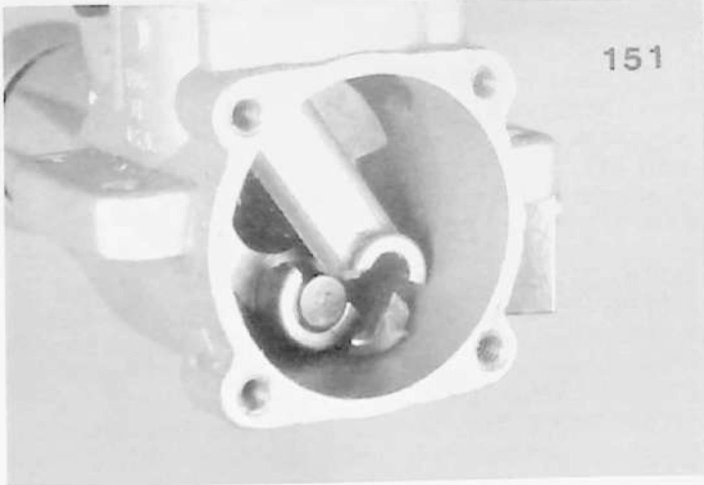
Well made fuels look just like inferior blends, so you must rely on the manufacturer's reputation for quality. Which fuel manufacturer should you choose? Fuel marketing is a cut throat business and some manufacturers lower quality to under price or at least stay competitive with other producers. There are several ways they do this. Water contaminated alcohol is cheap. Nitroethane can partially replace the more expensive nitromethane. When done to excess, the fuel burns hotter and dirtier. Oil prices and quality also vary considerably including castor oil. Poorly made fuel can run hot, under lubricate, and leave harmful deposits. Any of these things can and often do ruin an engine. I ran K&B and Sig fuels extensively for years and still do. Both companies offer uncompromised products. I have no first hand experience with other brands, though most major producers have good reputations. Sometimes a less well known or local manufacturer offers a good product at a reasonable price - and sometimes they do not. Ask flyers in your area what they run. If any brand, well known or unknown, has caused some problems, they will tell you.

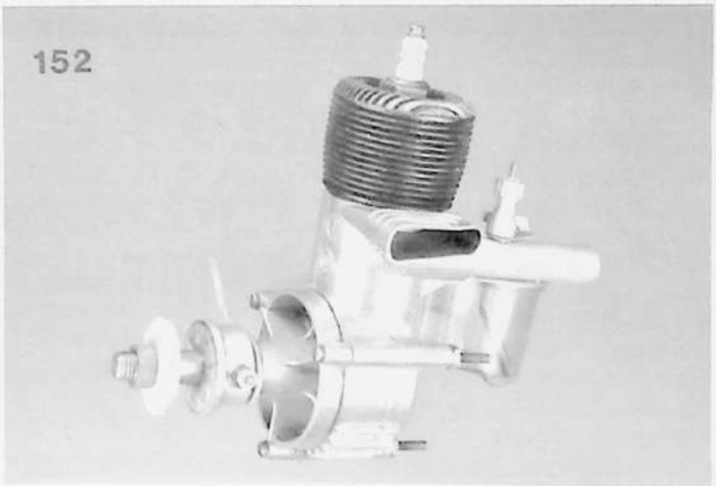
Let's emphasize the importance of fuel quality by examining some damaged parts. Chrome plating on the ABC sleeve in (150) was scraped off the cylinder wall because the oil broke down or wasn't present in sufficient quantities. Chrome chips then scored the piston. The engine was damaged in flight and resulted in a model destroying crash. That is a high price to pay for saving a little money on fuel. Poor oil caused the connecting rod and crankcase pin to seize while the engine was running in (151). That photograph clearly shows that cheap fuel is no bargain.

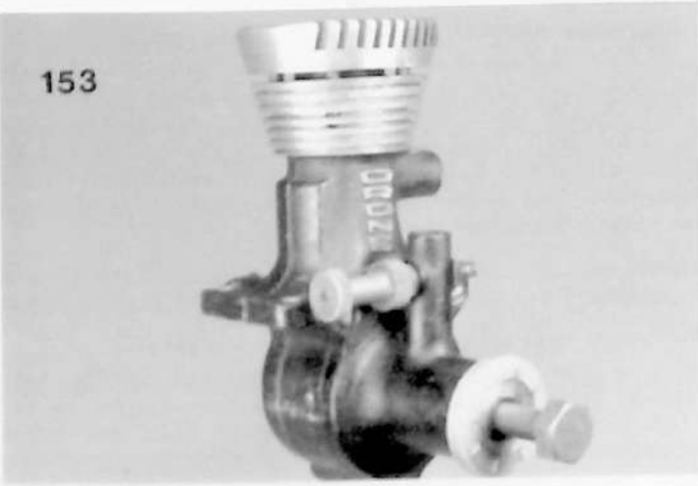
You might like to know about racing fuels though most modelers never use them. I met a control line speed flyer named Tony Grish in 1952 or maybe 53. He had many innovative ideas about engines and fuel, and his experience predated World War Two. Tony's 1948 formula was 3/3/2 [three parts nitromethane, three parts alcohol, and two parts castor oil]. Nitromethane and castor oil do not mix with each other, but remain in suspension only because both are soluble in methanol. If a fuel has much more than forty percent nitro, castor oil comes out of solution. The maximum nitro percentage depends on temperature. To get the last ounce of power, Tony would add nitro to his 3/3/2 mixture until castor oil just began to come out of solution. Later, speed flyers benefited from synthetic oils that mix with nitro. Racing fuels now contain seventy percent or more nitro with ten percent propylene oxide to help ignition and speed the nitro's burning. Unless you have a good reason to run a hot fuel like these, stick with five to fifteen percent. We only mentioned these expensive blends to complete the discussion of alcohol fuels.

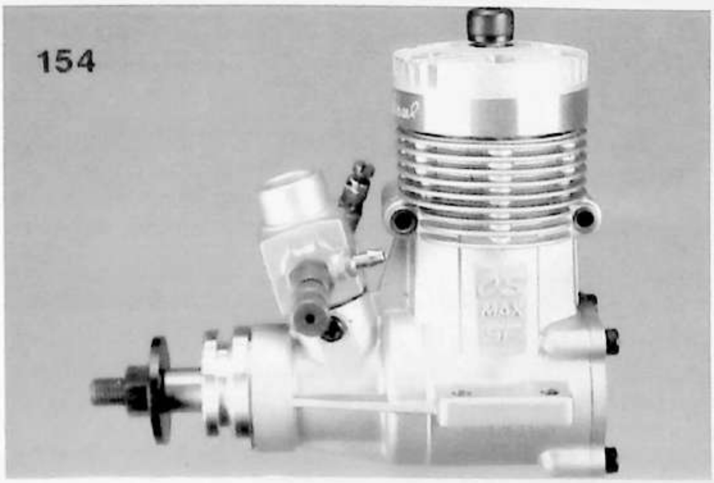
GASOLINE ON SPARK IGNITION

All gasolines you can buy in a service station will work in model engines, though many flyers prefer white gas. It has none of the additives in unleaded fuel nor does it have lead like old regular and ethyl gasolines. White gas leaves easily removed combustion chamber deposits and fouls the spark plug less. Coleman fuel also burns cleanly but costs a lot more than common gasoline.









Early spark ignition engines (152) ran on a mixture of 70 weight motorcycle oil and gasoline. In 1938 or 1939 that oil was not easy to locate, and you will find it almost nonexistent now. Today, modelers use two-stroke oil sold for lawn mowers, weed whackers, chain saws, motorcycles, or go carts. Marine outboard oils operate at a lower temperature and should not be used. Modelers tell me they like Bel-Ray oil. I've used Amzoil 100 to 1, though I don't mix it 100 to 1 as they recommend on the label. We run weed whacker and chain saw engines converted for model airplane use on a 25 to 1 mixture of gasoline and two cycle oil. If the engine is new, 15 to 1 would be better. This varies some with the engine, so check the manufacturer's recommendations. *Knowing that gas ignites easily and burns ferociously, modelers add oil to gasoline in a red metal can outdoors.* This is just like mixing two-stroke lawn mower fuel, and requires the same care.

KEROSENE FUEL ON DIESEL IGNITION

Diesels have the simplest ignition; fuel starts burning with only the heat of compression. This uncomplicated ignition does not also mean diesel fuels are simple. Pre World War II model diesel researchers looked for any fuel base with a low flash point so they wouldn't need excessive compression. Because ether boils at 78 degrees and ignites easily, early diesel fuels were a mixture of ether and motor oil. Modelers usually mixed them in three to one or four to one ratios. Ether's easy ignition was not predictable. Engines would run forwards, run backward, preignite, and postignite.

Ether isn't a particularly powerful fuel, but being a near perfect solvent mixes with almost anything. After understanding these things, diesel people tried different additives to slow the burning down and get some additional power. These included kerosene, turpentine, naphtha, benzine and many others. Eventually, they settled on kerosene, and a simple mixture with equal volumes of kerosene, ether, and oil worked much better than ether and oil alone. Engines like the Drone Diesel (153) were from that period. Kerosene burns with more energy than ether though it lacks ether's volatility and has less oxygen in its chemistry. Ether serves as a vaporizer and igniter more than a fuel. So, ether and kerosene complement each other well. Castor oil became the standard lubricant and remains common today. As with glow fuels, synthetic oils also work well. Motor oils dissolve in kerosene and ether so these can be used, but castor oil works better.

In the 1950's, another ingredient, amyl nitrate, was introduced. It contributes significantly to oxidation, and adds heat though not excessively. Having some additional residual heat means the engine can have a lower compression ratio. That puts less stress on the engine, especially the connecting rod. Some diesels need almost enough compression to bend the rod, so amyl nitrate was an important discovery.

We've suggested that mixing glow fuels may be unsafe and does not make good economic sense. I feel this more strongly about diesel fuel. Ether is a controlled substance so you need a license to buy it, but why would anyone want to? Vapors from this highly volatile liquid are excessively flammable and toxic. Besides, fuel manufacturers sell diesel fuel cheaper than you can mix it. Just for your reference we'll give a common formula for modern engines like the OS with a Davis Diesel Conversion (154). While we are on the subject of Davis Diesel, I'll mention that Bob Davis contributed significantly to this section.

BASIC DIESEL FUEL	
10 Percent	Castor Oil
10 Percent	Synthetic Oil
48 Percent	Kerosene
30 Percent	Ether
2 Percent	Amyl Nitrate

ALCOHOL ON SPARK IGNITION

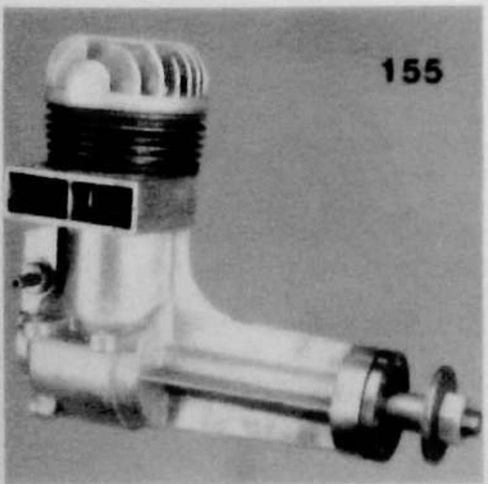
Most people running this combination have a spark ignition weed whacker modified so it mounts in a model airplane, and they want the advantages of alcohol fuel. This combination doesn't seem too popular, because anyone using alcohol can run glow ignition and does not want the extra weight and trouble spark accessories cause. So, people who convert weed whackers normally also modify them for glow ignition. A less expensive conversion does not include changing from spark to glow. If the carburetor was designed for alcohol or can be opened up to accommodate it, alcohol fuel runs fine on spark ignition and gives noticeably more power than gasoline. Alcohol ignites at a higher temperature than gasoline, but a few percent nitromethane in the mix solves that problem. The oil content should be what the engine manufacturer recommends.

GASOLINE ON GLOW IGNITION

Modelers running glow engines and wanting to save some money may wonder about switching from alcohol to gasoline. Since gasoline combustion mixture contains less fuel than an alcohol mixture, you can usually close the needle valve some and do not need to modify or replace the carburetor. The lower fuel content in the combustion mixture means a tank of gasoline will fly the model longer. While platinum does not affect gasoline as much as alcohol, the catalyst will ignite gasoline. All this may sound encouraging, but don't get your hopes up. Gasoline ignites easily but unpredictability, and a hot glow plug element often preignites the gas which overheats the engine. Even if you smooth out the ignition by adding a few percent nitropropane, gasoline still runs hot and with much less power than alcohol. The fuel economy isn't so great as you might think. Gas fuel which contains white gas and the 80/20 alcohol mix cost about the same, and the alcohol fuel has more power and runs cooler. Gasoline run with glow ignition is the least desirable combination, and I don't know of a single engine designed to use it.

SOME MORE OLDIES

Let's use the left over space in Chapter Six to show a few more engines from Fred Linde's collection. The 1948 vintage Fox 59 (155), was one of the first engines to feature glow ignition. The Super Cyclone (156) and Forester 99 (157) were among the last sparkers to be marketed about 1950. After that time nearly all engines had glow ignition.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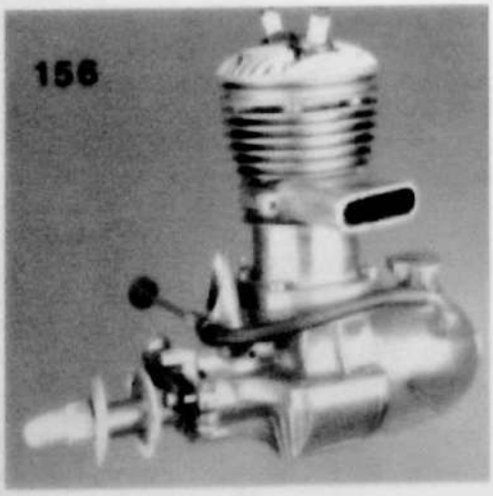
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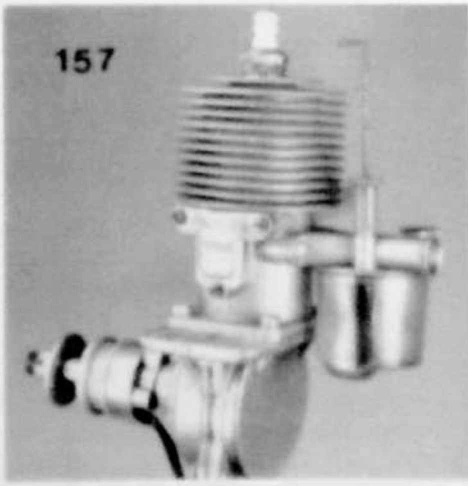
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MUFFLERS, NEIGHBOR PRESSURE, BACK PRESSURE, AND HEAT

INTRODUCTION

A flying model airplane generates sound in several ways. The air frame rattles, and the plastic covering vibrates like a snare drum. The propeller contributes significantly to noise, and the engine's internal parts do not move silently. However, exhaust noise overshadows all other sources. Any two-stroke model engine, regardless of its ignition type, makes an objectionable high pitch sound that annoys people many yards away. Some modelers, myself included, have hearing losses attributed to using unmuffled model engines. Nonmodelers will not tolerate the noise, and homeowners have managed to close many flying fields when inconsiderate flyers refused to quiet their two-strokers. To avoid losing a field, any club you join will undoubtedly require silenced engines. In years past, modelers had trouble complying with that rule. Engines came without mufflers and lacked muffler mounts. Universal silencers could be purchased at additional cost and mounted with a strap (158). These expensive, add on units often caused an excessive power loss, overheating, and were sometimes ineffective and heavy. Today, all but specialized engines come with mufflers that screw rigidly to special bosses cast in the block (159). The combination engine and muffler are engineered to operate together with a substantial noise reduction at the expense of a slight power loss.

Mufflers do more than reduce noise. They favorably affect low speed and idle. Nearly all modern engines use muffler pressure to pressurize the fuel tank. Note the line between the muffler and tank in (160). Most carburetors come calibrated for pressure fuel delivery like this. We'll say much more about these functions of a muffler in later chapters. They are mentioned now to explain why nearly everyone flies with a muffled engine and no longer fights club rules requiring them.

ENGINE DESIGN AND NOISE

A four-stroke engine expels exhaust once in two revolutions; a two-stroke does this every revolution, so four-strokers have a lower pitch and intensity. The long, low pressure four-stroke exhaust dissipates sound over a greater time, which also quiets things. Multiple cylinder four-strokes sometimes run with no muffler (161). Single cylinder four-strokes usually have a small muffler that attaches to a short header pipe (162). In contrast, noisy two-strokes need larger mufflers (163-166).


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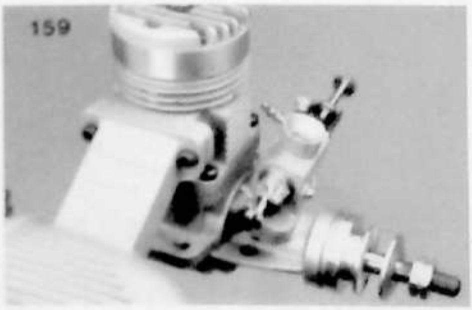
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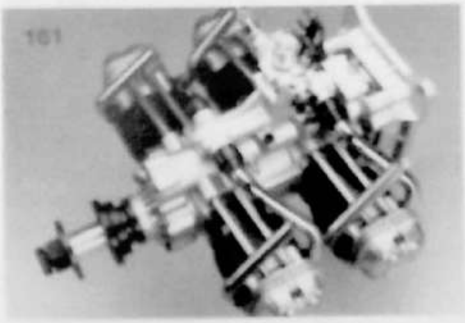
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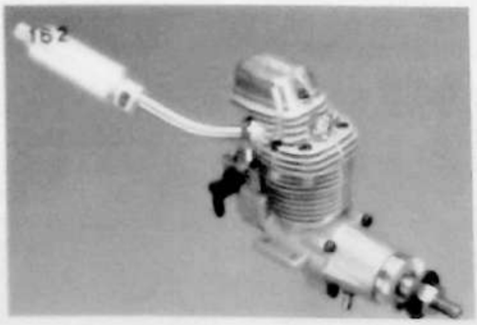
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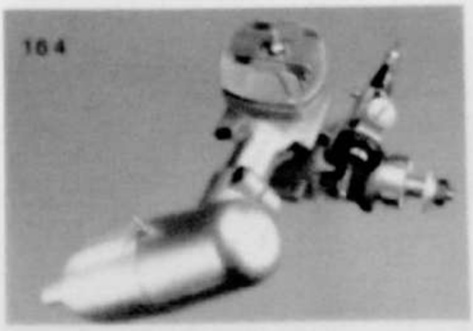
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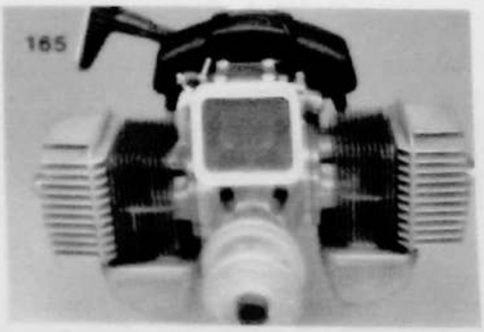
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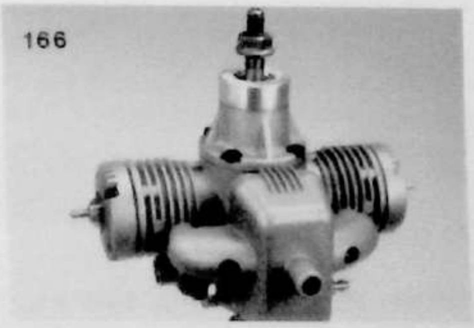
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A two-stroke engine's design affects noise levels to some extent. Obviously, a large engine makes more noise than a small one. Almost any change or modification that affects the combustion process and increases RPM also increases noise. For example, using a higher compression ratio can bring higher RPM and more noise. We hopped up control line speed engines by lengthening the exhaust period; if that speeded things up, there was also more noise. Old spark ignition engines (167) had low compression ratios, extremely short exhaust periods, and the exhaust ports were also small when compared to a modern two-stroke (168). Those old sparkers turned at low RPM, and could be run almost comfortably without mufflers. Lowering noise levels any meaningful amount by reducing the compression ratio, exhaust period, or exhaust port area also cuts power excessively. A two-stroke engine designer must be concerned with getting the maximum power, so he depends on the muffler, not engine design, for quiet operation.

NOISE REDUCTION VERSES HEAT AND POWER

A model engine muffler must expel hot gasses and dissipate sound energy; these are entirely different functions. One is done at the expense of the other. First, consider the task of reducing the exhaust noise level. The muffler housing should be made from sound absorbing materials. When that isn't possible, it should be coated with them. For example, firearms silencers used by the military are frequently wrapped with acoustic insulation. Other sound energy can be absorbed by baffles inside the muffler. Increasing the distance sound travels before leaving the muffler decreases its intensity. To do this, a muffler could contain pipes that fold back and forth upon themselves. Sound can be reduced in another way; waves reflected in a well designed muffler interfere and partially cancel each other.

Let's consider the second thing a muffler must do, move the exhaust away. Exhaust contains heat left over from combustion. Since exhaust heat no longer contributes to power, it is sometimes called waste heat. With no muffler at all, the exhaust and waste heat are simply, efficiently, and loudly blown away. We just mentioned several ways to quiet an engine, they all, except for sound insulation, restrict the exhaust passage. A long exhaust path, baffle, or any other restriction keeps the muffler interior at a positive pressure, which engine people call back pressure. It prevents some of the newly created exhaust from leaving the combustion chamber. Exhaust and waste heat remaining there do two things. First, the volume of incoming combustion mixture is less than without the back pressure, that reduces power. Secondly, since all waste heat cannot clear the engine, it runs hotter. To say this another way, back pressure associated with noise reduction costs power and makes the engine run hotter.

EXPANSION CHAMBERS AND MUFFLERS

Most modern mufflers are not acoustic engineering masterpieces. That comes as no surprise when you consider that beside removing exhaust and deadening sound, a muffler should also be inexpensive, light, and small. A primitive device called an expansion chamber silences most model engines. Expansion chambers are large, baffleless, empty aluminum shells. Actually, they should not even be called mufflers, but we'll concede the point.

First, let's describe what takes place in an expansion chamber when exhaust leaves the engine. Any expanding gas looses heat and pressure. An expansion chamber provides room for this desirable cooling to take place. The aluminum surface of an expansion chamber conducts a little waste heat away. Some examples have fins, though I don't know how effective they are. A small amount of the remaining waste heat is returned to the engine by back pressure; the rest of it exits with the exhaust gasses through the expansion chamber's outlet. A larger outlets permits more heat and gas to leave the engine.

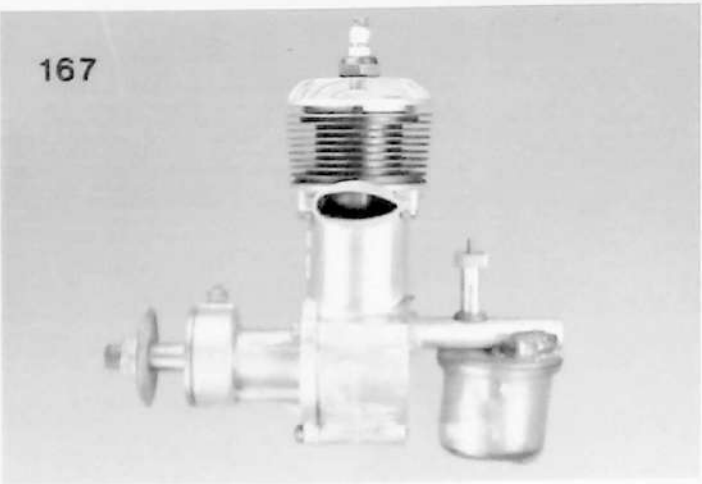
Now consider how expansion chambers deaden sound. The aluminum chamber wall conducts some sound away from the engine, reflects other sound back into the muffler, and absorbs the rest. Physicists tell us absorbed sound energy becomes heat, so we want to confine sound in the muffler while this transformation takes place. A small outlet keeps more sound in the muffler, but as we just mentioned restricting exhaust also increases temperature and back pressure. Again, we see that decreasing sound levels adversely affects exhaust passage and also power. Experience and a lot of experimentation has shown that an outlet hole size causing a 300 to 400 RPM loss, does not cause overheating and brings sound levels to a high but acceptable level. When you consider typical engines turn between 12,000 and 14,000 RPM, a power loss of a few hundred RPM is a small price to pay for quiet operation.

Expansion chambers are a great improvement over no silencers, but there is still room and need for improvement. Only a few mufflers use sound reducing ideas we mentioned earlier, and contain baffles and other restrictions like those shown in the Merco cutaway (169). Davis Diesel and Irvine Engines from England each make more sophisticated and quieter mufflers. K&B uses a quiet, well designed muffler on their Sport series engines (170). I look to see effective mufflers like these become commonplace as we all ask for quieter flying fields.

EXHAUST DIVERTERS

Exhaust residue leaves a mess on the plane that nobody enjoys cleaning. Four-stroke engines don't mind a reasonable exhaust diverter like the one in (171). I know that engine is not a four-stroke, but the tube length works fine on them. You might think piping exhaust away from a two-stroke powered airplane would also work.

It usually, though not always, makes a much bigger problem than exhaust mess. The hose increases back pressure, which sometimes overheats the engine. Often, everything seems fine, but the heat rises slowly and the engine quits in midflight. Exhaust diverters sometimes adversely affect a two-stroke's power, and idle. The one shown in (171) had a peculiar effect. The engine ran fine, only losing a few hundred RPM. The additional back pressure somehow caused fuel to be blown upward from the carburetor. So, instead of exhaust mess, I had raw fuel mess on the airplane. Ed Javiek's comparatively short diverter worked with his Super Tigre 3000 (172). Success like his is the exception not the rule. I've seen just a small copper or silicone, elbow attached to the muffler outlet cause trouble. If you want to use an exhaust diverter, get the engine running well without one. Then, try the diverter. Quit using it if the engine dies in midflight, overheats, lacks power, or cannot be made to idle. *I don't recommend an exhaust diverter for a new modeler.*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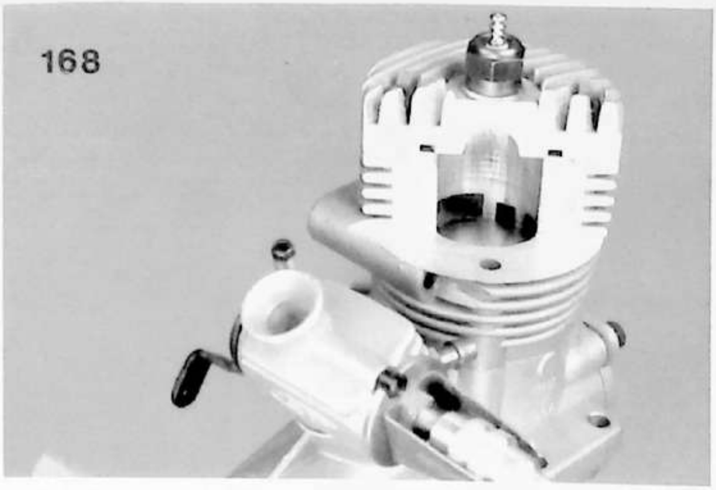
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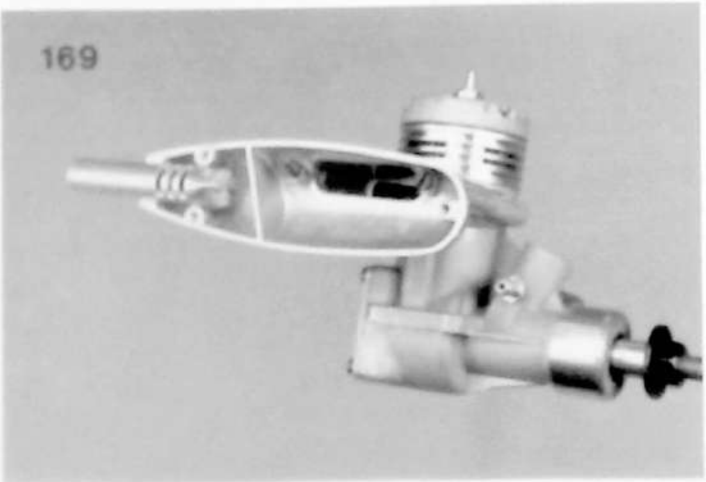
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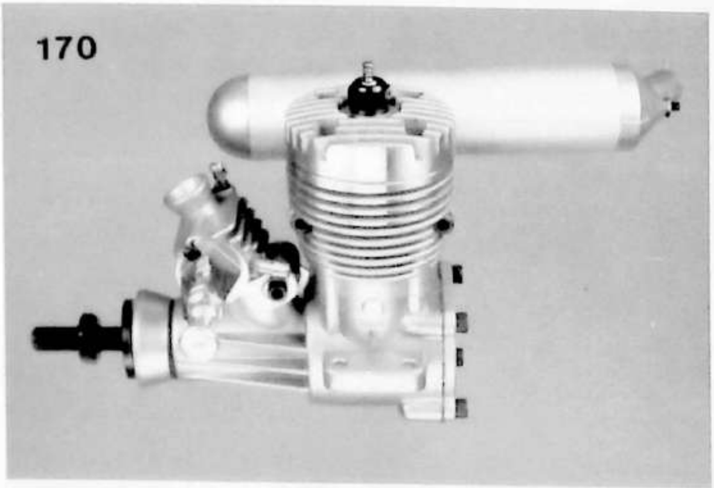
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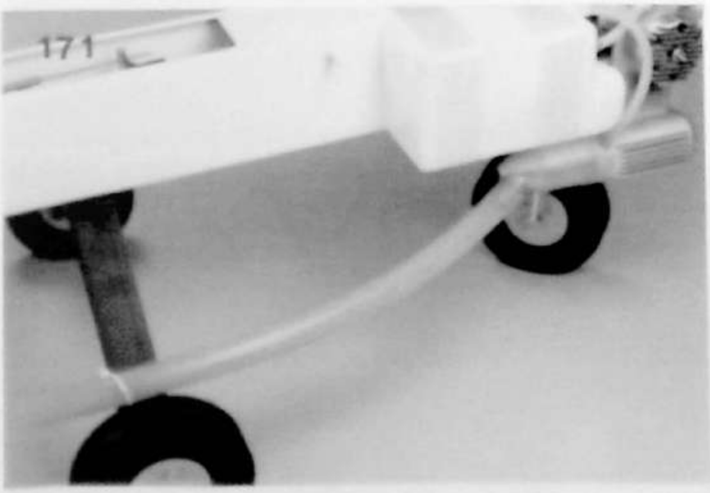
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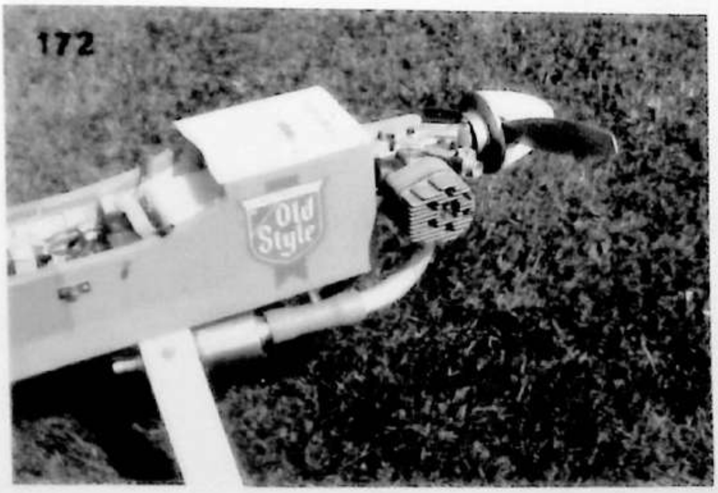

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CHAPTER EIGHT
THINGS YOU'LL NEED

INTRODUCTION

Until now, All About Engines stressed the basic theory and construction of a model engine. In this chapter you'll learn about some essential engine accessories that a new modeler may want to buy with his engine. Let's show what these things are and why you need them.

GLOW PLUG BATTERY

Earlier chapters explained how we light the glow plug coil with a low voltage battery but didn't say much about the battery or how to connect it. There are many battery and connector combinations from which to choose. If you want to save some money initially, any hobby shop carries a 1.5 volt hobby battery, some wire, and a clip that connects the battery and plug (173). Usually, you'll assemble the wire leads yourself. We make ours three or four feet long from 14 or 16 gage silicone insulated wire used to make battery packs for model cars. Any good hobby shop carries wire like this. The heavy, limp silicone wire coils easily for storage and offers current only a little resistance. Sullivan's low price glow plug clip gives long dependable service. The initial savings from buying a hobby battery are short lived because it won't last long and cannot be recharged. A modeler willing to spend a little more money might consider McDaniel's Metered Ni-Starter (174) or a similar product by other manufacturers. A Ni-Starter does not require leads, and attaches directly to the plug and releases with a simple twist. The Ni-Starter's rechargeable battery lasts for several years, and its meter takes some guess work out of trouble shooting.

FROM THE CAN TO THE TANK

You can transfer fuel from its gallon container into the tank in a couple of inexpensive ways. Sullivan Products and others manufacture something like a large ear syringe (175) that sucks fuel from the can and then forces it into the fuel tank. Two types are available, one for alcohol fuels like we use with glow ignition and another for diesel fuel and gasoline. Pick the largest one available because fuel tanks for 40 engines hold at least six ounces and many are larger. The second fuel transferring device, a five ounce veterinary syringe, comes from Sig Manufacturing. I recommend you buy one because Sig's product does much more than transfer fuel. At the flying field it provides compressed air to clean a fouled carburetor and check a tank for leaks. Experienced modelers prefer electric fuel pumps (176) that mount to a field box and operate off the starter battery, but these more expensive devices can wait a while.

You'll also need several feet of medium fuel tubing and a short length of brass tubing. Silicone tubing works for alcohol fuel and withstands heat, neoprene handles any fuel including petroleum based ones but won't take much heat. Since a piece of tubing slips over a fitting on the muffler to pressurize the tank, heat resistance is important. So, unless you're using gas or kerosene, get silicone tubing.

STARTER, STARTER BATTERY, AND CHARGER

When gasoline engine powered models became popular before World War II, people used their index finger to start the engine by flipping the propeller. Many still do, but I don't recommend it. Even small engines can cause a serious cut, larger ones have severed tendons and resulted in permanent damage. A modeler who cannot afford a starter should purchase some heater hose and flip the prop with that (177). Starting an engine with a heater hose is tiring and often not easy, especially with a new engine. After a single flying session, modelers who tried saving money by hand flipping nearly always purchase an electric starter (178) which greatly simplifies things. Why not buy one in advance and save some trouble?

A lead acid wet cell battery will power a starter, but they give off toxic and highly flammable gasses during charging, so we don't recommend them. Most flyers power the starter with a rechargeable twelve volt gel cell (179). One of my flying buddies, Art Haak, devised a simple way to attach the starter and charging cables with two pennies (180-181). A shorted gel cell discharges at a dangerously high rate that can cause burns and start a fire. So, be careful not to short the pennies or bare terminals with a tool or another metal object.

We market some starter related items you might consider. The starter cup (178) needs something to grip when turning the propeller. Our light weight Safety Spinner (182) replaces the simple nut and washer that come with most engines and gives the cup a large gripping area. Sometimes, the starter spins the nut (ours and anyone else's) and propeller off the crankshaft. The prop and nut can also be thrown off by an engine back firing - four-strokers do that often. In either case our Prop Lock works with a standard nut (183) or a Safety Spinner (184) to hold the prop on the engine. Appendix I lists crankshaft sizes for most engines.

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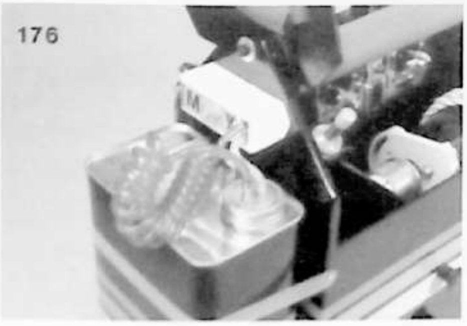

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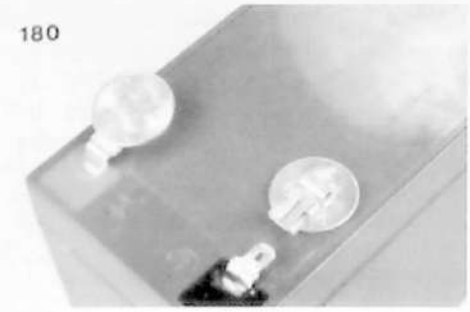

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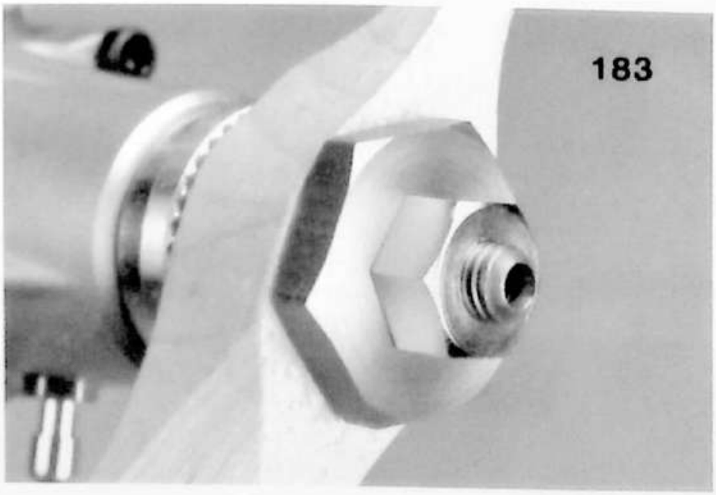

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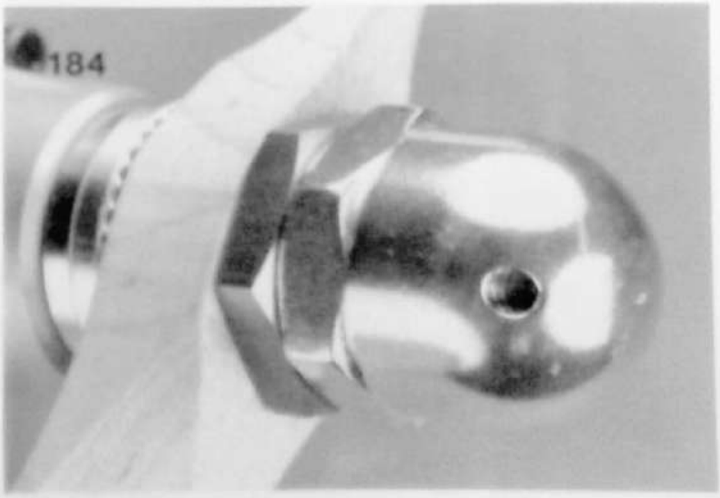

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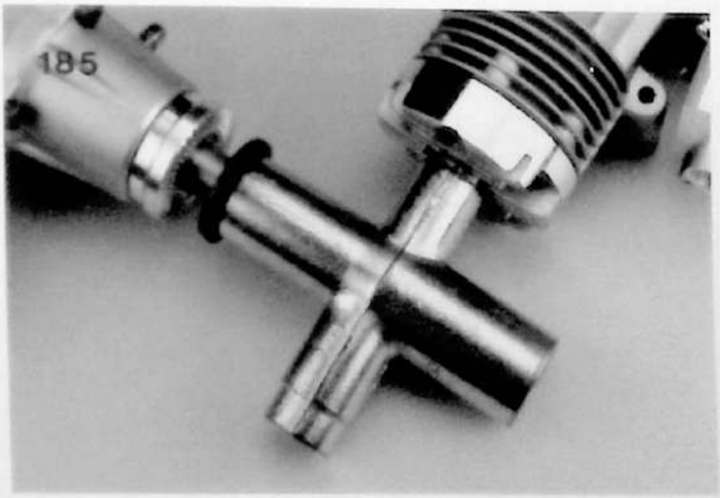

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PROPELLERS

If you want your engine to run well, it must be matched with the correct size propeller. An oversize prop loads the engine and causes overheating. A moderately undersize propeller is less of a problem, though it lacks much flywheel action and won't help keep the engine running at idle. A grossly undersized propeller will be too weak to withstand the high RPM an underloaded engine will turn. Since propeller size, expressed as two numbers separated by a dash, affects how an engine runs, we need to know what these numbers mean. The left number simply specifies the diameter. The right one, called pitch requires just a little explanation. Pitch gives the theoretical distance the prop would move forward in one revolution. For example, a 10-6 prop would pull an airplane forward six inches every revolution. The six inch pitch propeller actually moves the model about 4.5 inches per revolution - on a good day. We don't concern ourselves much with the disparity between theoretical and actual pitch, because all propeller sizes and recommendations are given in theoretical pitch. *Most beginners who follow our suggestion and buy a 40 glow engine also buy 10-6 propellers.*

Props are carved from wood or molded from tough synthetic materials like nylon filled with glass fiber choppings. A wood prop is more rigid and less likely to fly apart than one made from glass filled nylon, but plastic props tend to be less expensive and last longer than ones made from wood. Nylon only flexes during a rough landing that would break a wood prop.

A rotating propeller is extremely dangerous and special safety rules should be observed. They appear in the next chapter with other safety related considerations.

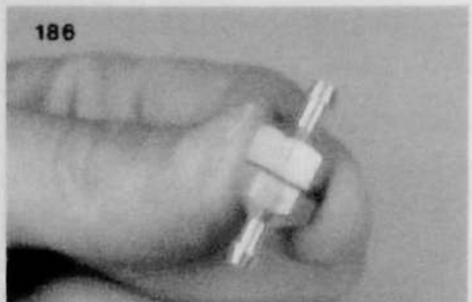
OTHER THINGS TO GET

You need to buy other things from a hobby shop including extra glow plugs, and a four-way wrench (185) to change them. A faulty glow plug is the single most common engine problem, so we always have a spare, and often several. Many engines come without glow plugs in which case you will need an additional one. Unless you selected an engine that requires a special plug, inexpensive plugs by Fox or K&B will work fine.

Unlike a dirty carburetor, a filter (186) can be cleaned or replaced in about a minute on the flying field. Many people disagree, but I think a fuel filter between the tank and engine saves some trouble. Having one in the tubing that attaches to the fuel syringe or pump doesn't hurt anything either. Those disagreeing with these recommendations argue that the filter is just another thing to go wrong. Filters sometimes can leak causing the engine to suck air through the leaking filter instead of fuel. If you keep the two halves [apparent in (186)] tightly screwed together, they will not leak and cause fuel flow problems. Select a filter like the one shown from Master Airscrew, which can be disassembled for inspection and cleaning.

BOXES, POWER PANELS, AND FUEL PUMPS

All flyers bring fuel, batteries, a starter, spare props, glow plugs, and tools to the flying field. A cardboard box placed inside a milk crate serves as a good tote case (187), and a rope handle makes carrying it easier. Don't waste money on a hardware variety tool box because modelers have special purpose units like Carl Goldberg Models' compact, well designed Super Tote (188-190). That example was assembled by Randy Zorich. All flight boxes have provisions for a twelve volt power panel (191). The least expensive panels have jacks for the starter and glow plug leads, and nearly all panels also have an ammeter to check the glow plug current. If a power panel does not have a fuel pump circuit, several companies offer pumps with integral switches, or you could try Dave Brown's simple hand cranked Six Shooter pump.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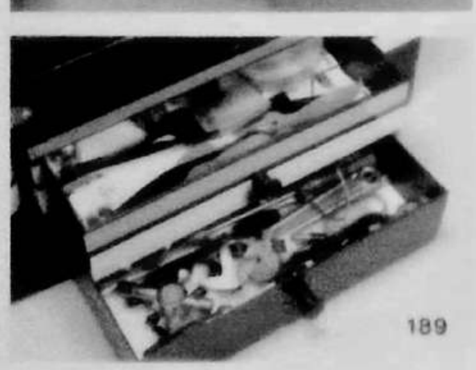
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CHAPTER NINE
AT THE FIELD

INTRODUCTION

Operating a radio controlled helicopter or airplane requires skills that take some time and "hands on" experience to learn. First among them are starting the engine, needle valve adjustment, break-in, and setting the low speed or idle. All this can be learned without an experienced helper. If you are learning to fly a model airplane and arrive at a flying field knowing these four engine essentials, busy instructors won't need to waste time teaching the basics. There is a more compelling reason to learn about a new engine leisurely and on your own. Running an engine for a considerable time makes it much easier to operate and more powerful. Later in this chapter we'll explain why engines respond this way to running. *If you're a beginner, you should know that most experienced modelers never fly until they know the engine will run dependably.* I do the things outlined in this chapter and recommend them for any modelers no matter what prior experience they have.

PREPARING THE PROP

Our Royal tachometer shows RPM divided by one hundred; the engine in (192) turns 6500 RPM. As that photo clearly shows, rotating black propellers are almost invisible on film, and the human eye can hardly see them either. By painting the tips white or yellow, the visible outer arc becomes an important reminder to stay clear (193). Manufacturers paint tips on large propellers but not on those made for 40 engines. If the props you purchased have unpainted tips, spend a few minutes painting a half inch wide section at each tip. One flyer I know stuck his hand in a propeller he didn't see and required hospitalization. His hand hasn't been right since the accident. As another safety precaution, sand the knifelike edges (194) off a fiberglass filled nylon propeller (195).

All piston engines vibrate to some extent, but an unbalanced propeller causes excessive vibration. Then, many unpleasant things happen. Vibration can break electrical contacts in the receiver or servo, and even shut off the switch. These catastrophic vibration related electrical problems have caused some newcomers to take up golf. I have nothing against golf, but why not avoid a crash and all the disappointment that it brings? With a few simple, inexpensive items (196) you can check and correct propeller balance in a few minutes. Some props come balanced, but most need a little work. Put a "T" pin in the shaft hole (197) and note which blade drops. Scrape (198) and sand (199) material from the thickest part of the heavier blade tip until the prop balances (200). As these photographs show, we only remove material from the front of the blade.


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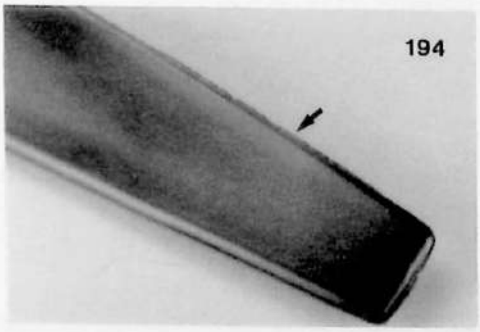
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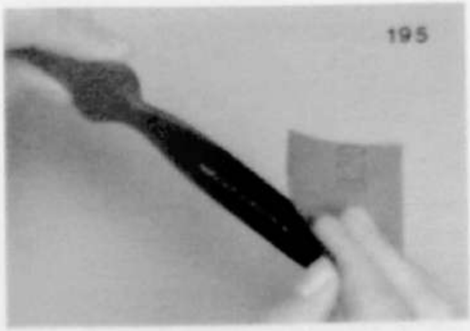
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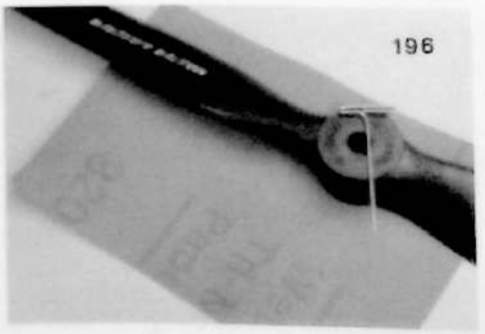
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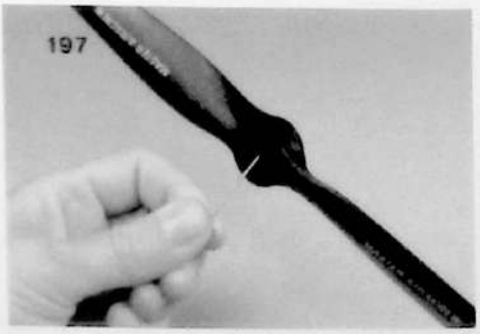
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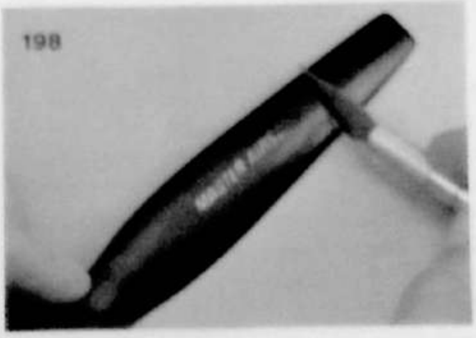
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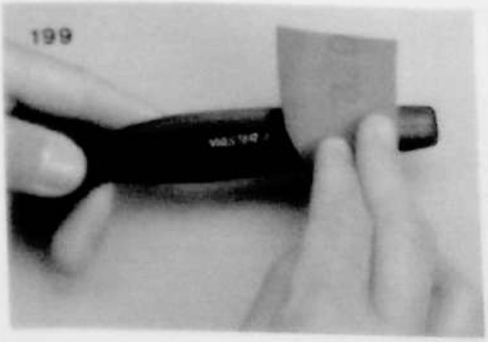
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CHECKING THE FUEL FILTER, PLUG, AND ENGINE

In the next section we'll show a simple test stand, but before mounting a new engine on it there are some simple checks you should perform. We'll begin with the fuel filter and glow plug. Filters are often assembled only finger tight by the manufacturer, so use the four way prop wrench you bought and any other wrench to tighten the two halves (201). Next, let's check the glow plug. Remove it (202) and connect the battery (203). If the coil fails to glow bright red, the plug or battery is faulty. To find out which, repeat the test with a spare glow plug. If it glows, the first plug was bad. If it doesn't, the battery could be discharged, or maybe you got a bad batch of plugs, though that seems unlikely.

Recall from our earlier work that high pressure gasses moving through a narrow passage cause overheating. Loose head screws allow this to happen, so we tighten them (204) and all other screws while we are at it (205). Be sure they are only moderately tight, and don't strip the threads. Tighten the plug snugly because a loose plug allows combustion mixture to escape through the threads, and that also causes severe heat problems. As a final check, put the cylinder head and upper block underwater (206), and rotate the crankshaft. Any bubbles mean something isn't tight and must be fixed before the engine will run satisfactorily.

Some engines need the carburetor installed, and it is held in place with a draw bar (207). Failing to compress the "O" ring seal (208) allows the engine to suck air through the leak. Then, the engine runs unpredictably and will be impossible to adjust. You can avoid this trouble by simply pressing the carburetor hard into the block while tightening the draw bar (209).

THE TEST STAND

After these common sense tests, you will decide whether to mount a new engine in an airplane or test stand. Most people choose the airplane, and I think they make a mistake for the following reasons. Running an engine in an airplane places the engine near the ground, and it sucks in tiny dirt particles that act like sandpaper. Engine adjustments are awkward at ground level, too. Extensive running that new engines require subjects a plane to unnecessary vibration that can damage the radio. Vibration also makes fuel in the tank foam, and the engine becomes impossible to adjust. A modeler running his new engine in an airplane must have the throttle control installed correctly, and that is a major undertaking. *Whenever possible, I run a new engine on a test stand before building because an airplane should be built around the engine, and it might as well run. A beginner should do the same thing.*

A smart modeler spends a few minutes making an inexpensive, simple test stand (210) from a board. The stand attaches to a picnic bench with a large "C" clamp (211). Cut a "U" shaped channel, drill holes for the engine mounting screws and attach the engine with machine screws and locking nuts (212) or nuts and lock washers. We don't want the engine to come loose. The tank attaches with soft wire or rubber bands looped around "J" bolts that are available in any hobby shop, or these bolts can be easily made by bending long machine screws. Epoxy cement, which you'll need to complete any model, fixes the "J" bolts in holes drilled into the board. The simple throttle linkage we suggest is made from 1/16" wire and two wheel collars (213-214). It initially holds the throttle open (213), and later we run the engine at reduced speeds by pulling the rubber band loaded lever back (214). The arrangement in those shots uses an aluminum post epoxied in place. Most readers could not expect to come up with a metal piece like that, but a similarly shaped half inch wooden dowel rod functions equally well.

COMMON FUEL SYSTEMS

Fuel tubing connects the engine and tank in different ways depending on how you want fuel delivered to the carburetor. Suction feed relies entirely on air passing through the carburetor to draw fuel from the tank, and a single tube connects the carburetor and the tank, which is vented to the atmosphere. Better systems get fuel to the carburetor under pressure and regulate the pressure at which the fuel arrives. An unexpectedly easy system, called muffler pressure, enjoys nearly universal acceptance, so let's see how this simple arrangement in (210) works. When an engine runs at full throttle, pressure within the muffler is greater than the surrounding air. Muffler pressure brought through the upper tube in (210) forces fuel toward the carburetor in the lower tube. The slight muffler pressure delivers fuel without needing any complicated pump or regulator. When the engine throttles down, muffler pressure drops dramatically and lowers pressure in the tank. That reduces fuel pressure at the carburetor just when the combustion mixture needs less fuel to keep from flooding the engine. In Chapter Twenty-Two we'll discuss fuel systems that include pumps and regulators. Modelers use them on airplanes with unusual tank locations. *A beginner should only install a simple muffler pressure system like the one shown.*

A small modification to the muffler pressure fuel line arrangement makes filling the tank and storing the airplane easier. I've shown this with a four-stroke engine mounted in an airplane, but it works equally well on a test stand. In (215) a short piece of brass tubing connects the fuel and pressure lines. Between flying sessions, that setup keeps residual fuel from draining out of the tank and making a mess. Photo (216) shows the tank being filled through the carburetor line while the pressure line acts as a vent. After filling the tank, we rearrange the tubing as in (217) so the engine can run. This convenient setup was shown with an alcohol fueled glow engine, but it offers another feature for gasoline and diesel fuels that deteriorate silicone tubing. The short piece of silicone tubing on the muffler fitting (217) lasts a long time because it


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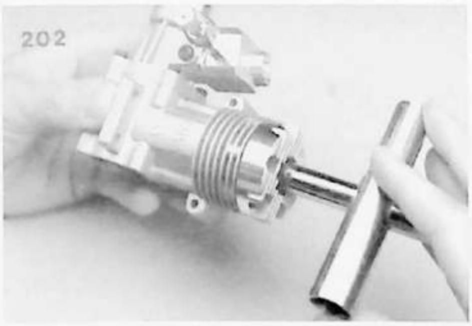
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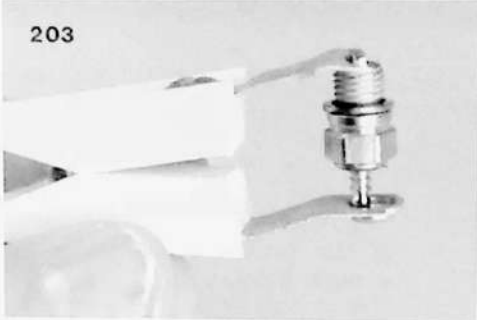
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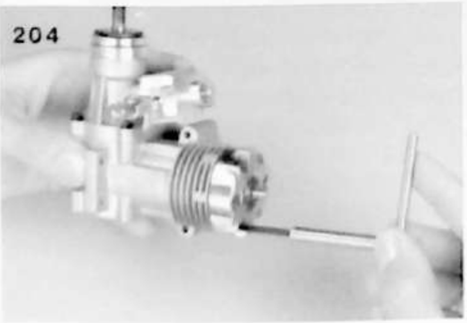
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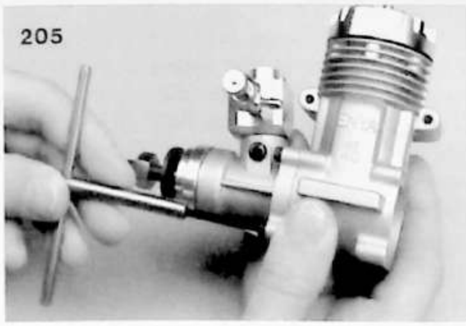
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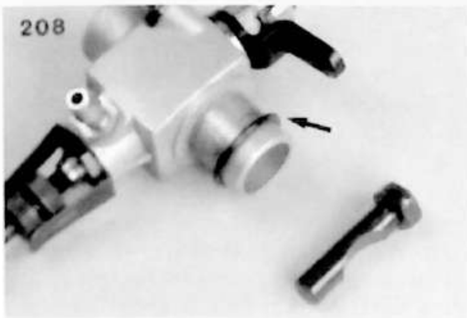
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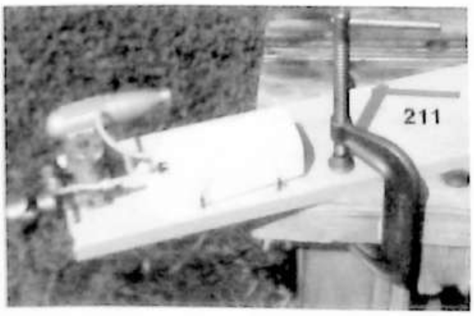
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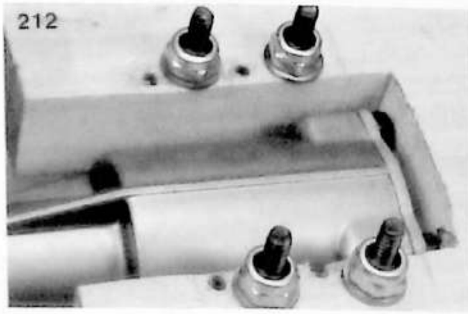
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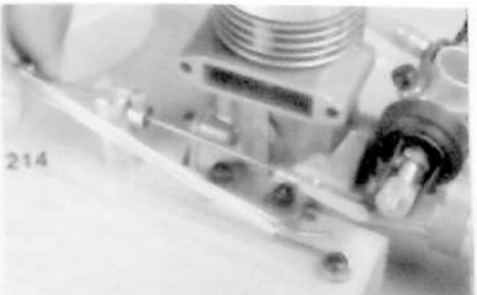
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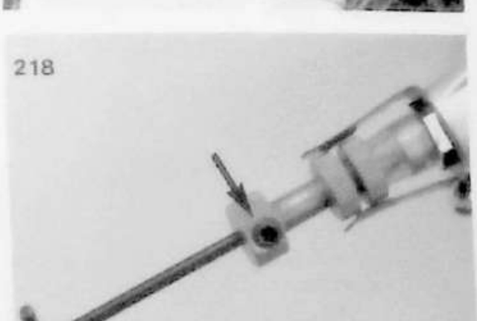
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doesn't get exposed to much raw fuel. If you're running diesel fuel or gasoline, the remaining tubes, which don't encounter excess heat, should be neoprene.

Filters play an important part in our fuel systems because tiny dirt particles find their way into the fuel. Symptoms of a dirty carburetor and an engine that won't throttle because it's too new are nearly identical. Since you don't need to complicate setting a throttle, use three filters. If you have a flight box, put filter paper in the funnel when you pour fuel into the flight box container. Mr. Coffee filters are a little slow but work fine otherwise. An auto body supply house sells or gives away disposable filters that work faster. Even this precaution does not insure clean fuel, so two fuel line filters are needed. Install one between the tank and engine, and another in the filler line. Arrows in photo (222) point to both filters. Fill the tank from behind the fuel line filter. Then, no unfiltered fuel reaches the engine.

NEEDLE VALVE RESPONSES COMMON TO ALL ENGINES

An engine must be started before the high speed needle can be adjusted. Logically, you might expect to learn starting before needle valve adjustments, but that isn't the case. A modeler must know how to adjust the high speed needle valve based on how the engine sounds, and he won't have time to learn how after the engine starts. For that reason, we discuss valve adjustment before starting.

Model engines run on alcohol, gasoline or kerosene and may ignite their fuel by the diesel effect, a spark, or a glowing wire. Some responses to the high speed needle valve are the same with any engine. For example, closing the valve too far stops the engine. Other responses depend on the fuel and ignition combination. This section discusses valve adjusting topics common to all engine types.

Some modelers find the terms rich and lean confusing because they each have two related but different meanings. A "rich" mixture has too much fuel, a "lean" one too little. Modelers use open and "richen" to mean screwing out the valve. Similarly close and "lean out" mean screwing in the valve. So, various forms of the words rich and lean describe both valve movement and fuel content in the combustion mixture. Let's move on to other terms. With the carburetor held open, the engine speed can span more than 7000 RPM without running rough or overheating. We'll call this its "usable RPM range". The high speed needle valve setting determines at what RPM within the usable range the engine runs. The engine's "maximum practical RPM" is near the lean end of the usable RPM range. At that valve setting an engine produces its greatest power without overheating, and we normally fly with the valve set that way. The high speed needle can be leaned out until the mixture has too little power to keep the engine running. Engine people call a mixture like that "over lean". Over lean mixtures do not lubricate or cool adequately and can damage the piston and cylinder no matter what fuel or ignition the engine uses.

All manufacturers suggest an initial setting and often supply the valve with a notch, screw (218), or another mark that makes it easy to count the turns. If no mark or screw exists, you should file a vee shaped slot near the screw location shown in that shot. Close the valve until it just stops and go no farther because continued tightening will damage the valve seat. Then, open the valve the suggested number of turns. If you don't know the manufacturer's recommendation, try about three turns. Either setting is only a starting point because all engines, even identical samples, run with different high speed valve positions. After the engine starts we find the maximum practical RPM for the individual engine, fuel, and propeller combination. Modelers have developed a clever "tubing pinch" test for this speed. While the engine runs, the fuel line is pinched briefly (219) and then released. When correctly done, the engine responds to the pinch test in only three ways.

1. If the engine speeds up during the pinch and richens after the release, the rich mixture can be leaned out.

2. If the engine speeds up during the pinch and continues at the higher RPM after the release, the mixture is about right but can be leaned out a little more.

3. If the engine does not speed up during the pinch and runs the same after the release, it runs at its maximum practical RPM.

The sounds of rich and lean mixtures are distinctive and vary with the fuel and ignition. A rich alcohol-fueled two-stroke glow ignition engine sounds entirely different than a rich diesel or gasoline engine. The next sections discuss how to adjust a needle valve for some popular fuel and ignition combinations.

ADJUSTING THE NEEDLE VALVE FOR TWO-STROKE ALCOHOL GLOW ENGINES

Nearly all beginners select alcohol-fueled glow engines and need to recognize their unique sounds. With its needle valve open too far, an engine sounds like ignition does not occur every revolution. We say a rich alcohol fueled engine "four-cycles" because it sounds a little like a four-stroke engine, though this common term misuses the word cycle just a little. As you slowly close the valve, the RPM increases steadily, but at some valve position the pitch jumps suddenly in a small fraction of one valve turn. Then, the engine sounds like ignition occurs every revolution so we say the engine "two-cycles". By using the pinch test the RPM can be increased to its maximum practical RPM. Continuing to lean out beyond that will make the mixture over lean.

Any flyer with a new engine should apply these ideas in the following ways. After starting the engine, open the valve until the engine almost quits. It will undoubtedly be four-cycling. Next, close the valve slowly until the engine just changes from four-cycling to two-cycling. A new modeler should do this several times to become familiar with two and four-cycling sounds. Lastly, open the valve until four-cycling begins and shut the engine off by squeezing the fuel line. The engine is ready for the next step, a break-in.

ADJUSTING THE NEEDLE VALVE FOR FOUR-STROKE ALCOHOL GLOW ENGINES

A four-stroker has a less complex sound than the two-stroke engines discussed in the last section, and that makes them the easiest engines to adjust. As with any other engine, initially set the high speed needle valve according to the manufacturer's recommendation. If you purchased a used engine or don't have the instructions, try three turns. Either setting usually puts the valve somewhere in the usable RPM range. After starting, open the valve until the engine runs roughly at the rich end of the usable range. From that setting, closing the valve will be accompanied by a steady increase in speed until the engine slows down or has a loud popping sound distinguishable from the normal tone. In the latter case, we have preignition. Both symptoms indicate the valve was closed beyond the usable RPM range. At that point, richen the valve until the engine smooths, and it will be running near its maximum practical RPM. You could then refine the setting slightly by using the pinch test. After successfully performing these tests, it's time for the break-in.

ADJUSTING THE NEEDLE VALVE FOR GASOLINE ON SPARK IGNITION

Gasoline and diesels engines do not respond to needle valve adjustments with two and four-cycling sounds like a two-cycle glow engine does. A rich engine runs rough in an irregular or random way. A lean setting sags or gives short cycles consisting of a brief power burst followed by an equal period with no apparent ignition. Mechanics sometimes use the term "rolling" to describe this. If you're running a gasoline engine for the first time, experiment with the valve position and listen for the sounds just described. A gas engine's usable RPM range lies between rough running and sagging or rolling. When you can identify both ends of the usable RPM range, try the pinch test. Then, continue with a break-in.

ADJUSTING THE NEEDLE VALVE FOR DIESEL

The variable compression feature makes setting a diesel's high speed needle valve slightly more complicated than with other engines. The needle valve and compression screw are not randomly played against each other, instead we use a simple three step procedure. First, find a compression setting for cold starting. Secondly, set the needle and compression screw so the engine runs rich at operating temperature. Last, find the maximum practical RPM. Once these steps are learned, operating a diesel becomes no more difficult than any other engine.

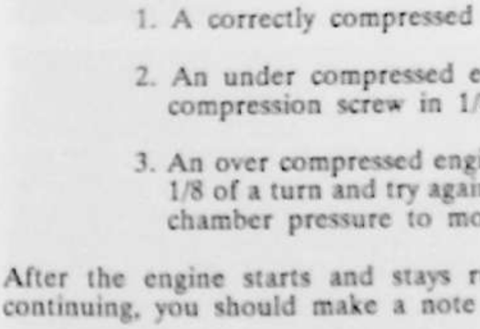
We initially set the compression screw to the manufacturer's specifications. Do the same for the needle valve. The engine should now have a slightly rich mixture and compression near the starting position. Next, we change the settings to suit the individual prop, fuel and engine in the following way. Apply the starter for brief periods, and see which of the following three things happens.

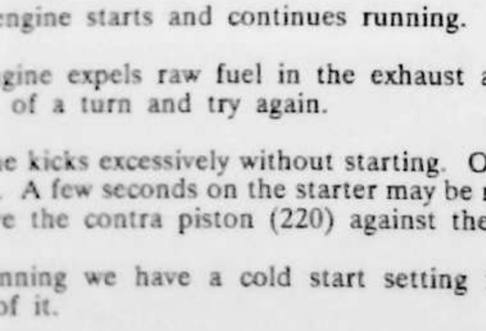
1. A correctly compressed engine starts and continues running.

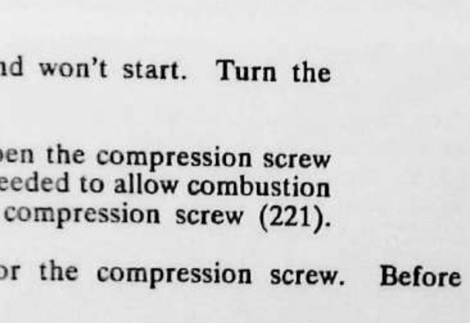
2. An under compressed engine expels raw fuel in the exhaust and won't start. Turn the compression screw in 1/8 of a turn and try again.

3. An over compressed engine kicks excessively without starting. Open the compression screw 1/8 of a turn and try again. A few seconds on the starter may be needed to allow combustion chamber pressure to move the contra piston (220) against the compression screw (221).

After the engine starts and stays running we have a cold start setting for the compression screw. Before continuing, you should make a note of it.







An earlier chapter mentioned that starting a cold diesel takes more compression than maintaining combustion in a warm, running engine. Next, we adjust the needle valve for rich running and reduce the compression ratio for normal operating temperatures. After the head becomes warm to touch, turn the compression screw out 1/8 of a turn at a time until the engine runs as smoothly as it can. The mixture may be rich or lean causing the engine to still run rough. Experiment by opening and closing the high speed needle valve until the engine runs smoothly. Then, open the needle valve as far as you can without encountering rough running. Now your engine runs at the rich, low compression end of the usable RPM range. Continue closing the needle valve small amounts accompanied by slight compression increases. If the engine sags or starts missing, you've gone too far. Reduce the compression and richen the mixture. Use the pinch test as a double check once you think the engine runs at its maximum practical RPM. A new diesel needs to be broken in so don't run it long at that setting.

GETTING STARTED

Now that you understand high speed valve adjustment, it's time for a trip to the flying field. Clamp the test stand to a picnic bench (211), rubberband the carburetor fully open (213), and fill the tank (222). Gently turn the needle valve closed until it stops. Then, open it as the manufacturer suggests or about three turns. Before starting an engine, we lubricate the inside with fresh fuel in the following way. Place a finger over the carburetor opening and draw fuel from the tank into the engine by turning the propeller over a few times by hand. That is also called choking the engine. You should see fuel moving through the line connecting the tank and engine. If you have a glow engine, connect the battery (223). A few seconds on the starter normally gets the engine running (224). After the engine starts *stand behind the rotating propeller, never in front of it or to the side in the path of any pieces that may break off, and never reach around the propeller.*

There are only a few reasons an engine will not start, the more common ones are:

1. The high speed needle valve is improperly set. If the exhaust contains raw fuel, the mixture may be too rich, close the valve a quarter turn and try again. If you're running a diesel, try compressing it before leaning out the mixture. An engine that starts but won't stay running may be too lean, open the valve a quarter of a turn and try again.

2. The filter or carburetor is clogged. Attach a piece of fuel line to the carb fuel inlet and blow gently into the carburetor (225). If air doesn't pass into the engine, try cleaning the carburetor by sucking out the foreign particles with a syringe (226). Disassemble the fuel line filter and remove any dirt it contains.

3. Something is wrong with the spark or glow ignition system. A glow ignition engine may have a weak starting battery or bad glow plug. Remove the glow plug and attach the battery (203), or use its meter to determine whether the plug glows (227) or not (228) as we described a little earlier in this chapter. Spark ignition engines may have a bad plug, but more than likely the wiring or magneto is at fault.

Now it's time to experiment with the needle valve by trying different settings in the usable RPM range. Our engine, a glow ASP 46, (229) runs at a fast four-cycle, and when the valve was closed one turn the engine was two-cycling (230). Most modelers rely on sound and do not use a tachometer to adjust the mixture. The tachometer was shown only to give a feel for the engine RPM.

BREAK-IN

New engines often run poorly during the first hour or two for several reasons. No matter how carefully a manufacturer produces an engine, its moving parts have microscopic ridges that cause excess friction. Engine parts, especially pistons, grow the first few times they are heated. The ridges and piston growth need to be worn away before the engine will run at maximum power. Modelers call wearing moving surfaces smooth by an initial running a "break-in". Break-in time may vary from a few minutes to more than an hour, and depends mostly on how well the engine is made. We don't try to find the minimum break-in time. Instead, our methods will leave any engine ready to fly.

First, run the engine for five minutes near the rich end of the usable RPM range to verify that the engine will start and that the fuel and ignition system are working properly. The next period of running is different for an ABC glow engine than any other type. A brass sleeve in an ABC engine expands slightly more than the aluminum piston. To have a good fit at operating temperature, the piston and sleeve fit very tightly at room temperature. We run an ABC engine a little hotter than other engines to get these parts expanded to the right size. Set a glow ABC engine's high speed needle valve in the two-cycle range but close to four cycling. All non-ABC glow engine should be run four-cycling just before the point of two cycling. Diesel and gas fueled engines are broken in with the engine running at the rich end of the usable RPM range. Check occasionally for overheating by touching the cylinder (231). An engine that cannot be touched, is not broken in and needs more running. Let it cool off and continue with five minute runs until no overheating occurs. After that, use the pinch test to set the engine's maximum RPM. If the engine runs at that setting for ten minutes without overheating, the break-in is complete.

SETTING THE IDLE

Many carburetors come from the factory with the idle adjustments preset, but a new engine with excess friction still won't idle reliably. So, no attempt to set the idle should be made until after a break-in. Then, try the factory idle settings before changing anything because the engine may idle perfectly or require only minor adjustments.

The first of two carburetor adjustments controls the air volume. A rotating barrel regulates the air entry (232), and a small screw usually limits how much the barrel closes. For most modeling applications the screw is set so the barrel closes completely, and we rely on adjustable servo travel to limit the barrel closing. Since a test stand has no servo, set the limit screw so the barrel closes about as shown in (232) with only a tiny moon shaped passage still open.

The second idle adjustment will be an auxiliary needle valve or screw, and we set it in the following way. With the barrel wide open, start the engine and set its high speed needle as explained above. An engine set perfectly for normal high speed running may become rich or lean as the throttle closes. Always stop the engine to make any screwdriver adjustment because you don't want to stick a metal blade in a running propeller. An engine that gives off smoke or raw fuel has too rich a mixture. Close the idle adjustment slightly and try again (233). An absence of any smoke and raw fuel indicates a lean engine. Try opening the idle fuel adjustment slightly. After the engine stays running at low speed, the idle mixture adjustment should be reset so it becomes a little rich as the engine slows down. Photos (234) and (235) show a British Irvine Diesel idling at 2700 RPM and running full bore at 12,600 RPM. If you have a tachometer, set the idle somewhere between 2500 and 3000 RPM.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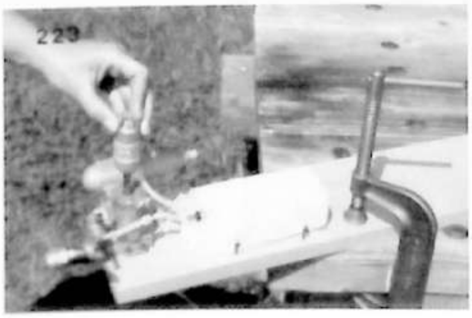
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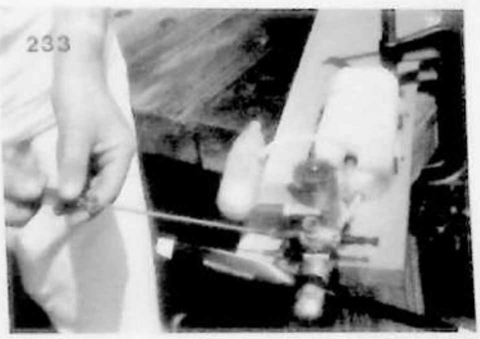
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CLEAN-UP AND GO HOME

Since alcohol attracts moisture that rusts internal parts, you should clean up an alcohol fueled engine after every flying session. Let's first show how to do that on a glow two-stroker. Cleaning consists of removing fuel from the engine and coating its internal working parts with a high-grade rust-preventing penetrating oil like those in (236). First, clean the engine out by running it at normal speed and then pinching the fuel line (237) or pulling it off the carburetor. The dying engine goes over lean but for too brief a time to hurt anything. Put a half ounce of oil [not just a few drops] in the carburetor (238) and turn the engine over a few times (239) to distribute the oil. That photo shows a starter, but I'd feel better if you hand flipped because of a problem called hydro lock, which happens when too much oil works its way into the combustion chamber. The upward moving piston cannot compress the oil and locks, bending the connecting rod or worse.

A glow four-stroker with its many small, steel parts needs cleaning more than any other engine. Despite the engine's complexity, it cleans quickly if you purchase some air tool oil and a Sig fueler (240) and follow a few simple steps. As with the two-stroker, pull the fuel line from the running engine and let it go dry. Connect the fueler to the crankcase vent and fill the fueler with oil (241). Hold the fueler above the engine so the crankcase vent is on top of the engine and turn the propeller over by hand (242). The engine sucks in oil, and only a few turns of the propeller fills the crankcase. The OS 70 Surpass in took nearly an ounce. The internal parts only need to be coated not immersed, so we now remove the surplus oil. With the crankcase vent beneath the rest of the engine, all the surplus oil squirts out when the propeller is turned over (243) just a few times. That photograph makes the point well, but we don't pump the surplus on a picnic table or even onto the ground. A small plastic bottle with two pressure fittings screwed into the lid recovers every drop of surplus oil (244) and stores it (245) until the next flying session. Fuel residue in the crankcase contaminates the surplus oil, so I discard it after three cleanings.

Recall from our earlier discussion on four-stroke engines that they have no direct passage between the crankcase and combustion chambers. The previous operation only cleans the case and valve driving mechanism. To clean the combustion chamber, remove the glow plug and squirt a quarter of an ounce of oil in the chamber (246). Turn the engine over several times to distribute the oil over the piston and cylinder wall. Putting a piece of one eighth inch wire in the vent tube (247) prevents any residue from leaking out. The engine can now be stored until the next flying session with no fear of rust.

Diesel and gasoline fueled engines are less rust sensitive because kerosene and gasoline do not attract water like alcohol does. Even so, I clean a diesel like a two-stroke glow engine to enhance the rust inhibiting qualities of the castor oil found in diesel fuel. I run the fuel out of a gasoline engine to keep the carburetor from becoming gummed up with gas residue. Except that one precaution, little cleaning is needed because oil in the gas coats the internal parts.

I'm sure after reading this chapter you realize that operating an engine takes understanding, and maybe the reasons for taking a day to learn these things before trying to fly are clearer.


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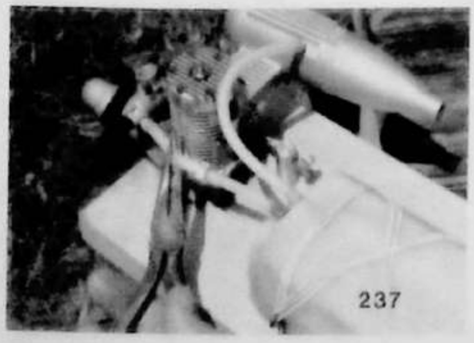
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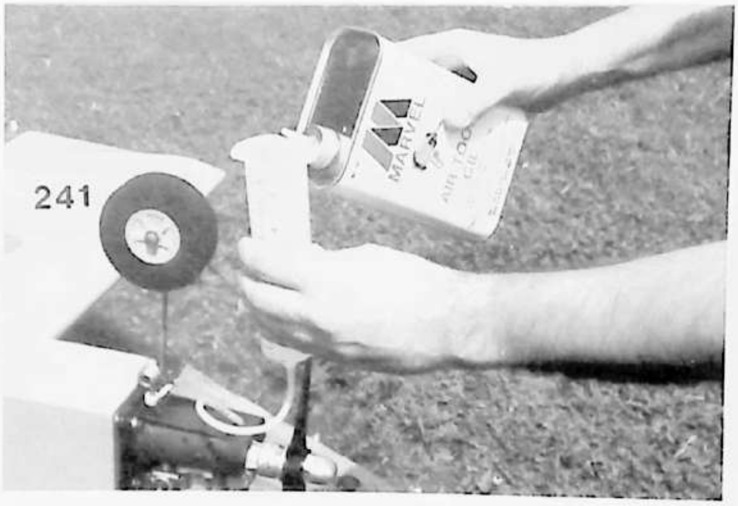

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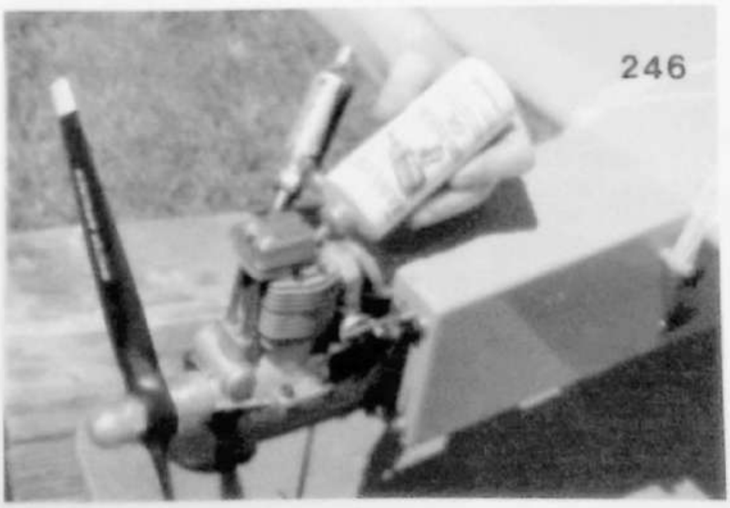

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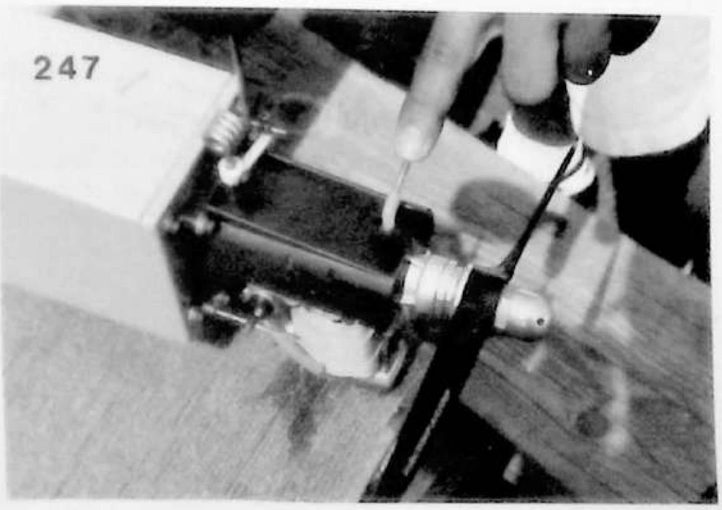

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CHAPTER TEN
MOSTLY MOUNTING

INTRODUCTION

For many years I have wanted to write a book titled Mostly Mounting that explains how an engine, tank, landing gear and controls go into a model. People entering the hobby have more trouble with this than any other part of building or finishing - and it must be done right. Chapter Ten contains a few of these mounting subjects including correct engine installation and some important related details.

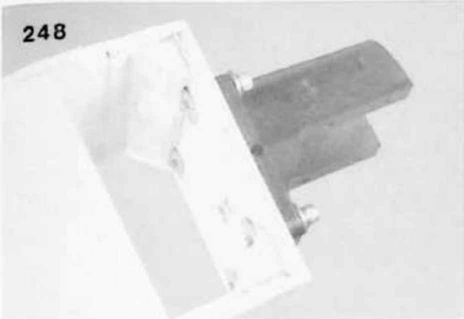
FIBERGLASS MOUNTS

There are many ways the fuselage structure can incorporate the engine, but fiberglass engine mounts are by far the most popular. A manufacturer molds them from nylon resin with fiberglass choppings mixed in, and the term "glass filled nylon" describes the material. Typically, a fiberglass mount bolts to a 1/4" plywood firewall as depicted in photos (248-249). Blind mounting nuts, imbedded in the rear surface of the firewall, allow the motor mount to be removed any time without accessing the nuts. That is important, since you cannot easily get at the rear of the firewall with the tank and controls in place.

Glass filled nylon mounts come predrilled for the firewall bolts, but their manufacturer leaves the engine holes for the builder. Most mounts include self-tapping sheet metal screws for attaching the engine. These screws have simple slotted heads that do not hold a screw driver blade well during the tremendous torque required to thread the tough nylon resin. Do yourself a favor by throwing these cheap screws away, and buy Allen type screws (250) from your hobby shop. Engines smaller than a forty mount with 4-40s while 6-32 screws secure forty to sixty size engines. Larger engines attach with 8-32s or 10-32s depending on just how huge the engine is. We suggest you drill and tap the motor mount and, if possible, use aircraft lock nuts that have nylon locking inserts (251) to keep everything in place.

There are two difficulties with drilling the mount - locating the holes and keeping the drill straight. Both things must be done nearly to perfection. Modelers, even experienced ones, foul up this job more than any other. Let's see how to do it right the first time and every time. First, we'll show two ways to locate the holes. A dowel rod and piece of 1/16" piano wire goes together easily making a right angle scriber (252). Moving the wire against the hole's wall in a circular motion while pressing down (253) scratches a small circle on the motor mount. Your naked eye can accurately tell when a scriber point lies centered in the small circle (254). Poke the center with the scriber point and then drill the mount as we will explain shortly. While "eyeball accuracy" works surprisingly well in this application, you should consider a much better, dead accurate way to locate those holes. Purchase a six inch aircraft drill with the same diameter as the engine's mounting lug holes or just a little larger when you cannot find the exact drill. Holes in foreign engines are metric and it may be difficult to locate an aircraft drill like that. If your drill is slightly oversize, enlarge the engine's mounting holes (255). Modelers do not like to enlarge holes in their engines and try this method with a small diameter drill. The results are usually off enough to ruin the mount, so don't be afraid to enlarge the holes a little. Clamp the engine and mount together and use the aircraft drill to just mark the surface (256). We call this "spot drilling". Centers of these spotted holes lie exactly under the engine mounting hole centers. Whether you choose a right angle scriber or aircraft drill to find the four hole centers, drill shallow pilot holes with a long, small-diameter, flexible drill (257). A spindly drill like that will not drift away from the spotted hole's center. Since two free hands makes any job easier, you should consider attaching the mount to a board (258) before drilling the pilot holes (259). The completed pilot holes appear in (260). That particular photo also has one hole drilled and tapped.

If you have a drill press, drilling holes straight and parallel presents no challenge. Since most modelers do not have one, we devised a simple tool called a Tap-N-Drill Guide, stocked by most hobby shops, that gives good drill (261) and tap alignment (264). Look in Appendix III for the correct size tap drill. After chucking the drill, slip the Tap-N-Drill Guide on the drill, and put the drill in the pilot hole. Then, align the drill by pushing the guide flush against the motor mount (261) and drill the hole. Some modelers clamp the guide in place (262). Either way you choose, the drill goes in straight. Common hand taps come three ways, bottoming, plug, and tapered (263). If you have any choice, get a tapered tap like the right one in (263) because it has more cutting teeth. Hold or clamp the guide over the hole and tap it through the guide (264). After several turns, the guide is no longer needed so let it slide back on the tap (265). That allows you to concentrate on not breaking the tap without worrying about its alignment. When you're done, the engine mount will exhibit crisp workmanship that would make a toolmaker proud. Though it has nothing to do with engines, I can't resist showing you how a Tap-N-Drill Guide makes drilling and tapping wing bolt holes easy (266-268). We hope you won't mind.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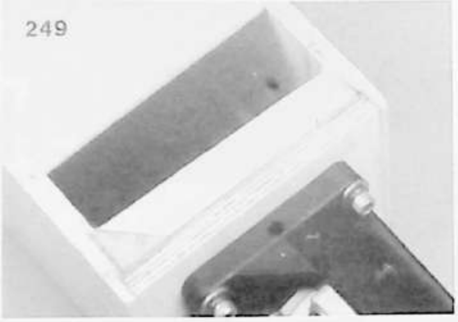
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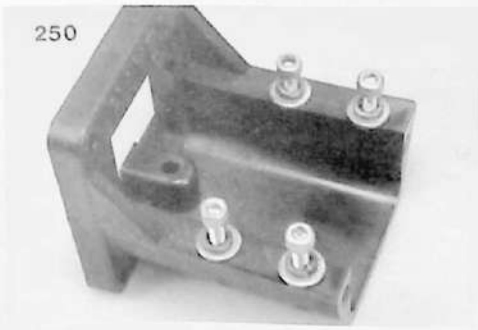
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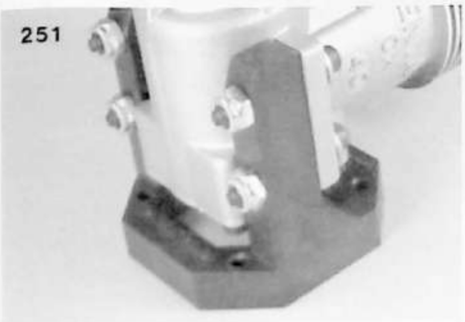
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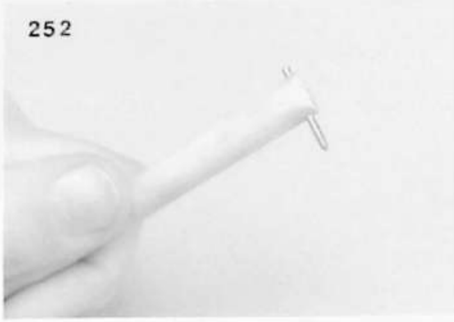
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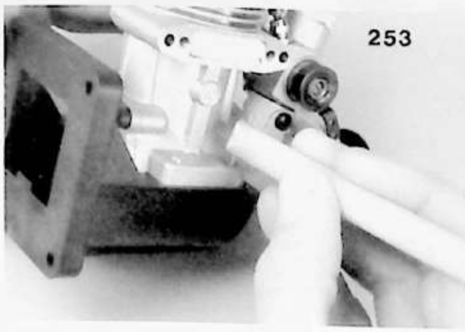
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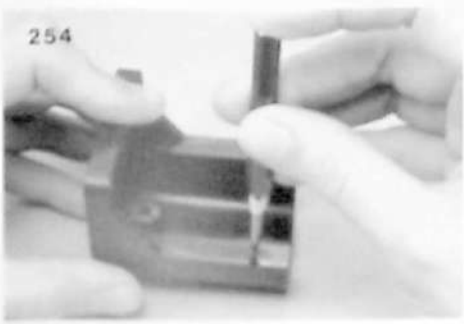
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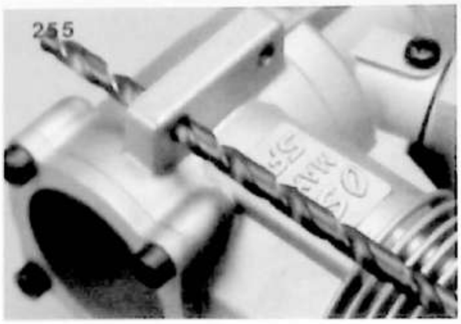
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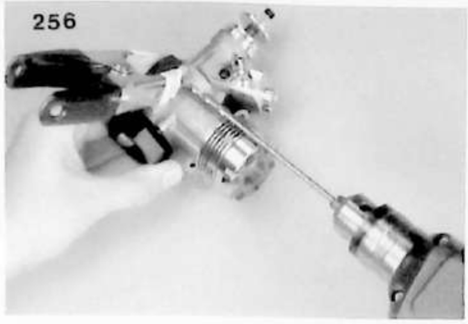
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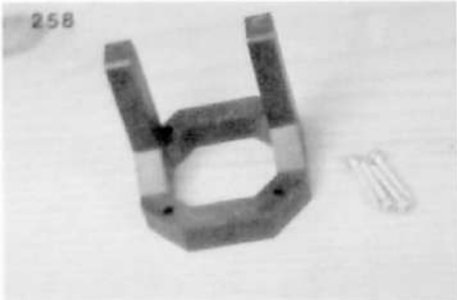
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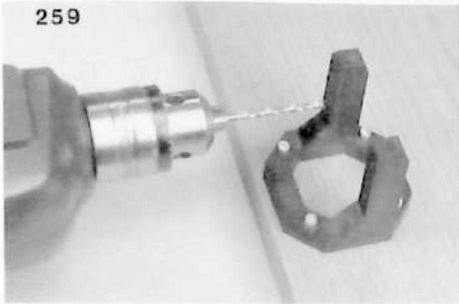
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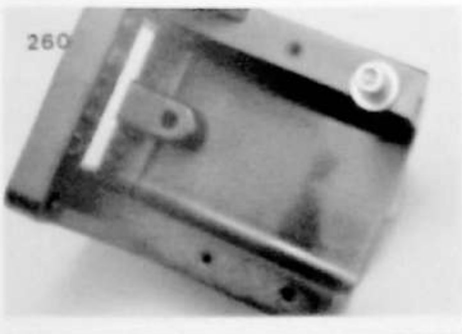
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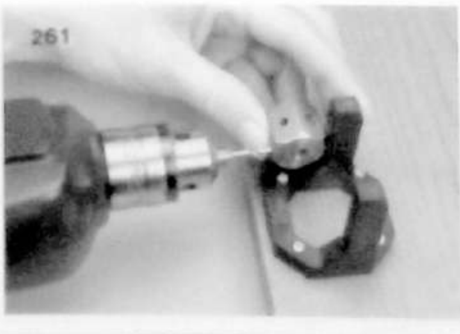
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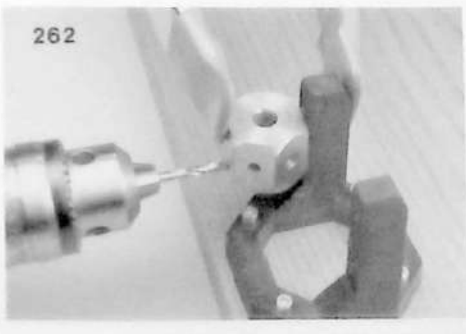
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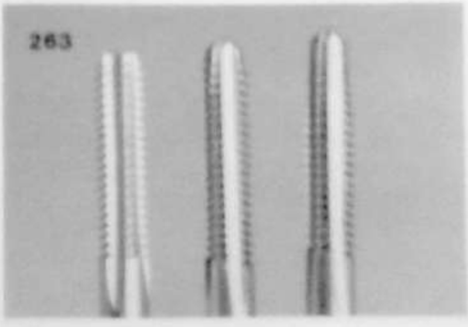
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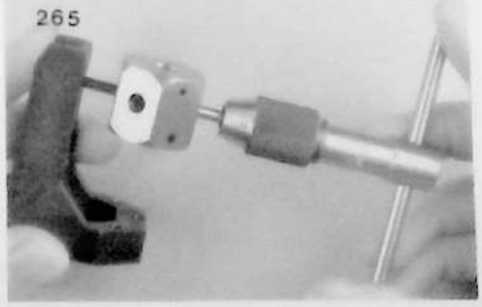
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A REMOVABLE FIREWALL

All About Engines includes many more engines than we could build airplanes for. Should you find yourself in that situation, why not try a replaceable firewall (269-270)? The motor mount bolts to a second firewall that attaches to the one on the airplane. During construction, holes in the second firewall are accurately drilled by using the original as a template (271). There can be one complication - if the engines have their throttle linkages on opposite sides, a second control cable will be necessary. Anyone using a removable firewall should consider installing the extra cable while he builds the model, when the installation is easy. A removable firewall requires little building time, and allows several different engines (270) to be tested in a single flying session.

SOFT MOUNTS

Until recently, model engines have been rigidly mounted as you might conclude from looking at photographs (248-250). A rigid mount transmits all vibration to the airplane, so very few other engines are mounted like that. Automobile and man carrying aircraft engines have rubber-like vibration damping devices between the power plant and frame.

Vibration induced problems have been discussed earlier, so we'll only repeat one now. A vibrating model airplane structure and its covering are noisy. To reduce noise, competition pattern flyers have developed mounts that absorb vibration. That event has some tough noise restrictions. A flying airplane can be subjectively judged too noisy, so these contestants take quiet operation seriously. Dave von Linsowe, a world class pattern flyer and expert on reducing noise in this way, helped us with this section. I have a hunch that "soft mounts", as these vibration damping devices are called, will become just as important as mufflers at all noise sensitive flying fields, not just with a few pattern flyers. So, we included this introduction.

Performance Products Unlimited's Vibra Damp beam mount has fiberglas filled beams that attach to the firewall with "isolation bushings". These flexible bushings, which appear deflected in (272), absorb or damp the engine's vibration. The beams drill and tap like the earlier example, except they are done one half at a time, but the firewall installation sequence is just a little different. Let's see why. If you grip the rubber part of the isolation bushing and screw it tightly into a blind nut, set in the firewall, the bushing may flex beyond its elastic limit and fail at some later time. So, the isolation bushings attach with standard hex nuts, tightened from behind the firewall (273). With a conventional firewall these nuts are tightened through the wing cutout and tank compartment. Our removable firewall gives an additional method. Large holes may be drilled in the original firewall to make space for the nuts, or the removable firewall can be countersunk with a Fostner Bit that you can buy at any woodworking supply company (274). I prefer countersinking the removable firewall because fuel leaks into the fuselage through holes in the original firewall. The remaining photographs, (275-277) show how the well designed unit makes space for the landing gear and isolates engine vibration from the airframe.

We tried a second soft mount and a different engine. The same isolation bushings (278) and metal tabs (279) attach to the engine block through the back plate screws (280). This inexpensive, adaptable soft mount has no beams to drill and tap, and it works with any sixty or smaller engine. Getting the tabs pointed correctly is the only problem, and photo (281) shows how to do that easily and precisely by tightening the tabs while they are forced against a straight edge. We recessed this removable firewall just like the last one (282). The soft mounted engine appears ready to fly in (283). Any mount that attaches to the engine's backplate holes, whether soft or rigid, is called a "radial mount". *For no rational reason, many modelers do not like radial mounts, but we think the lack of precision this system requires makes it ideally suited for a beginner.*

As you experiment with soft mounts, always remember that a failure can result in a loose, running engine, so take the appropriate safety precautions. Many flyers make an unsuccessful soft mounting system by placing isolation bushings between the firewall and a standard rigid mount (284). The closely spaced bushing pattern or "footprint" on the firewall together with the engine's excessive distance from the firewall (285) permits too much vibration, so this unsafe system should not be used. There are two ways to make a soft mount safer - increase the bushing footprint and reduce the distance between the engine and firewall. When we increased the footprint size on the firewall by adapting a radial system to a standard rigid mount (286), the engine ran without excessive vibration. The standard radial soft mount (287) gives a footprint about like the one in (284), but the distance between the engine and firewall is much less. This setup also damped vibration without letting the engine move excessively.

AN EXTENDED MOUNT

We wanted to fly the Aero Sport with a Saito 90 Twin, but the nose gear mount interfered. It could have been moved behind the firewall, but that makes the lock screw, shown by the arrow in (288), almost inaccessible. So, the gear remained on the firewall, and the Saito was located ahead of the gear mount by aluminum spacers that we found in an electronics surplus store. The mounting system depicted in (289-291) turned out dead solid and worked without a hitch. Most of you will never have a mounting situation like this one, but we thought you might enjoy seeing it anyway.


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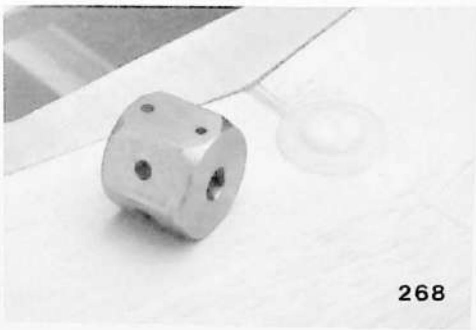
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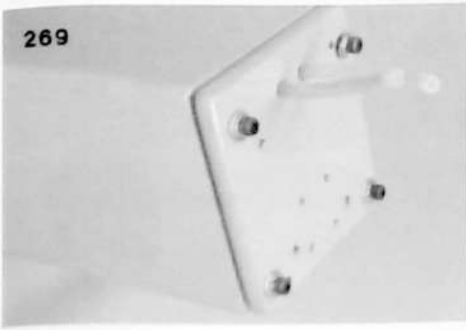
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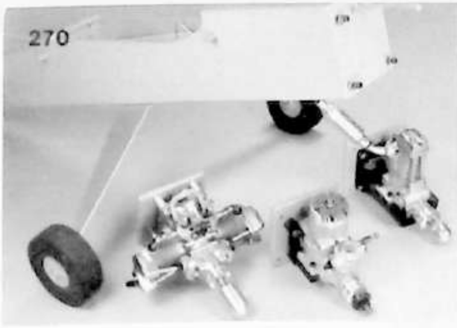
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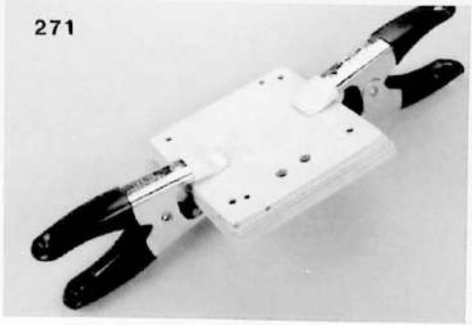
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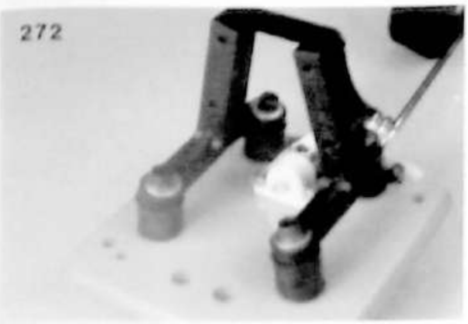
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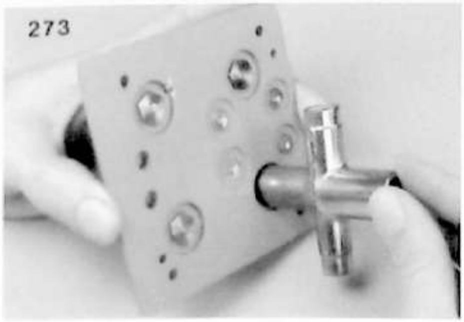
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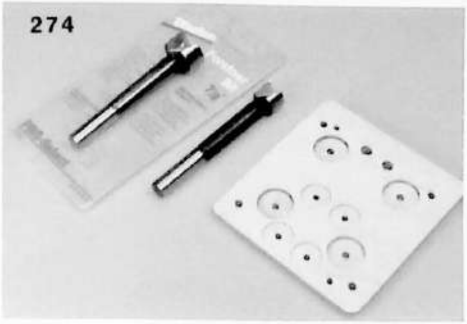
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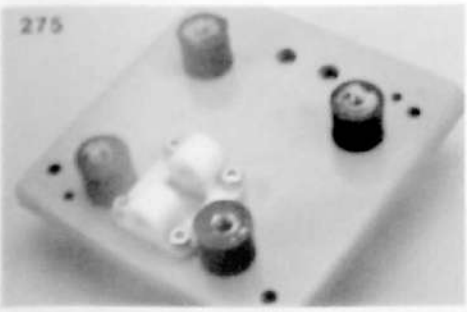
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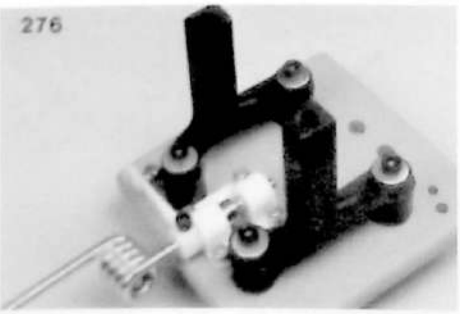
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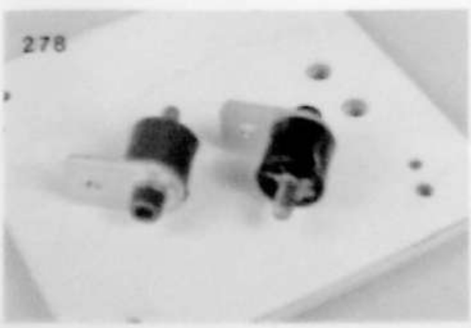
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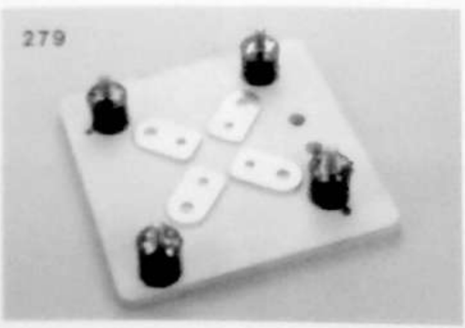
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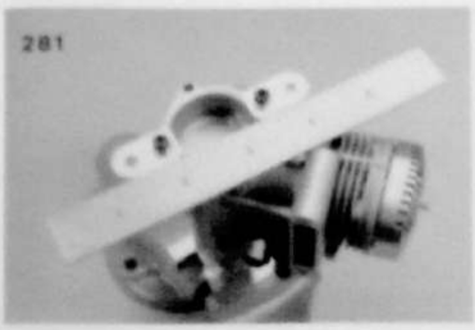
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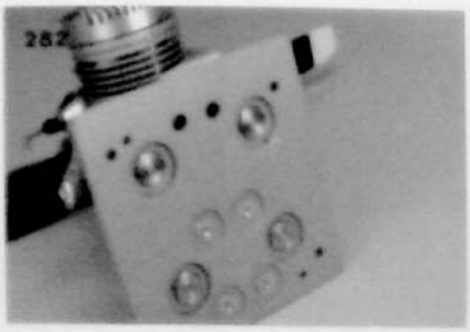
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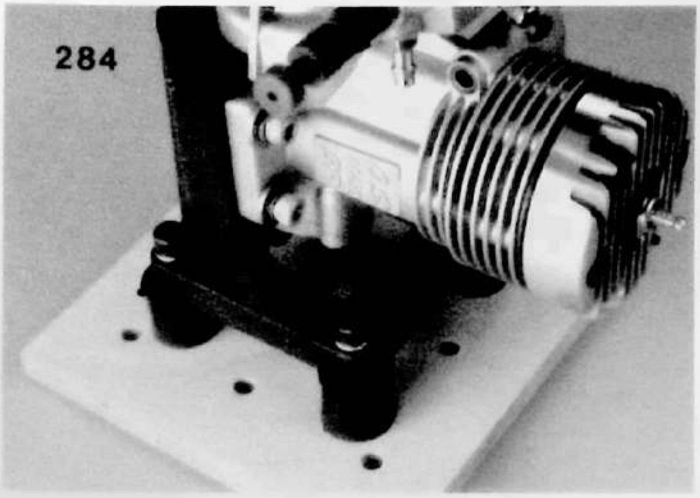
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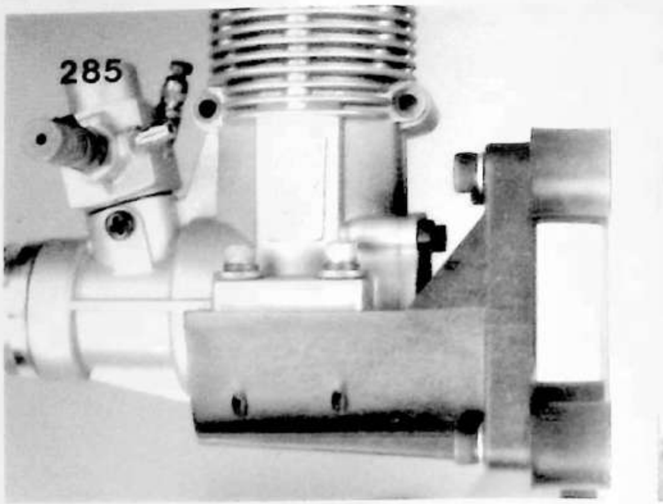
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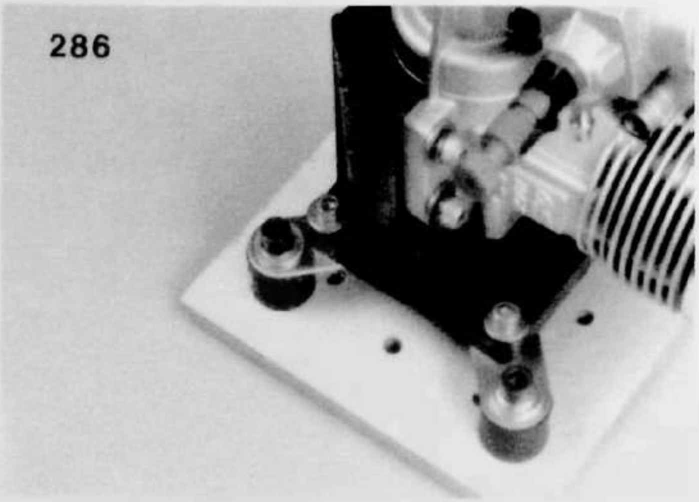
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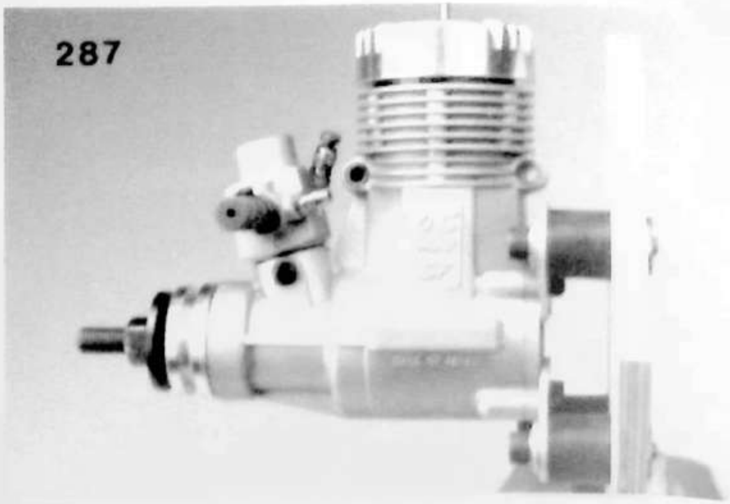
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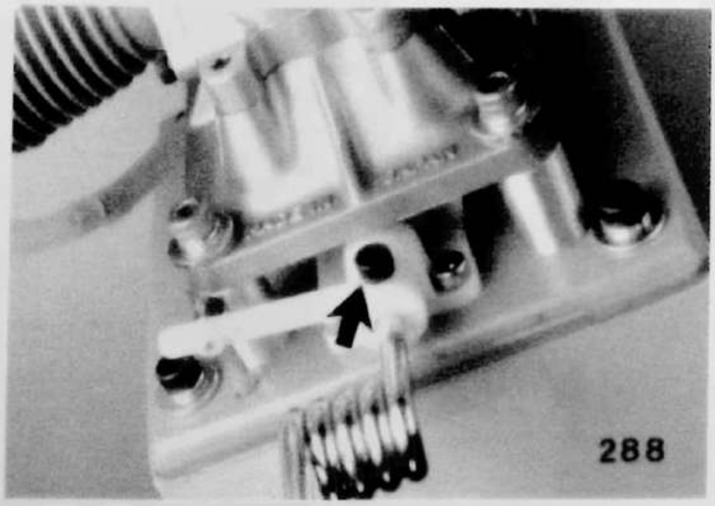
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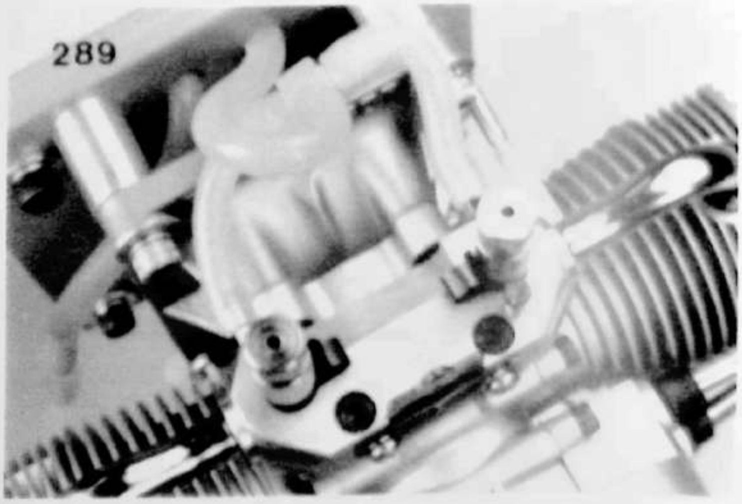
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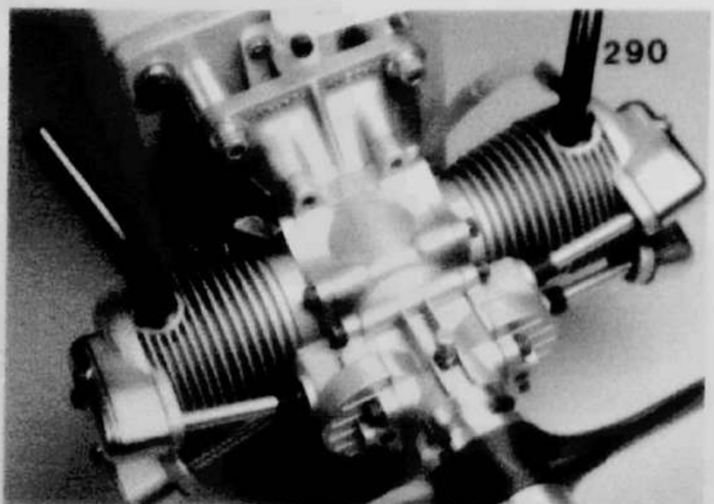
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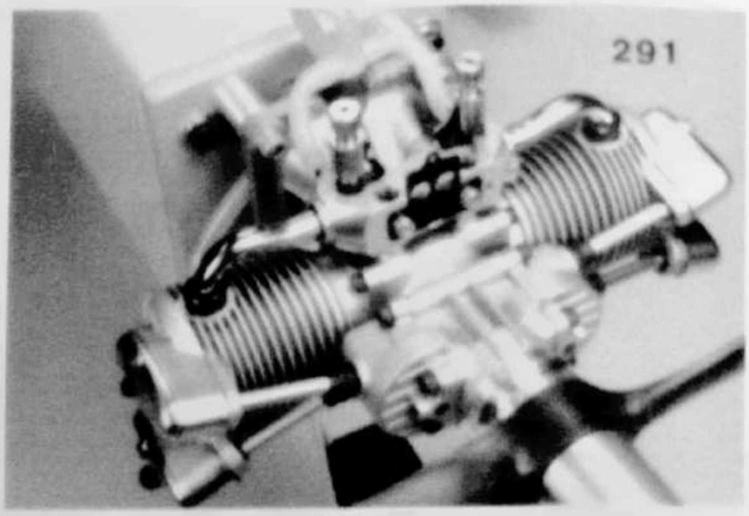
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INTRODUCTION

Successful engine operation involves more than just running it on a test stand. Some aspects of model building also greatly affect an engine's performance. Even a good running engine must be correctly mounted or it won't function well. For that reason we included Chapter Ten, Mostly Mounting. Chapter Eleven continues in this vein by discussing tanks and throttle control cables. These seemingly unrelated subjects have two things in common, both items often fit in a tight space right next to each other, and no engine runs reliably unless these installations fall within narrow, acceptable limits.

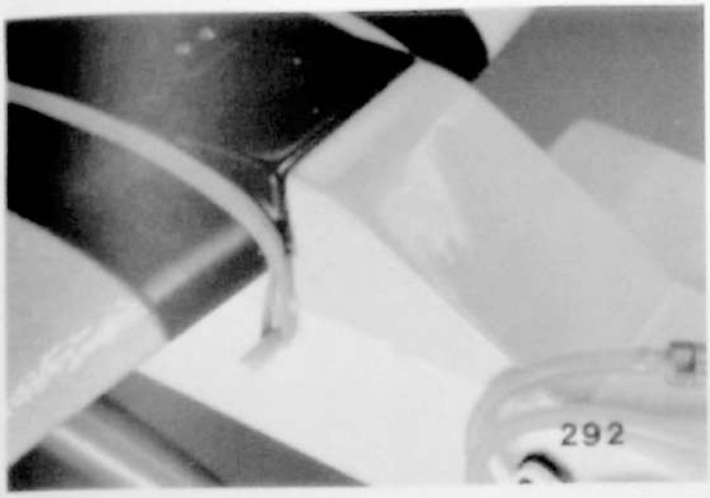
A SIMPLE TANK SETUP

In the next section we will use a DuraBat with an external tank to illustrate what constitutes a good tank location. We thought you might also like to see several photographs of our own DuraBat tank mount, in case you actually build this homely but great flying ship. A balsa wood cowl that attaches to the wing leading edge (292) replaces the plastic piece supplied by DuraCraft. The external tank mounts with fiberglass strapping tape, and the replacement cowl fits over the tape like photograph (292) shows. The stock cowl would not do that so easily. Initially, BoLink double stick servo mounting tape (293) holds the tank in place while you complete the job with fiberglass strapping tape (294). Without the servo tape the tank would eventually shift on the smooth fuselage side. The tank, mounted like this (295) flew over three hundred flights without shifting or coming loose.

TANK LOCATION

In this chapter we'll discuss two tank location rules for engines with muffler pressure systems. Chapter Twenty-Two goes into how a fuel pump allows a serious pattern flyer to put the tank in any convenient place, but nearly all other models have muffler pressure fuel systems. The first rule states that *the fuel line between the tank and engine should be no more than eight inches long.* The one in (296) falls within that range.

The second tank location rule, while not difficult, involves two terms you may not be familiar with - head and axis. Gravity affects the pressure forcing fuel through the carburetor jet. For example, a tank three feet above an engine provides fuel at a greater pressure than a tank below the engine. The amount of gravity induced pressure depends on the fuel depth measured vertically from the carburetor jet. Engineers call that depth a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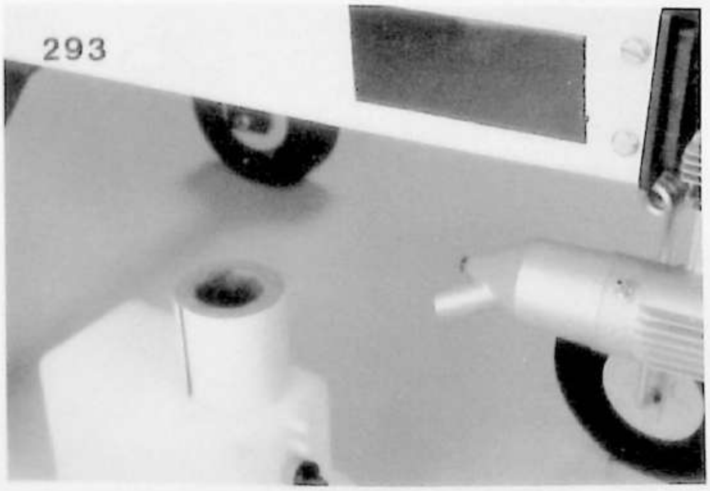
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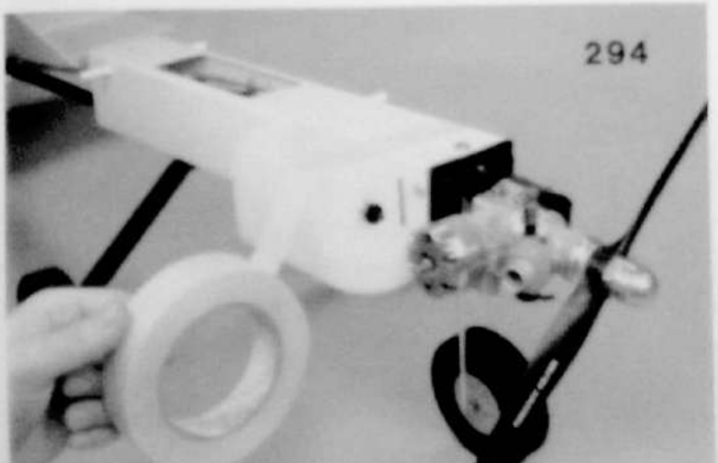
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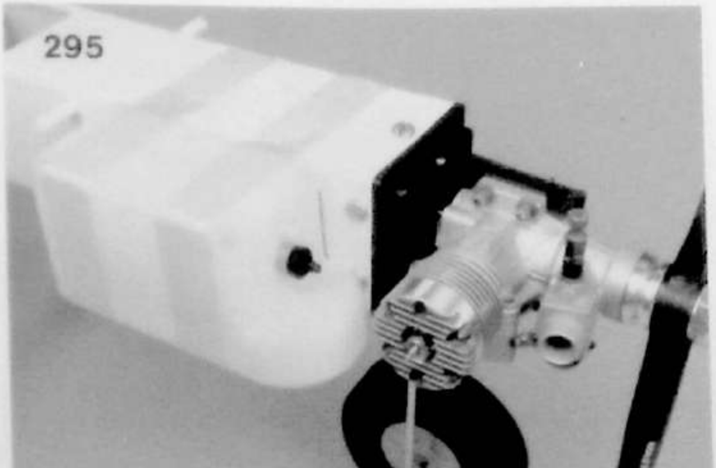
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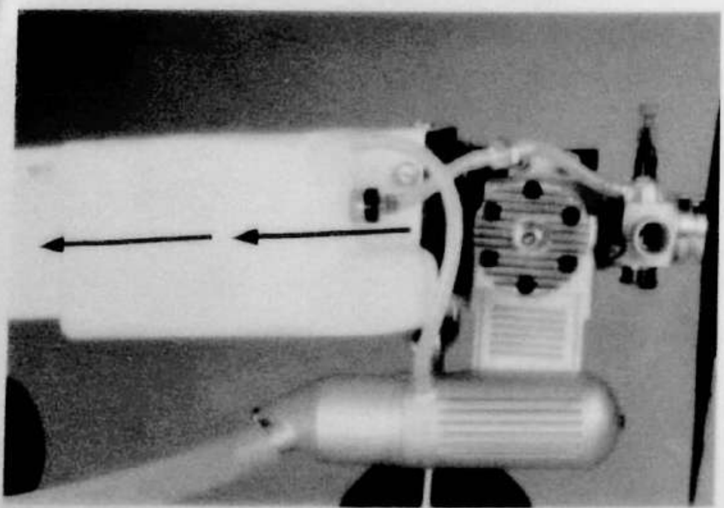
pressure head or simply a "head". If the needle valve setting remains unchanged, more head gives more pressure and a richer mixture than a smaller head. A tank's "axis" is a special line in the direction of flight. If the tank is full, the axis runs through the middle of the fuel. You can also think of the axis in the following way. The vertical distances from the top and bottom of the fuel to the tank's axis are equal, and the horizontal distances from the axis to the tank's side walls are also equal. The arrows in (296-297) lie on the tank's axis.

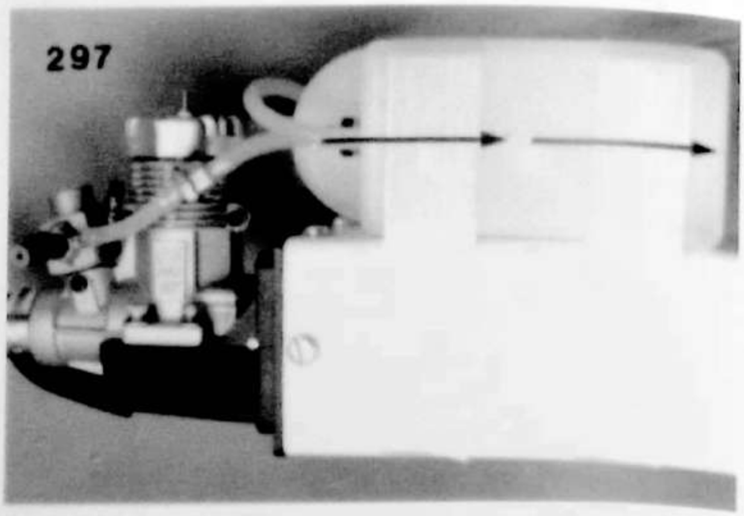
Ideally, we would like an unchanging head no matter what attitude the model assumes; that is not possible with a muffler pressure system. The pressure head changes radically during maneuvers like loops, but head variations during vertical maneuvers usually do not last long enough to change the mixture much. We are more concerned with extended pressure head variations such as those that occur during level inverted flight or a slow roll. If the carburetor jet lies on the tank's axis, the head would remain constant during these maneuvers. The side view of the tank axis in (296) lies slightly above the jet. As you can guess, the engine leaned out just a little during inverted flight. Most designers *locate the tank axis about a 1/4" below the jet* because the engine runs normally when the model flies upright and goes just a little rich during inverted flight, which is much better than going lean. Looking at the top view (297), the fuel jet and tank axis are way off; that only affects the head while the model flies horizontally with the wings vertical. A knife edge, as modelers call that attitude, is not the DuraBat's best stunt and few flyers do it often, so that head variation does not have an opportunity to cause trouble.

A TANK AND THROTTLE PUSHROD INSTALLATION

An internal tank must be installed with enough room left for the throttle control and sometimes a nose gear control. These two controls are nearly identical, so we'll only show the throttle. Look at (311-313) to see what it looks like. The throttle pushrod, normally flexible multistranded cable or 1/32 piano wire, moves through a plastic tube called a "cable housing" or "pushrod housing". The wire installs a little easier, but the cable offers less resistance. Do not be too concerned about these differences, because both types work well. You can find them in any hobby shop.

We first verified that the tank and its surrounding foam would fit by placing them on the plan (298). This ship, designed for a smaller fuel supply, needed part of a bulkhead removed (299-301) before the tank would slide in and out easily (302-303).





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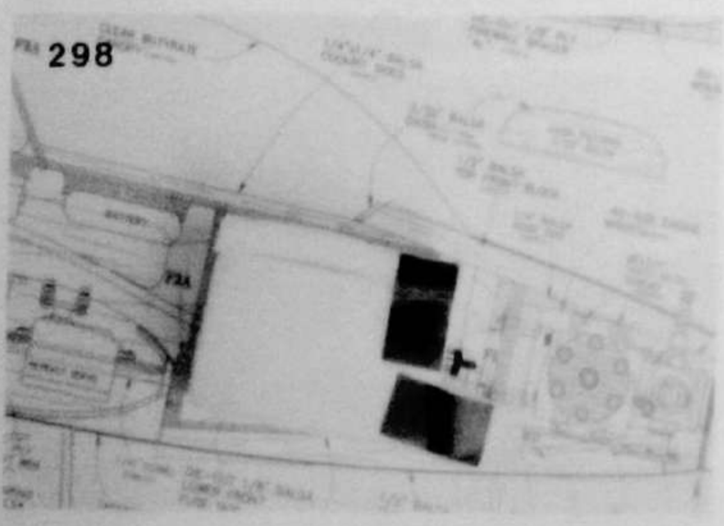

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Now, let's install the servo and pushrod housing so they give smooth, positive responses. The throttle servo mounts in a plastic tray (304), but that must be done with a little thought. This long tray flexes easily in the middle if it is attached at the end screw locations shown by the arrows. The flexing takes place when anything pushes against a servo such as the force against up elevator near the bottom of a loop. A flexing tray changes the throttle an unpredictable amount. So, use the side screw mounts and reinforce the plastic tray with 1/8" plywood (305). Lay the pushrod housing on the fuselage (306) and find a gently curving path. That photograph shows a completed fuselage because we didn't take the shot during assembly when we should have. Under no circumstances should you wait until the model is covered for these tasks.

Put a wire through the throttle linkage and mark the firewall where the control wire must come through (307), and drill a hole there (308). Mark and drill any bulkheads for the pushrod housing (309) and (310). The finished cable installation appears in (311-313). In (314) you can see the pushrod housing clears the tank.

We slid the tank in place with foam taped on (315). Photograph (316) gives another view showing other foam pieces already in the tank compartment. The two tubes in (316) are fuel line we use to guide the tank into place. That tubing appears in the fuselage nose (315). Sometimes, I drill a hole in the bulkhead and stuff small foam pieces tightly into the tank compartment (317). Photograph (318) shows the engine end of this installation including a YS 45 with a built in pump.

TESTING A TANK FOR LEAKS

Tank bodies almost never leak, but the tubing, filters, and seals between the lines and tank body frequently do. Then, the engine sucks air through the leak causing a lean run and overheating. These are also symptoms of other problems and our check verifies whether a fuel leak is at fault. The test was photographed on a stand so you could see everything. It works fine with a completed airplane, even one having an internal tank. Pinch the end of one line with a hemostat and inflate the tank with a Sig Fueler (319). Then pinch the other line (320) and wait several minutes. When you release the second hemostat (321), a rush of air should leave the tank. If that doesn't happen, the pressure leaked out during the waiting period, and you must find the leak.


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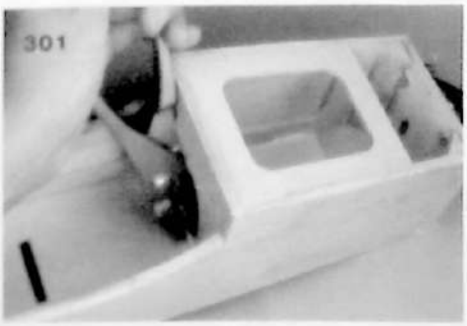
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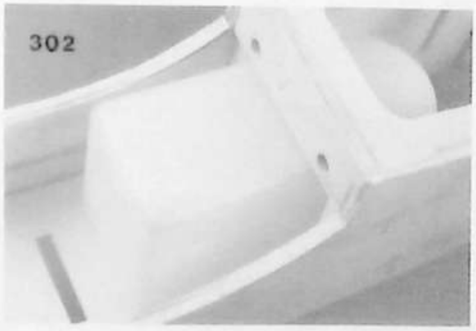
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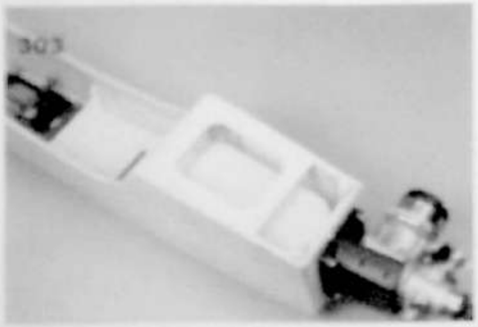
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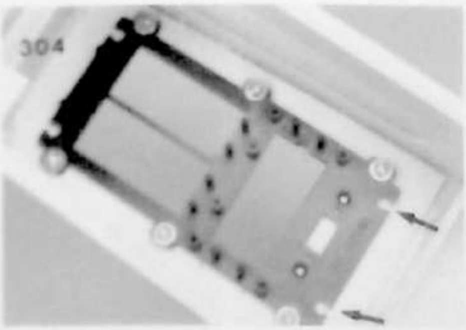
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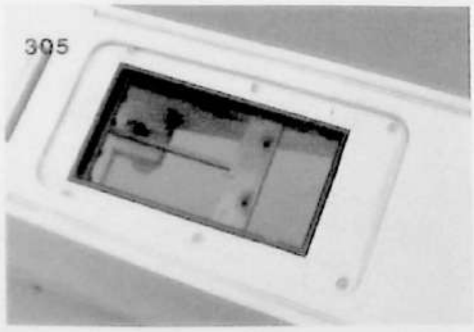
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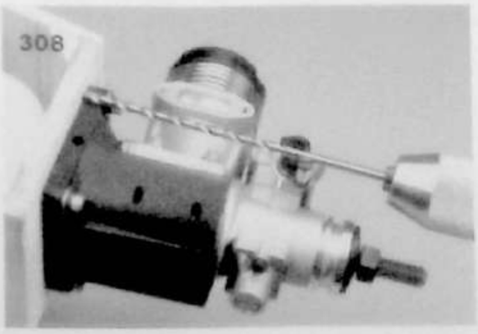
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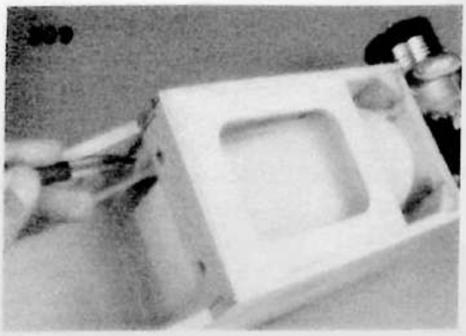
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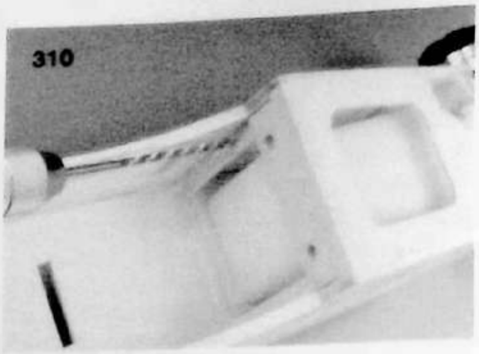
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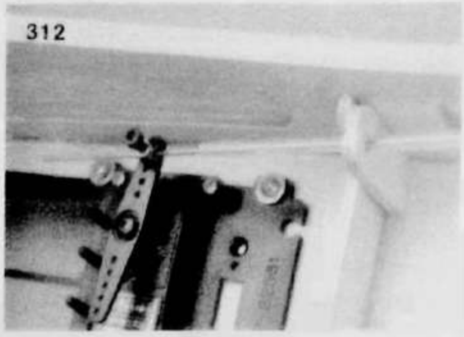
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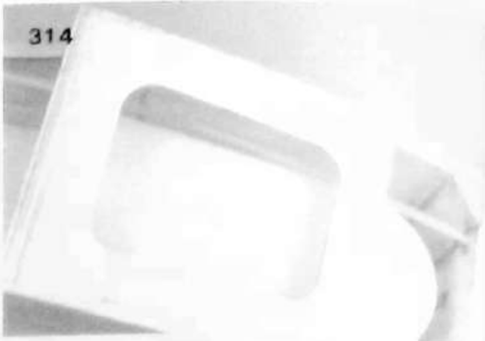
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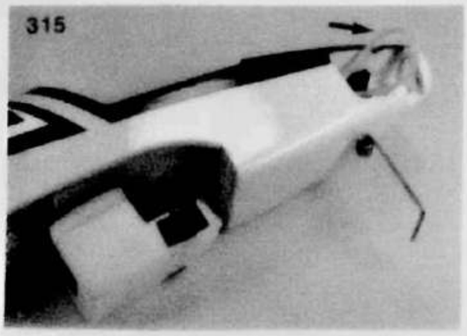
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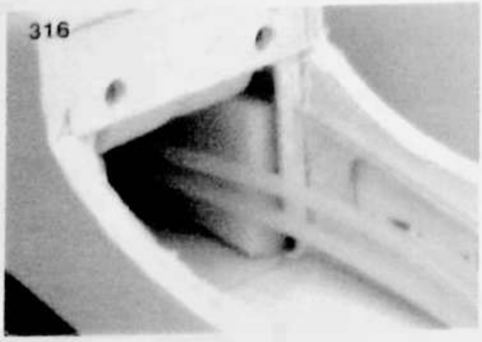
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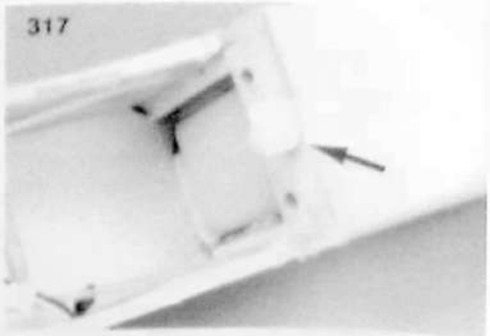
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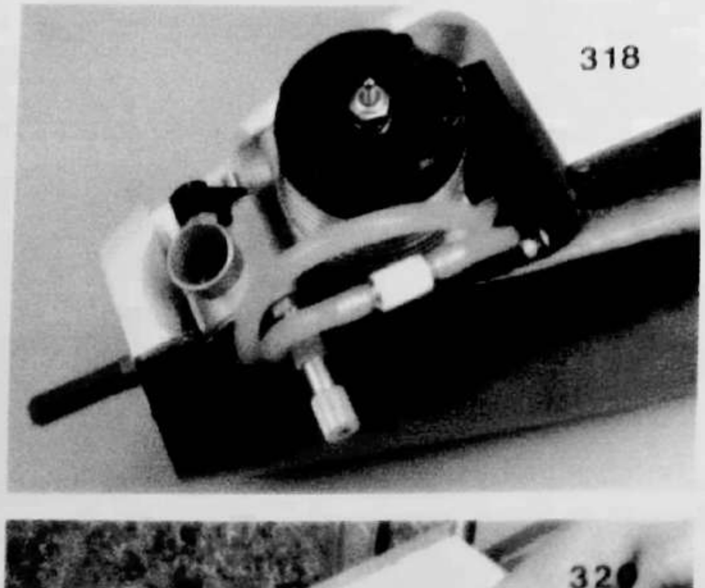
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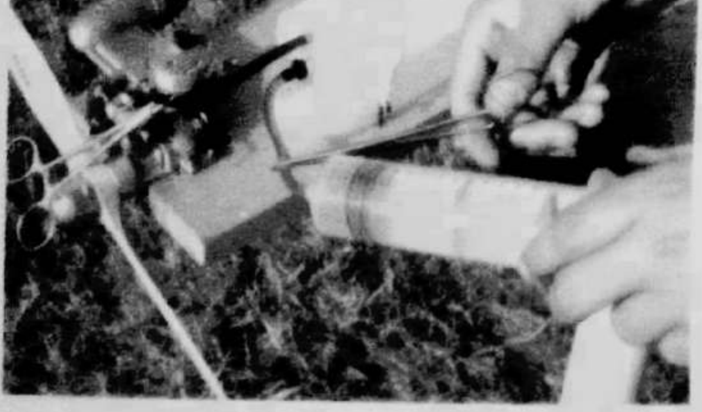
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INTRODUCTION

Chapter Nine includes sections about setting the high speed needle valve and adjusting the idle. After flying for a while, you will want to know more. Chapter Twelve explains how most popular carburetors work and gives information that helps you understand the adjustments we explained in Chapter Nine. Seeing carburetors in different stages of disassembly will also help you clean and repair most carburetors.

ALCOHOL ON GLOW IGNITION IS TOUGH

The various fuel and ignition combinations do not idle equally well, and some have trouble maintaining the 2500 RPM needed for a normal landing. Easily ignited gasoline running in a spark-ignition engine gives few problems because a hot spark sets the mixture burning with little regard for the engine's speed. Diesels fire when the heat of compression supports ignition no matter what speed the engine turns. The Irvine Diesel 40 in (322) idles easily at 1700 RPM, which proves the point well. A two-stroke glow engine running cool-burning hard-to-ignite alcohol may not keep the glow plug hot at reduced RPM settings. When that happens, the engine quits.

A closely related factor, propeller size, also determines the difficulty with which an engine idles. Gas, diesel, and four-stroke glow-ignition engines run on large propellers that are effective flywheels and help keep an engine running at low speeds. Recall that we use small propellers on two-stroke glow engines so they run near their maximum horsepower. Small propellers do not provide much flywheel action at low speeds. Besides the flywheel action at low speeds, an engine turning a large propeller has a lower high speed, and fewer RPM separate the maximum and minimum speeds. Slowing an engine with plenty of flywheel action from 8000 RPM to 2500 RPM is easy. But, a typical hard-to-throttle glow engine has little flywheel action yet it must go from 13000 to 2500 RPM. In our discussion we'll consider alcohol-fueled glow-ignition engines because they have these special problems, but things that make a glow engine idle well also work for gasoline burners and diesels.

WHAT CARBURETORS DO

You should know about some early work on carburetors and other speed controls because they illustrate important, helpful ideas. A specialized control line event called Navy Carrier required throttled racing engines long before radio controlled models became practical. The United States Navy created the event and offered it for the first time at the 1950 Dallas National Model Airplane Championships. Before that, no one conducted much research on throttling a model engine. The lessons learned by these early competitors led the way to today's easily adjusted carburetors. Like you, these Navy Carrier flyers knew that combustion mixture volume largely determines how fast an engine will run, and they tried regulating the mixture volume in an interesting way. After only a few years, someone thought to control exhaust back pressure with a clever sliding valve shown on a vintage Rossie 60 (323). Back pressure accurately limits the mixture entering the combustion chamber. Those same people soon learned *a combustion mixture set for high speed becomes rich at lower speeds, and that is true for any speed control method, not just exhaust back pressure*. You'll notice an arm connected to a device that slows the fuel flow at idle in (323). Sometimes we call slowing fuel flow in that way, metering. The exhaust slide valve and fuel-flow or metering device could get the engine speed down to thirty-five hundred RPM, still a thousand RPM too high for a landing with a radio controlled airplane. So, these early Navy Carrier speed controls were not practical for radio controlled applications, but they did regulate the combustion mixture volume with exhaust backpressure and showed the need to lean out an engine as it throttles down.


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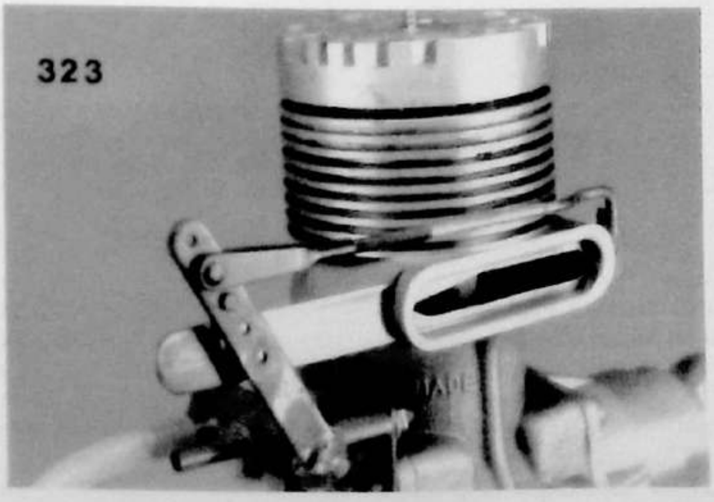
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While carrier flyers continued using the exhaust slide valve and metering device, others developed general purpose carburetors that had different fuel metering methods. Photo (324) shows a 1955 carburetor with a remarkable innovation, a rotating drum like those found on nearly every engine today. Look at (349) and see what a rotating drum valve looks like. That part reduces the combustion mixture by restricting the incoming air in a way that also leans the mixture out - though not accurately nor enough in most cases. About 1959 Hi Johnson invented and successfully marketed the first carburetor (325) that adequately leaned out the idle mixture. His Automix Carburetor featured a stop screw for the drum valve, and leaned the mixture with a rotating drum in a unique way. The stop screw rides in a slot cut at an angle in the drum [arrow in (326)], so the drum shifts toward the center of the carburetor bore as the engine slows down (327-328). That lateral drum motion moves the needle valve deeper into the seat and leans out the engine far more than just rotating the drum valve alone. Hi Johnson sold a set of three needle valves with different tapers. A highly tapered valve would be just a little leaner at idle than a less tapered valve. Modelers recognized the need for idle mixture adjustment but found that changing needle valves was too clumsy. However, Johnson's idea of leaning the idle mixture with lateral drum movement remains popular today. Shortly, we'll look at some carburetors that still use his simple, brilliant idea.

Today, all glow engine carburetors do the same things but in different ways. So, as this section's title suggests, let's take a general look at just what happens in a carburetor. A two-stroke glow-ignition speed control:

1. Uses exhaust back pressure to keep the glow plug hot and to reduce the combustion mixture volume entering the combustion chamber,

2. Varies the mixture volume entering the combustion chamber by restricting the airflow into the crankcase,

3. Leans out the low speed mixture as the engine slows down, and

4. Provides some means for idle mixture adjustment.

Items one and two are done about the same ways on all engines. The muffler, mentioned in item one above, requires no adjustments and causes few throttle related problems unless it falls off in flight. Then, you quickly realize its importance when the engine quits on a low speed landing approach. Item two above is normally done with a rotating drum (349), but there are other ways. Webra's highest quality carburetor controls air entry into the crankcase with a sliding plate. That carburetor is set for high speed in (329) and near idle in (330). YS has a butterfly valve shown open in (331) and at idle in (332). An OS car throttle uses a cylinder that closes the carburetor bore by moving laterally (333). These three carburetors are exceptions, and most other carburetors have a rotating drum limited by a stop screw.

Items three and four above, leaning and adjusting the low speed mixture, cause most of the problems. If the two speed control features are well implemented by the manufacturer and understood by the operator, a hard to idle glow engine will run slow enough for any landing. The remainder of Chapter Twelve shows how items three and four work on many different carburetors.

CARBURETORS WITH LATERAL DRUM MOVEMENT

Hi Johnson's lateral drum movement exists in many modern carburetors including those by Super Tigre (334). An engineer at Super Tiger thought to control the rotary and lateral movements with two screws instead of one like the Johnson had. The vertical screw in (334) limits the barrel's closing, while the front one rides in an angled slot cut in the drum and causes the lateral movement. Let's call it the lateral movement screw. The disassembled unit in (335) shows other interesting features. The idle adjustment is extremely sensitive and will not tolerate looseness caused by wear on the lateral movement screw or in the drum slot. The spring in that photograph pushes the drum outward, which compensates for wear by keeping the drum tight against the lateral movement screw. Sometimes a modeler disassembling an engine doesn't know about the spring and loses it. Then, he wonders why his engine will not idle at a constant speed. An idling engine will not stay running with the smallest air leakage, so Super Tiger seals the drum and carburetor body with a rubber boot shown in (334-335).

Items three and four in the list above tells us we need some means to lean the mixture as the engine slows down, and we also need a way to adjust the mixture at idle. Super Tigre carburetors perform both tasks simply with an untapered-wire idle needle valve. In (335) the wire extends into the hole in the drum. The drum and high speed needle valve appear in (336) and are positioned in an assembled carburetor about like shown in (337). During the transition from high speed to idle, the drum's lateral movement brings the idle needle into the fuel passage [shown by the arrow in (337)], which leans the mixture. Turning the idle needle fine tunes the low speed.

Other manufacturers make engines with carburetors like Super Tigre's. Fox uses them extensively. The one in (338) fits the Fox Eagle 60. As you can see, Irvine's well made carburetors (339) have many Super Tigre features. Some low cost but surprisingly well made ASP engines from China also come with this carburetor type (340).


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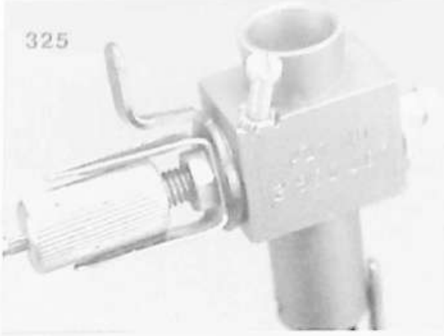
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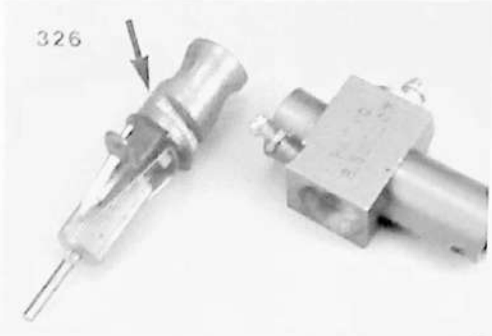
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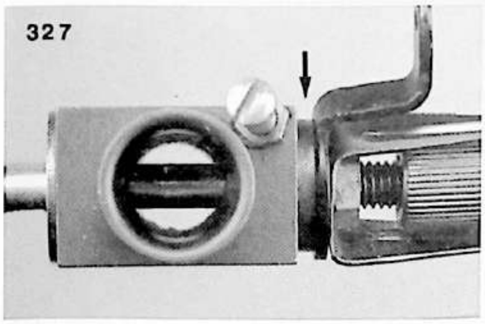
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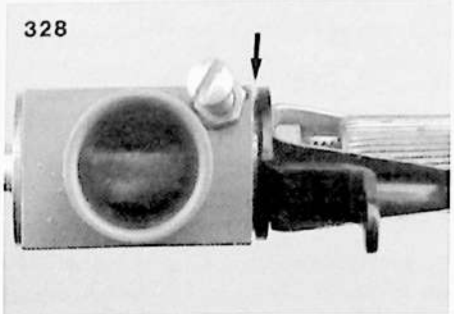
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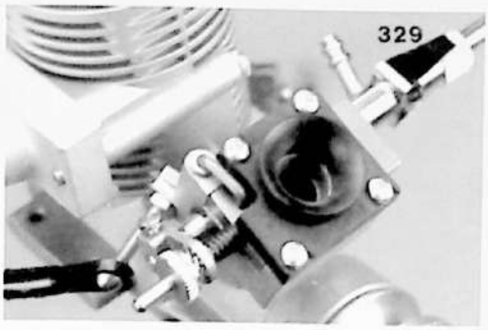
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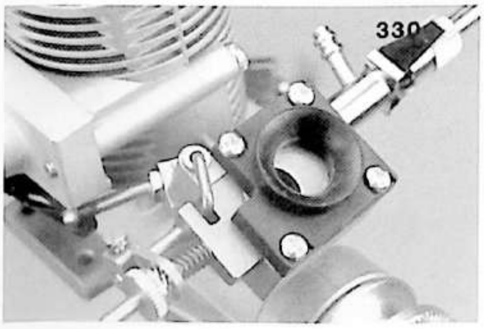
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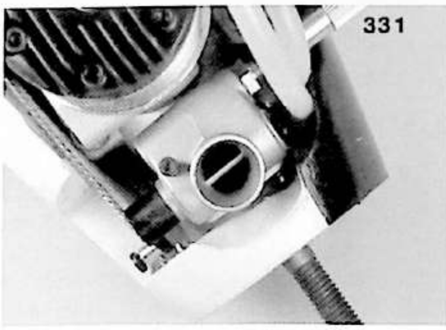
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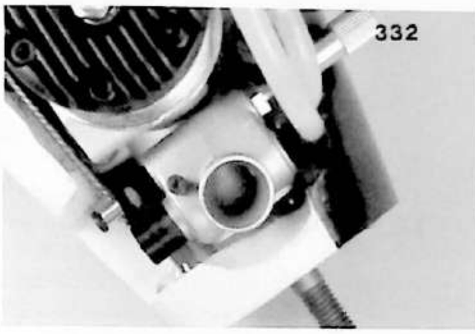
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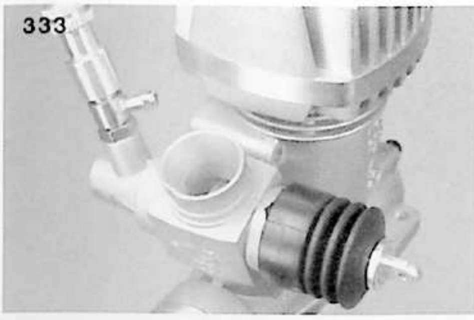
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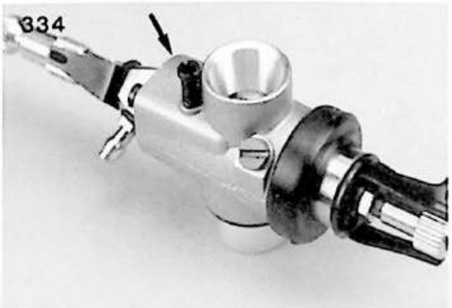
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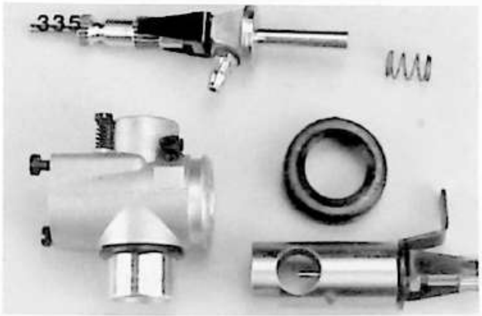
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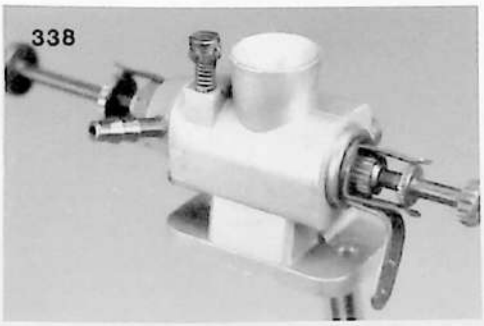
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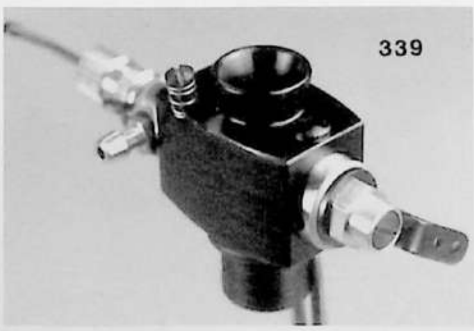
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The OS Type Two (341) and Webra (342) high performance carburetors use lateral drum movement to lean the engine in a slightly different way. In photo (343) the high speed assembly sticks into the right of the bore. As you can see, the idle needle is completely withdrawn. When the drum closes (344), it brings the idle needle into the fuel outlet and leans out the mixture. Turning the idle valve, shown by arrows in (341-342), adjust the idle mixture. The silver colored knob in (345) locks the high speed needle on the K&B marine and ducted fan carburetors because those applications produce more vibration than a standard airplane would.

OS Type Four and some Type Seven carburetors use lateral drum movement in an entirely different way. A typical example, the OS Type Four D, appears in (346) assembled and unassembled in (347). OS also uses a spring to hold the drum against the lateral movement screw (348). Photo (349) shows a screwdriver slot in the idle adjuster. In the next shot (350) we have unscrewed the adjuster so you can see it more clearly. The "O" ring prevents air leakage into the carburetor and keeps vibration from turning the adjuster. Let's see how the adjuster varies the incoming mixture. After passing through the high-speed needle valve seat, fuel enters a tube fixed in the carburetor body [arrow in (351)]. By looking closely at (352) you'll see that tube has a long narrow slit through which the fuel passes. That shot also shows the idle adjuster in place over the tube. Lateral drum movement into the carburetor body carries the adjuster over the smaller fixed tube and restricts the narrow fuel outlet slit. OS's quality machining and well thought out carburetors make them popular. Royal's low cost unit (353) has the same general layout and samples I have used worked well.

K&B'S SPORT CARBURETORS

K&B sells many inexpensive engines with a carburetor (354) that leans the mixture at low speeds and has a unique feature for fine tuning the idle. Since seeing the parts helps us understand how they work, let's first disassemble this carburetor. Begin by prying the high speed needle valve assembly away from the carburetor with two small screwdrivers (355). We've nearly finished pulling the assembly out in (356), and completely removed it in (357). After unscrewing the limit screw the drum is pulled from the carburetor, and the various pieces appear in (358). Now that the parts are separated, you can see how the low speed features work. Look at (356-357) and verify that fuel enters the nipple and goes into the region between the "O" rings. Next the fuel moves through the hole in the high speed needle valve assembly [shown by the arrow in (356)]. Then it passes through the high speed valve seat and out the narrow slot [see the arrow in (357)]. Look at (357) and notice the tube in the drum which fits over the high speed needle valve assembly as shown in (359-360). When the drum closes, a hole in the drum tube rotates out of alignment with the hole in the high speed needle valve and leans the low speed mixture adjustment. K&B uses a screw with an off center head for fine tuning the idle mixture. The screw head rotates the high speed needle valve assembly (361-362), and that slightly changes its relation to the drum tube and alters the idle mixture.


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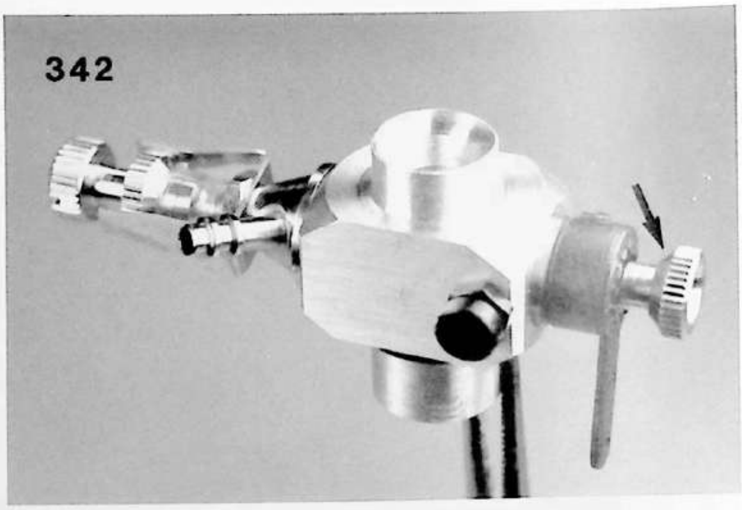
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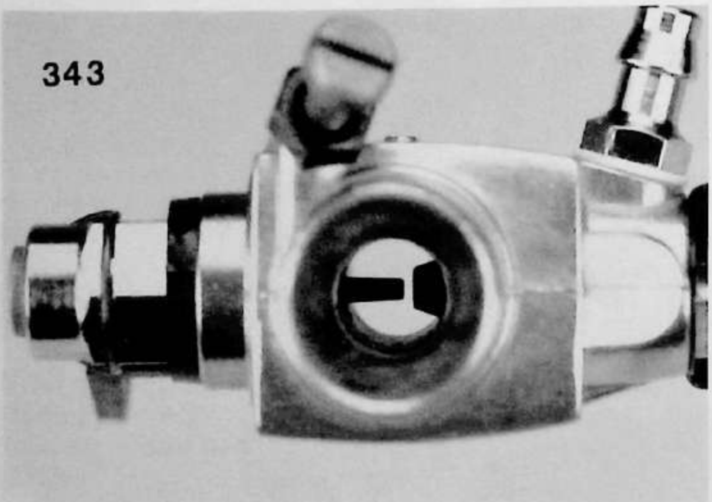
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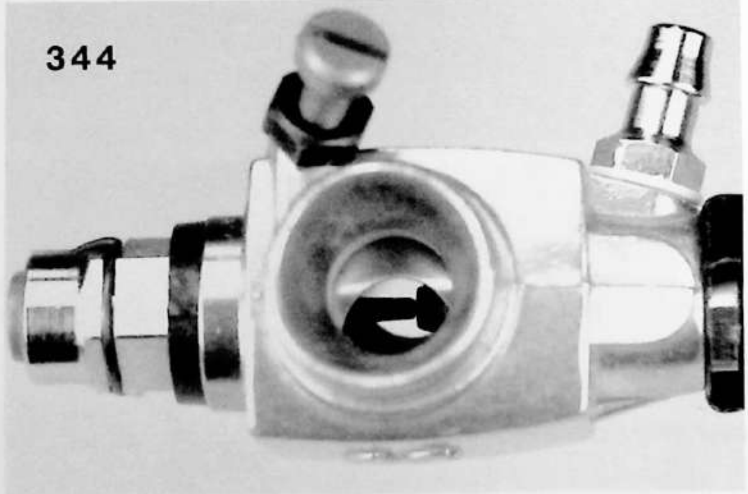
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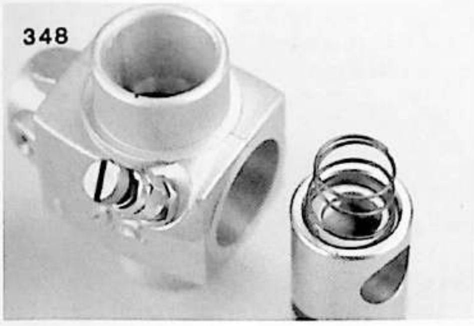
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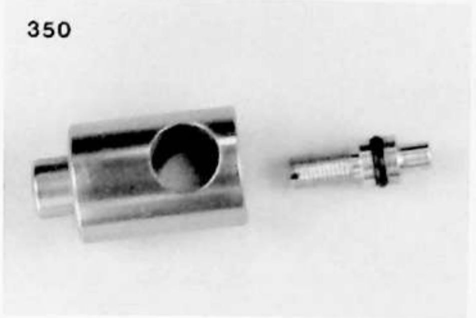
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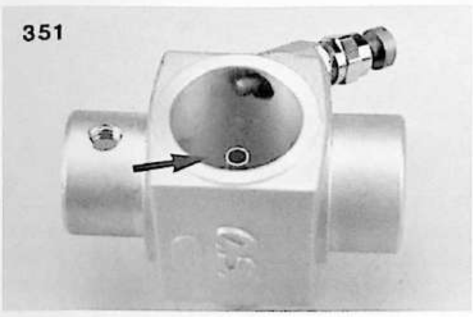
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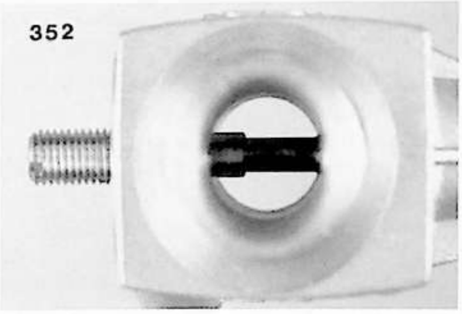
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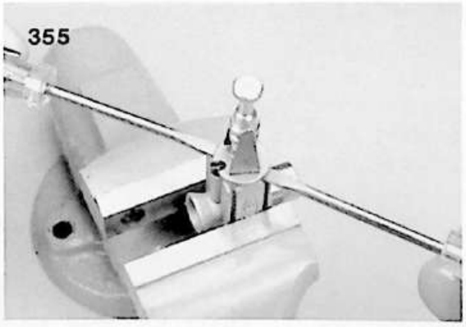
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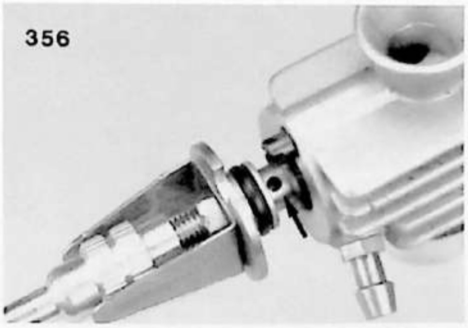
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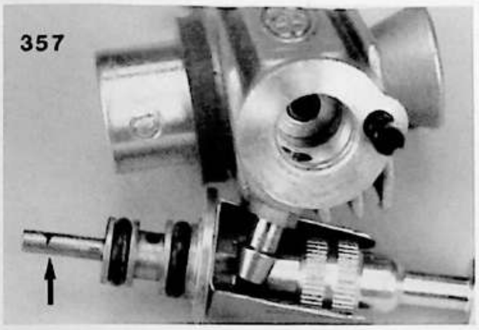
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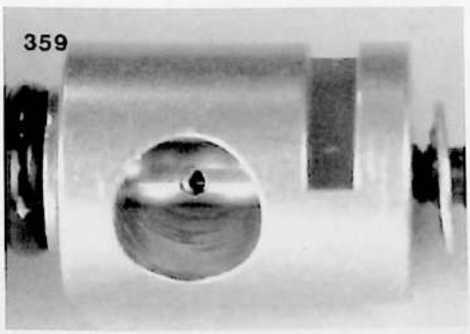
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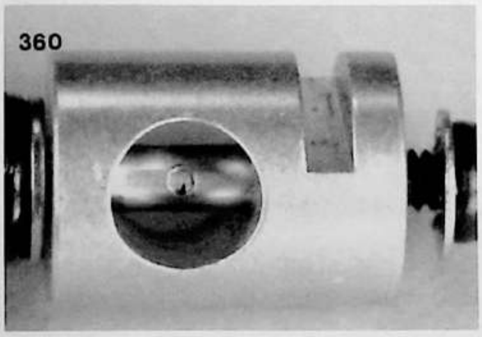
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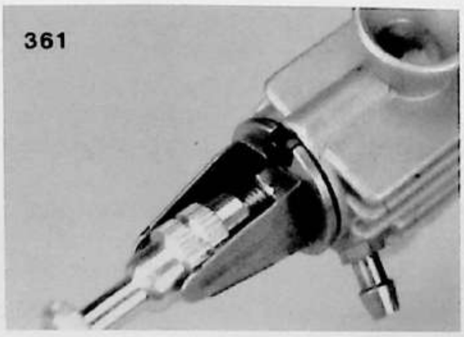
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AIR BLEED CARBURETORS

Item three in our carburetion essentials list involves leaning the mixture as the engine slows down. Until now, we have shown how to do that by reducing the fuel flow, but there is another approach - increasing air in the combustion mixture. We call this technique air bleeding, and units that use it are known as air bleed carburetors. For those interested in history, I'll mention that developments with air bleed carburetors took place about the same time as Hi Johnson's work, though I don't know any individual credited with the development. Let's see how a pure air bleed carburetor works. Consider OS's Type Three air bleed carburetor (363-365) that comes on their popular FP series engines. The arrow in (363) points to a bleed hole drilled through the body and into the carburetor bore. The drum covers the bleed hole when the carburetor is open. As the drum closes, its bore size hole rotates and exposes the bleed hole. So, air enters the carburetor bore through the bleed hole and dilutes the combustion mixture with air. The bleed hole adjusting screw [see the arrow in (365)] varies the air volume passing through the bleed hole and provides an idle adjustment. These carburetors are easier to operate and less expensive to manufacture than the fuel metered types we have just discussed. Today, popular air bleed carburetors are found on many engines, including nearly all four-strokes (366-368).

Before continuing, we need to understand how the area of the hole down the middle of the carburetor, its bore size, affects maximum power when the carburetor is wide open and low speed reliability after the drum closes. These ideas apply to all carburetors but have special significance with the air bleed varieties. Carburetor bores normally have some restrictions like the cross tubes in (352) and (359). Minimum bore area usually means the total bore area minus the area occupied by the tube. Calling minimum bore area simply "bore area" or bore size makes this section easier to read, so please allow us to take that liberty. Let's first consider the effect of bore size on the power generated by an engine running with a wide open carburetor. We know that reducing combustion mixture volume slows the engine and reduces its power. A carburetor does this by decreasing the area through which combustion mixture enters the crankcase. You could reverse that idea and ask - Would drilling the carburetor bore larger produce an increase in combustion mixture volume and also more power? In most cases the answer is yes, but not indefinitely. The size of the engine, not the bore area, limits the largest combustion mixture volume the engine can handle. The piston in a 40 size engine increases the crankcase volume .4 cubic inches as it rises, so in one crankshaft revolution a 40 sucks in at most .4 cubic inches of combustion mixture. There is a bore size at which our 40 draws the most mixture it can, and larger sizes won't increase the combustion mixture volume or the engine's power. At some carburetor bore size smaller than the one that gives maximum power, incoming air volume no longer moves fast enough to atomize the fuel properly. When this happens, the engine will not run consistently and becomes difficult to adjust while running at high speed. During low speeds it always quits because the fuel was atomized poorly. So, one aspect of carburetor design involves matching the bore size to the engine in a way that gives low speed reliability and lets the engine develop power near its maximum.

Leaning the low speed mixture with an air bleed does not work as well as metering the fuel flow. The less reliable air bleed carburetor needs a smaller bore than a similar fuel metered carburetor to idle reliably. The power loss caused by this small bore affects some engines more than others. Medium performance two-cyclers and all four strokers produce less power and use less combustion mixture than the same size racing engines. So, the small diameter air bleed carburetors allow these non-racing engines to produce nearly their maximum power.

You may have noticed we mentioned "pure" air bleed carburetors earlier and wondered what an impure one would be. It only meant there are engines that lean out the low speed mixtures using both air bleeding and fuel metering. Enya has used hybrid carburetors like this since they first offered throttleable engines. By looking at (369-370) you might think their Type G carburetor differs very little from the OS Type Three, but it does. Photo (371) shows that fuel leaving the needle valve enters a void in the carburetor body between the needle valve assembly and the end of the drum. The fuel then moves into a cavity cut in the carburetor body [arrow in (372)]. From there, fuel moves into the hole near the arrow point in (373) and then into the carburetor bore. The slot in (373) rotating over the cutout in (372) meters the fuel at reduced speeds. Enya's Type GM carburetors (374-375) have an adjustable idle feature. We included some pictures of a Type GM to show the workmanship needed to make a high performance unit like this.

TWO COMMON CARBURETOR PROBLEMS

We'll end our chapter on carburetors by showing typical things that drive modelers to the golf course. Fuel enters many carburetors through a nipple (376), and then goes into a cavity just in front of the needle valve seat (377-378). Any foreign matter entering with the fuel usually finds its way into this region. If the engine was running well and suddenly will not hold either its high or low speed setting, there may be dirt fouling the needle valve seat. You can usually remove it by taking out the nipple. The blade of grass that came out with the nipple in [arrow in (379)] gave one new flyer at our field fits.

The lower needle valve assembly in (380) is broken in half while a normal one appears immediately above it. The "O" ring kept the valve assembly and carburetor body together and allowed the engine to run with intermittent problems that eventually caused a crash. Taking the carburetor apart when the engine refuses to run right often pays.


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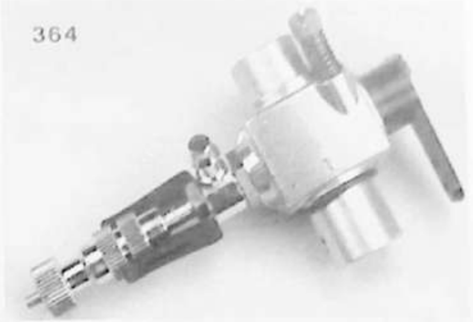
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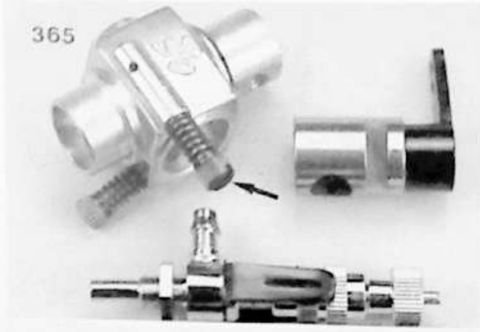
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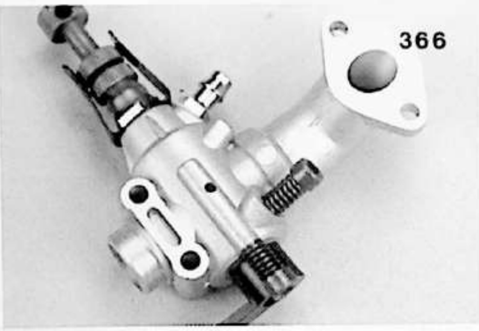
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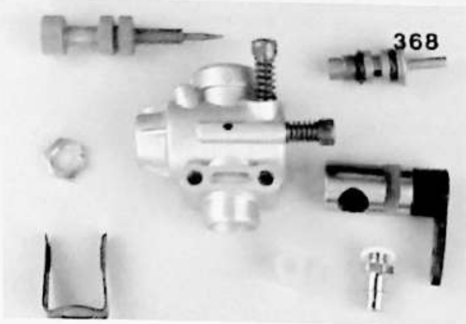
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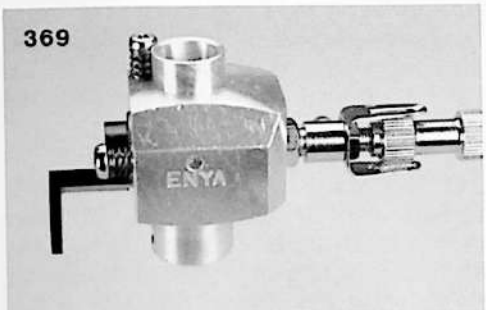

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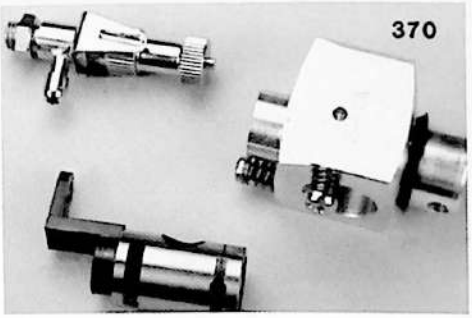
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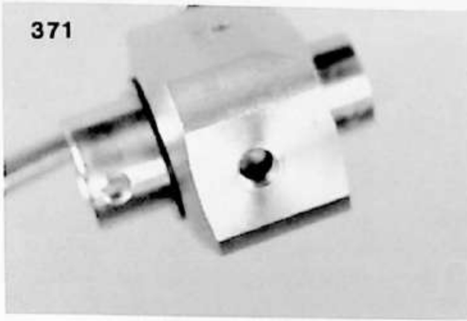
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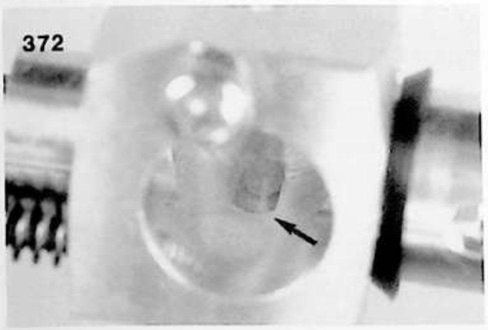
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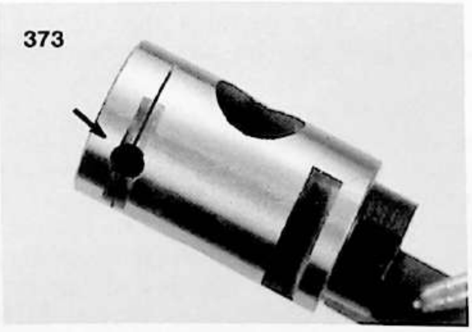
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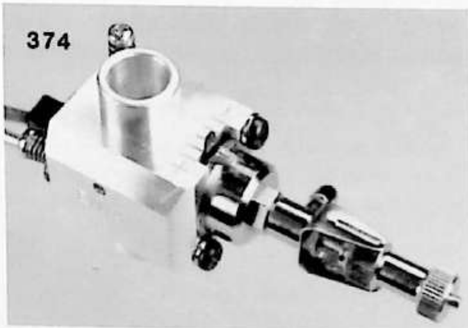
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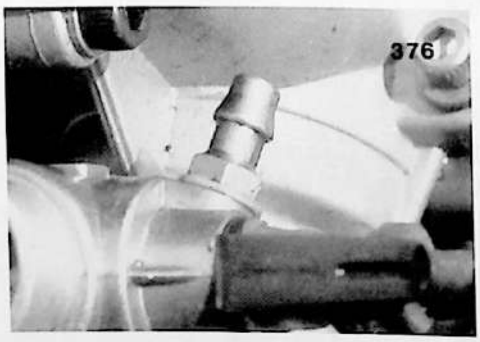
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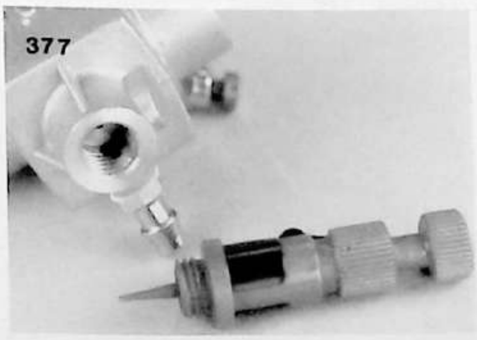
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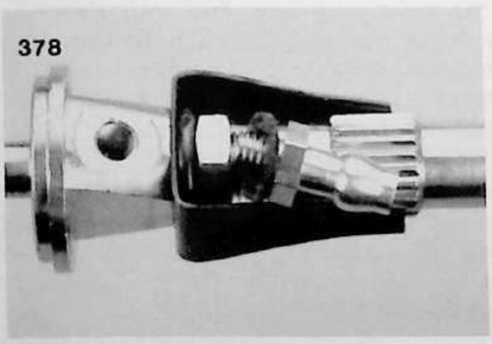
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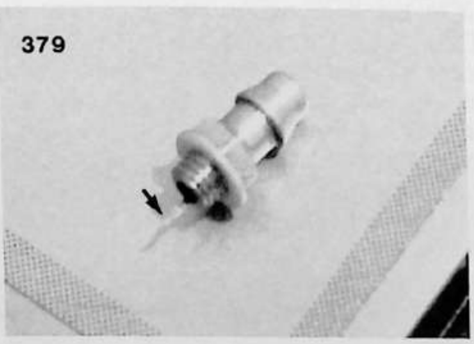
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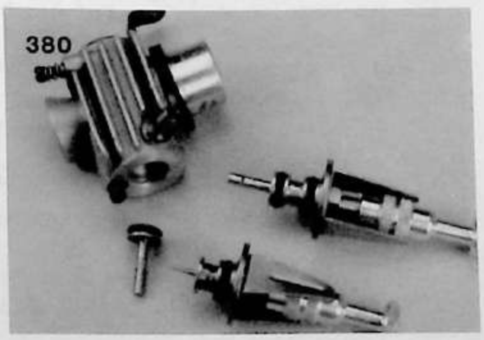
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INTRODUCTION

In Chapter Nine you learned how we routinely clean and oil glow engines after every flying session. Those lessons were important because alcohol in the fuel absorbs water that rusts steel parts, and castor oil turns to a hard varnish that glues the moving parts together. Those procedures are adequate for periods between flying sessions, but an engine that has been crashed or stored without first removing fuel residue needs a thorough cleaning. Chapter Thirteen shows how to do this for both two and four-stroke engines without completely disassembling them.

CLEANING TWO-STROKE ENGINES

Our old Fox 35 (381) had been crashed, thrown in a box, and left for ten years. Hours of running before the crash baked hard-to-remove black carbon deposits on the head. Long storage with castor oil left the interior heavily varnished but rust free, and the exterior was coated with a sticky residue. During the crash, dirt particles found their way into the engine and also coated its outer surface. The dirty but undamaged engine only needs a good cleaning to make it airworthy again.

We'll clean the exterior first with special engine cleaner that contains highly caustic chemicals. *These can cause eye injuries and even loss of vision, so be sure to wear safety glasses when you use the stuff.* Remove dirt from the carburetor bore (382) and exhaust stack with a cotton swab, and pack paper towel pieces tightly into these openings (383). Engine cleaners should never touch your skin, and we suggest attaching wood molding to the crankshaft (384). Then, you can hold the stick while working with the cleaner (385). A stiff acid brush shown in that shot forces cleaner into every crevice including those between the cooling fins (386). The cleaner takes about forty-five minutes to work. After that, a tooth brush and plain tap water washes the cleaner and dissolved residue off (387). Unusually heavy carbon deposits may require another treatment, but the outside of our Fox 35 came clean with one application (388).

The engine in (388) looks clean, but its interior contains dirt from the crash, varnish, and maybe a little water that entered when the cleaner was rinsed off, so we'll use alcohol to clean and dry the inside. Remove the glow plug and backplate (389) so solvent can enter and clean the crankcase and combustion chambers. The alcohol shown in (390) instantly absorbs any water (391) in the two chambers. After a long soaking, the varnished castor oil dissolves. Then, move the engine around in the alcohol to wash out loose dirt. Now the alcohol is dirty and should be discard or filtered. Put fresh alcohol in the container, immerse the engine again, and rotate the shaft rapidly (392). That agitates the alcohol and washes away any remaining dirt particles. Shake the engine to remove alcohol and let any that remains evaporate.

Now the engine is susceptible to rust and must be oiled immediately. Starrett Instrument Oil (390) or any gun oil works fine, but we prefer Marvel Air Tool Oil for general model engine work. Begin rust proofing by dropping oil through the carburetor onto the steel shaft (393). Rotate the shaft several times to distribute oil over it and into the bearings [bushing in this simple Fox design]. Squirt oil through the exhaust stack (394) and glow plug hole. Again, rotate the crankshaft to spread the oil. Put oil on both connecting rod ends (395-396) and rotate the shaft one last time (397). Before reassembling the engine, you should read how to screw in a glow plug at the end of the next section, because doing it incorrectly can strip the head. After replacing the glow plug and backplate, the engine is ready to use (398) and will stay that way indefinitely. Though we chose a collectable engine for this demonstration, the methods also work on modern two-strokers.

AN EASY FOUR-STROKE CLEANUP

When we forget to clean a four-stroke engine before an extended storage, castor oil residue hardens. While the hardened oil prevents rust, it also locks up moving parts that must then be cleaned and freed up. Alcohol quickly dissolves varnished castor oil, and air tool oil or a high grade gun oil rust proofs the engine's steel parts (399). The procedure for doing this looks like the four-stroke cleanup you read about in Chapter Nine, but there are differences because that cleanup involved a recently run engine, not one locked up by castor oil residue.

First, we free the engine. Put alcohol in the combustion chamber through the glow plug hole and wait about an hour for any residue to dissolve. Then, bolt on a propeller to get some leverage, and try turning the shaft without using excessive force. Whether or not the engine breaks free, the following steps are the same. A four-stroker's vent fitting allows us to get solvents into the crankcase chamber without removing the backplate or front cover. We first pour alcohol into a Sig five ounce fueler (400) and let it drip into the engine (401). If the crankcase has a second vent, use the fueler as a syringe and inject alcohol into the crankcase chamber. You may need a little creativity to find a second vent. Frequently, screw holes in the block for the back cover are drilled through into the crankcase chamber, and removing a back cover screw vents the crankcase. A leaky front bearing also works as well. After filling the crankcase with alcohol, let it dissolve the residue for an hour. Use the propeller and try to free the engine again. If the shaft still doesn't rotate you will need to partially disassemble the engine as we explain in the next section, A Major Four-Stroke Cleanup.


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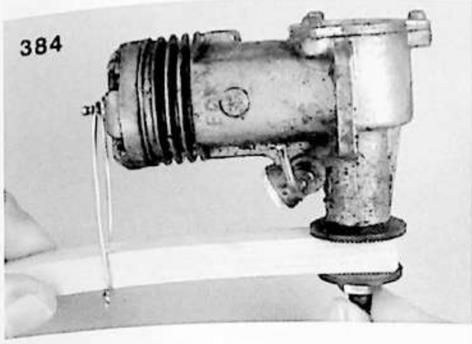
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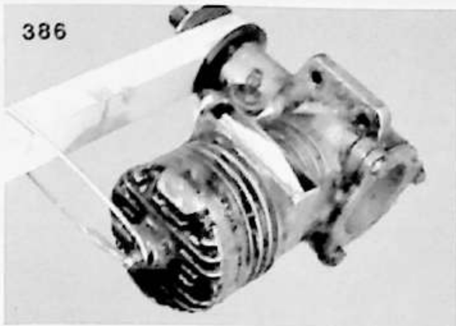
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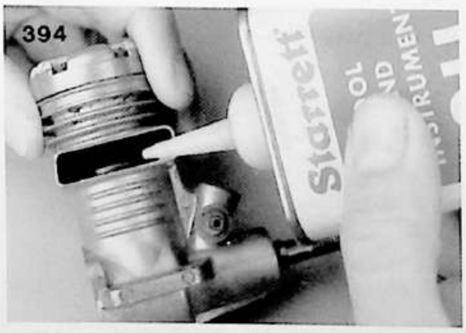

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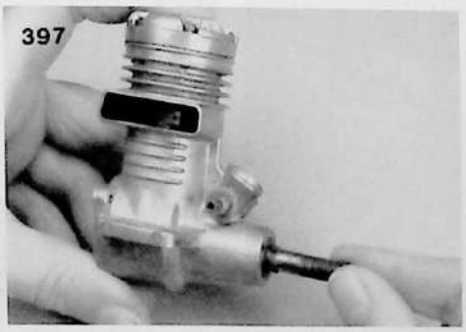
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Once things loosen up, fill the fueler with alcohol, hold the engine below the fueler and rotate the shaft ten or fifteen times (401). That pumps alcohol into every nook. Then, remove the alcohol by holding the engine above the fueler and rotating the shaft (402) again. Give the remaining alcohol time to evaporate. This leaves absolutely no rust inhibitors in the engine, and it begins rusting in just a few hours - sometimes less. So, oil the crankcase chamber using the same steps as we just showed for alcohol (403), and then deposit oil in the combustion chamber (404). Rotate the shaft ten or fifteen times to spread oil over the entire combustion chamber. Always be careful reinstalling the plug, and start it by hand (405). If the plug and head are misaligned, you cannot hand tighten the plug with enough force to strip the head. After the plugs starts, finish tightening it down with a wrench. With only this short procedure, the engine may be stored or flown.

A MAJOR FOUR-STROKE CLEANUP

If the cleanup in the last section fails to free up the engine or it ingested dirt during a minor crash, some disassembly will be necessary. Many modelers don't like to adjust rocker arms, and even though that is easy, our methods leave the valve train unaffected. We chose an Enya to show a major cleanup because its removable front cover adds a little difficulty.

Let's first disassemble the engine and break any stuck parts free. Begin by removing the rocker cover (406), carburetor assembly (407), glow plug (408), and front cover assembly (409). If you have a Saito or an OS, remove the backplate instead of the front cover assembly. You will not be bothered by having to reattach a front cover several times like the Enya requires. Soak the front cover and block assemblies (409) in alcohol for several hours to loosen any stuck parts. Reattach the front cover, bolt on a propeller, and work it back and forth until the engine breaks loose. Do not force anything as the delicate valve mechanism is easily damaged. If the engine fails to come free, you need a more complete disassembly as described in later chapters.

After freeing up the stuck parts, we give the engine a good cleaning. Immerse the head in alcohol until the intake and exhaust are submerged (410). Rotate the shaft ten or more complete turns. That rinses dirt from the combustion chamber by drawing alcohol in and expelling it. Detach the front cover assembly again and clean the crankcase chamber by moving the block rapidly in alcohol (411). Free up and clean the front cover assembly by repeatedly immersing it (412) and the spinning the shaft (413).

Now, we are ready to reassemble and oil the unit. Photos (414-419) show the traditional, careful oiling two-stroke engines receive when they are put back together. Those shots are included for completeness, but we prefer the oiling method shown earlier in (403-404), because it takes less time and is much more effective. After replacing the glow plug, the clean, oiled engine is ready to fly again.

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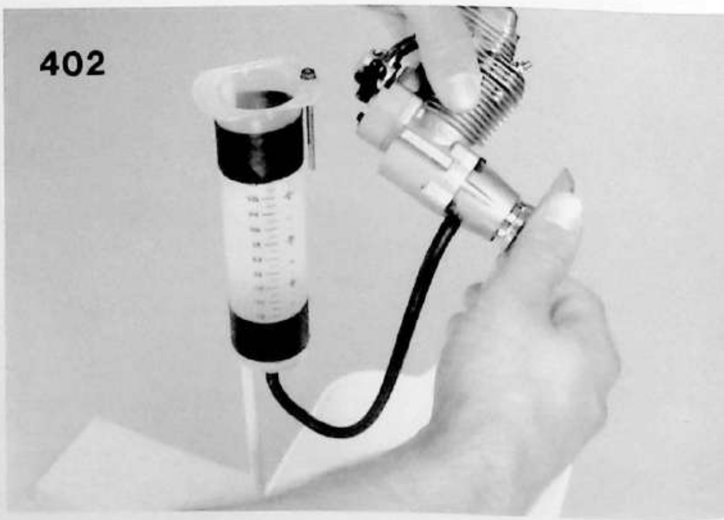
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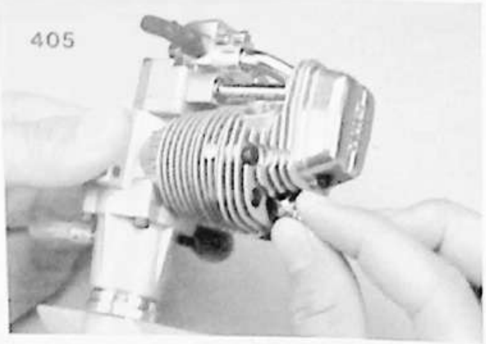

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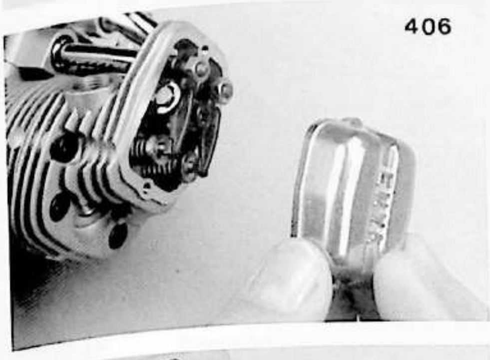

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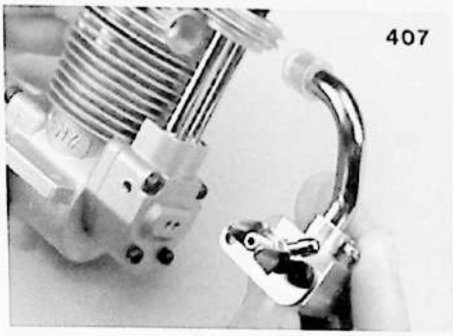

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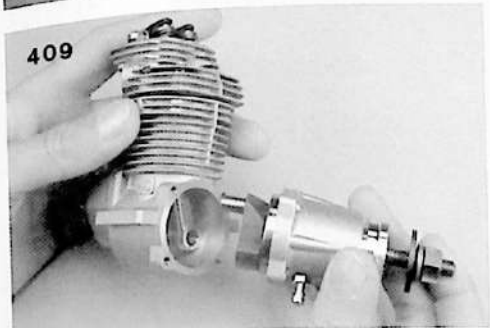

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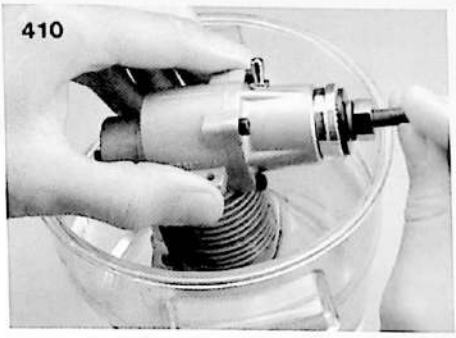

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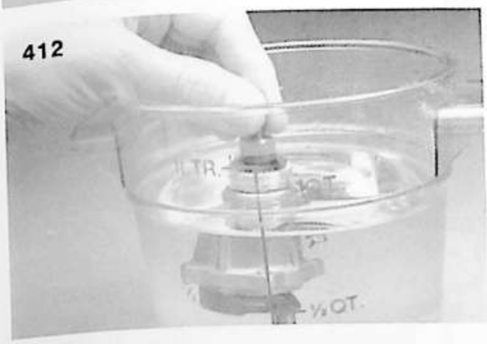

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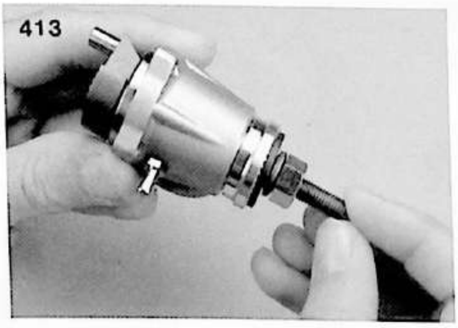

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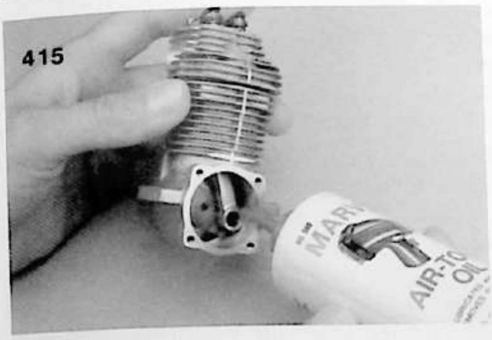

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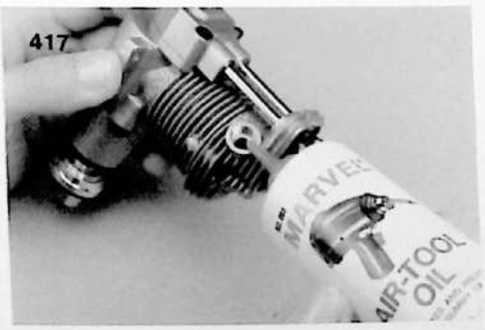

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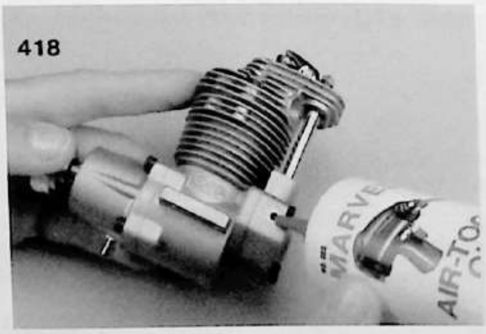

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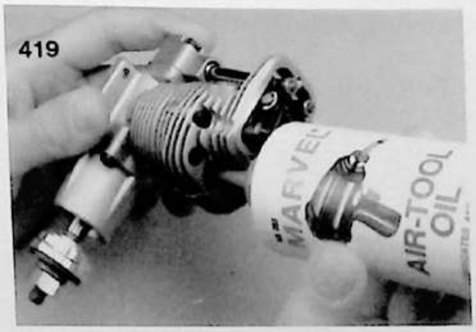

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CHAPTER FOURTEEN
RINGS, MAIN BEARINGS AND PROP WASHERS

INTRODUCTION

Most piston rings, crankshaft main bearings, and propeller drive washers are removed about the same no matter who made the engine or how its other parts disassemble. Crankshaft main bearings on some K&B engines are an exception to this and require a unique removal method that appears in Chapter Sixteen. Other than the K&B bearings, these universal disassembly procedures are shown now rather than every time we take a different engine apart.

PISTON RINGS

Piston rings need to be removed and replaced once in a while because they usually wear out before any other part, and a single over lean flight often warps a ring. Either occurrence causes low power, overheating, and hard starting because the ring no longer seals the combustion and crankcase chambers. Usually the other engine parts are not badly worn - except the piston, which may have a damaged ring groove. We routinely scrap both the ring and piston, but most modelers prefer replacing only the ring. If a ring replacement doesn't restore the lost power, the engine must come apart again for a piston replacement. Whether you initially replace the piston or not, the following procedures and just a little skill will get the ring off and on without breaking it.

Manufacturers supply rings that either rotate and float freely in the piston ring groove, or rotate only a few degrees in either direction. Generally, four-strokers and single bypass two-stroke engines have floating rings, while Schnuerle ported two-strokes need rings with restricted movement to keep the ring ends away from ports. Otherwise, the ring ends could spring open into the ports. A small pin extending into the ring groove between the piston ring ends limits the ring's rotation on multiple bypass engines. This pin eliminates serious rotation, but the ring still moves a few degrees in either direction. While reassembling an engine, keep the pin in the piston ring gap or you will break the ring and damage the piston.

To find out if hardened fuel residue has locked the ring in the piston ring groove, hold the piston and try rotating the ring (420). Be careful with a pinned ring which only rotates a little and breaks when forced more. If the ring doesn't rotate at all, hardened fuel residue has locked it, but an overnight soaking in lacquer thinner usually frees the ring.

We remove a piston ring in several steps so as not to spring or break it. While holding one end tightly in the piston ring groove, use a thumbnail to pull the other end out (421), and slide that end onto the piston top (422). Keep the ring from rotating by holding it against the piston, and with a thumbnail, spread the remaining ring end (423) enough to place it immediately above the groove. The piston shown in these photos has a baffle on which the ring rests in (424). Finally, pull the ring off (425).

Like the ring removal method you just saw, our ring replacement procedure will not break this fragile part. Always begin by getting every trace of dirt and fuel residue out of the ring groove (426). Put one end of the ring in the groove (427) and pull the ring open with your index finger (428) so half the ring slips onto the groove as photo (429) shows. Pull the other end out (430) just enough to slide it into the ring groove (431).

The piston always enters the bottom of the cylinder. Sometimes, the piston won't even go in the top because most cylinder bores are slightly tapered with the larger end at the bottom. This subtle taper cannot be seen but provides a good seal near TDC while reducing friction at BDC. There is another reason to put the piston in the bottom. Carbon builds up on the cylinder wall above the piston's highest position. Even with a good scraping, enough carbon may remain to make the upper cylinder's diameter smaller than the piston. Manufacturers know these things and machine a taper at the bottom of the cylinder (432) that compresses the ring. Unlike the cylinder taper we just mentioned, the ring compressing taper measures only about a sixteenth of an inch long and can be easily seen. Now that we know where to put the piston, let's see how to install it correctly. First, oil or grease the ring compressing taper (433). If the engine has a pinned ring, move both ring ends so they straddle the pin. Next, hold the piston and cylinder at an angle so the ring area opposite the gap rests on the cylinder's ring compressing taper (434). Finally, a single gentle rocking motion brings the piston and sleeve into alignment and compresses the ring, starting at the back of the ring and moving around to the ring ends.

REMOVING A PROPELLER DRIVE WASHER

The propeller drive washer and crankshaft must lock together so they rotate as a rigid unit. Engine manufacturers make this connection in several ways. OS four-stroke engines keep the propeller drive washer and shaft aligned with a small square key (435), while many Enya designs have flats on the shaft that mate with cutouts in the washer (436). Another popular locking method uses a "split, tapered ring" (437), and a drive washer with its hole tapered the same amount. When you tighten the propeller nut, the tapered hole in the washer compresses the split ring, locking it on the crankshaft.


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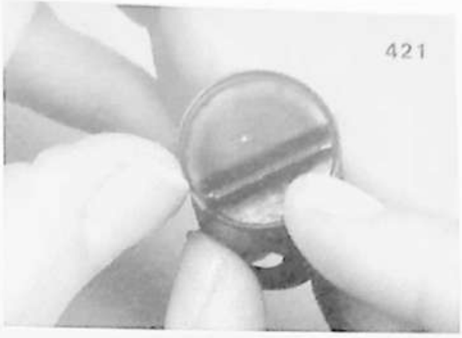
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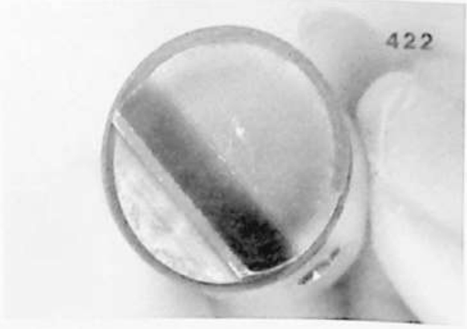
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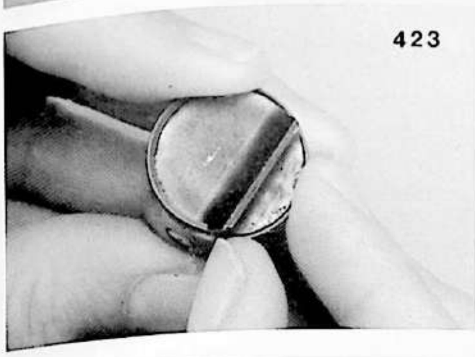
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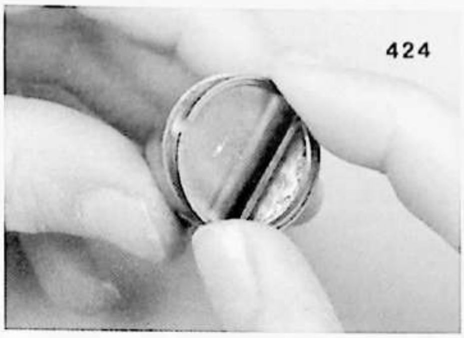
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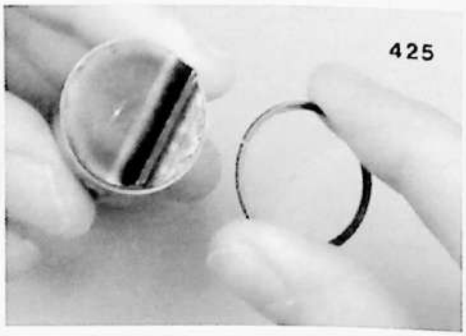
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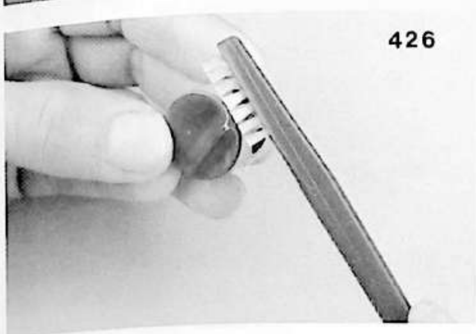
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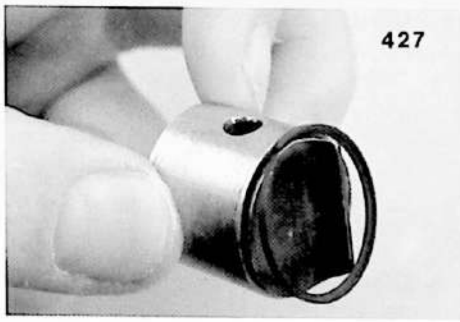
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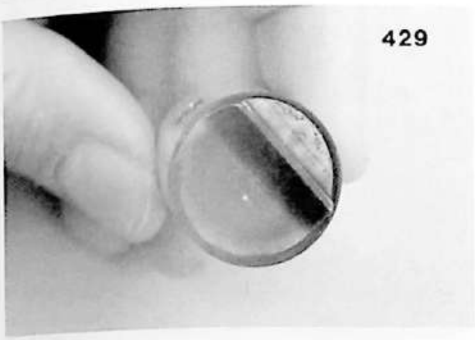
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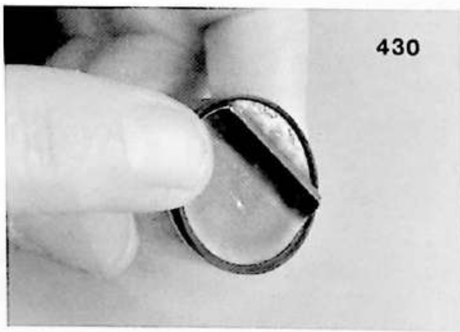
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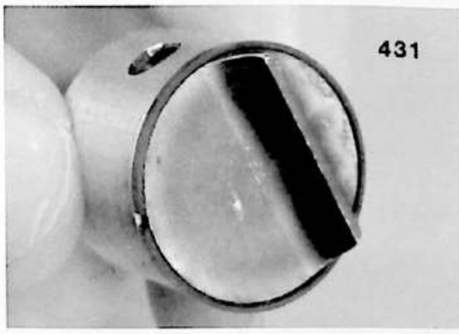
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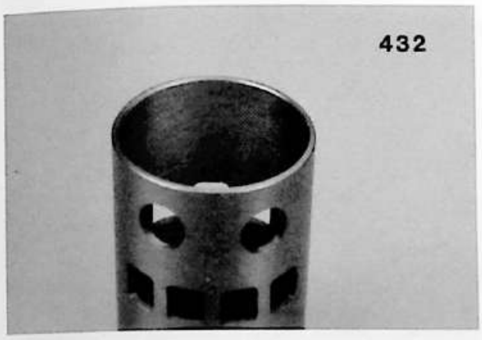
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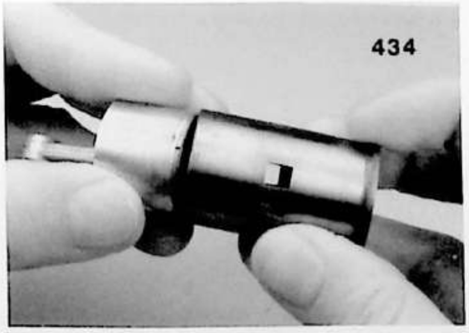
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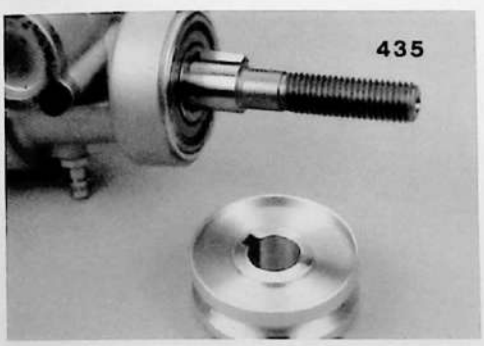
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Keyed propeller drive washers and those with matching flats simply pull off the shaft. You only need to be careful not to lose the key. Separating a drive washer and split tapered ring isn't hard either if you use the correct tools. All drive washers locked with a split tapered ring have a slot to accept a puller (438). The puller does not need to anything fancy; even an inexpensive automotive battery terminal puller works if you modify it slightly. The square ends (439) do not go deeply enough into the slot (440) and come out during the pulling operation. By grinding a bevel on the arm as shown in (441) it goes to the bottom of the slot, but sometimes you still need a "C" clamp (442) to keep the arms in place while the puller does its job. Those of you flying an OS SF series engine should consider OS's special puller (443) and (444).

MAIN BEARINGS

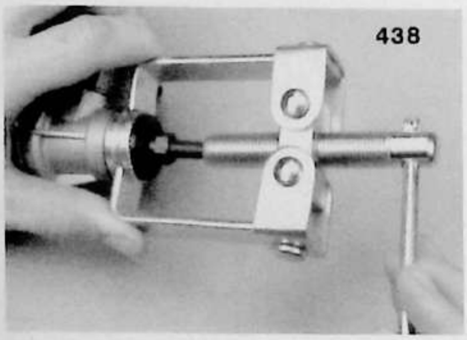
If an entire bearing assembly and crankshaft turned together, friction between the bearing and block would quickly cause overheating. To keep this from happening, ball bearing assemblies fit tightly in the block. In spite of being tightly fitted, bearings are easily removed and replaced if you use the following simple methods. Cut two wooden dowel rods about five inches long (445). We drive the front bearing out with one dowel rod (450), so it should be larger than the hole in the front bearing. Choose the second rod so it barely slides into the crankshaft hole (455). Find a third, shorter, dowel rod just a little smaller than the front bearing assembly (459). The expensive bench block pictured in (456) was made for demanding toolmakers, but a piece of two by four lumber with a hole drilled through it works just as well when replacing the front bearing. You'll also need a pad of paper or a short length of leather belt. The only other tools needed are a light plastic hammer and a propane torch.

Now let's see how these things help get out the bearings. Strike the crankshaft end with the plastic hammer (446) and pull the shaft out (447). Next, heat the block around the rear main bearing (448) until the block is just hot to touch. If the engine got a little too hot to hold, use a rag something like in (454). With a solid downward motion, strike the rear of the block several times against a thick pad of paper (449) or piece of leather belt until the bearing drops out. The paper pad or leather prevents damage, but stops the downward motion fast enough to jar the bearing loose. Next comes the front bearing. Heat the block around the front main bearing and tap it out with the plastic hammer and a dowel rod like in (450). The block and two bearings appear in (451). Now we test, clean, and maybe replace the bearings, which are topics appearing in Chapter Sixteen, Overhaul And Devarnishing.

The serviced or new bearings are put back in the following way. Tap the rear main bearing to its home position on the shaft (452) and heat the block as shown in (453). Insert the shaft and bearing into the block (454) and seat the bearing with a sharp blow from the plastic hammer as photo (455) illustrates. The remaining photographs show a removable front end so you can better see what these steps look like, but the same methods apply to any front bearing installation. If the shaft isn't in the engine, install it now and slide the front bearing on the shaft as far as it will go. The shaft keeps the bearing perfectly aligned with the bearing housing. Heat the engine block near the front bearing (457), and lightly tap the bearing into the engine block (458). Often, that last step does not seat the bearing all the way into the block, so remove the shaft and seat the bearing by a smart tap as shown in (459).

MORE OLD ENGINES

We inserted some old engines in the two left over photograph positions. The Brown Junior in (460) dates from the 1930s and was the first commercially successful engine. The McCoy 60 (461) was the last racing design by that company. That engine was purchased in 1955.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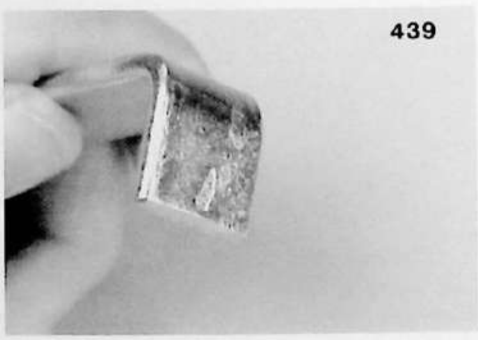
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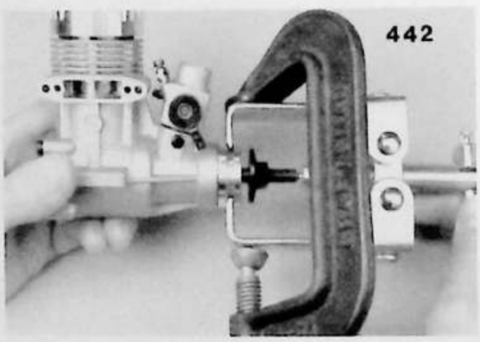
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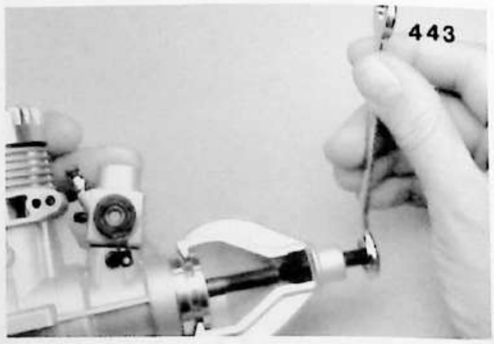
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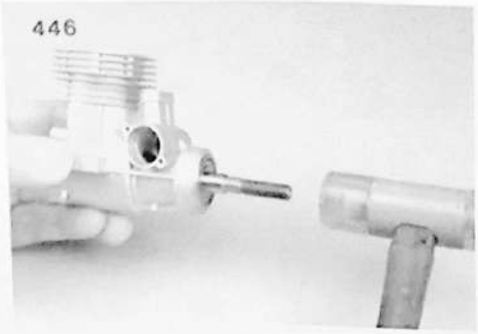
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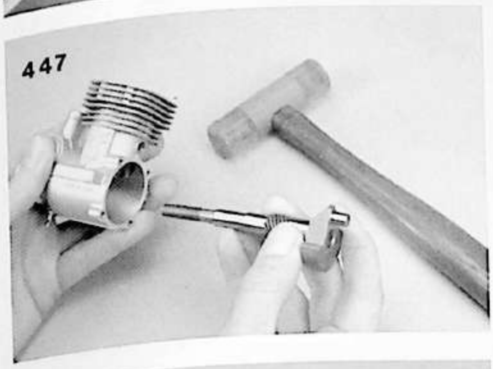
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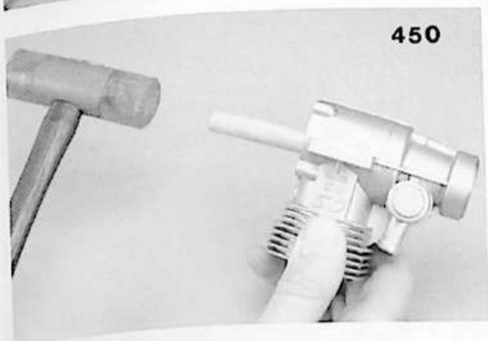
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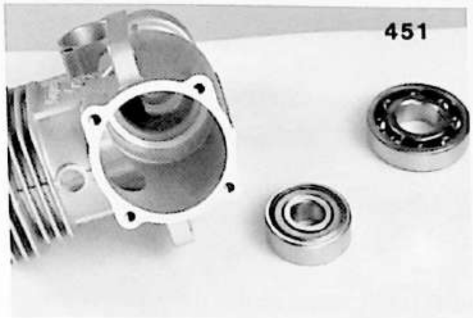
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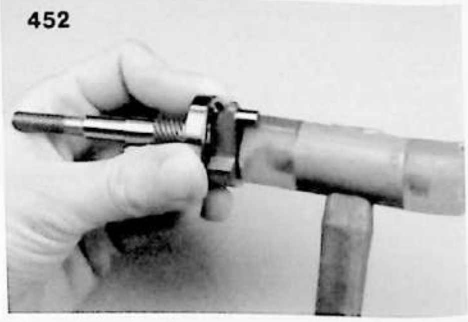
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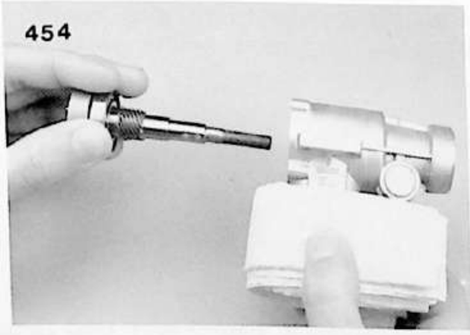
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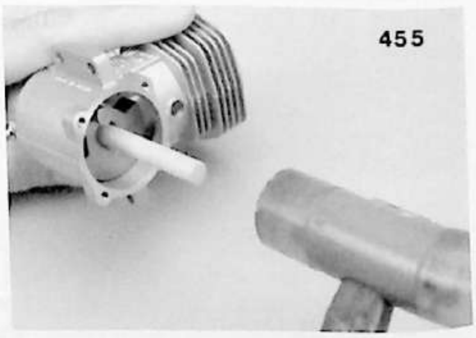
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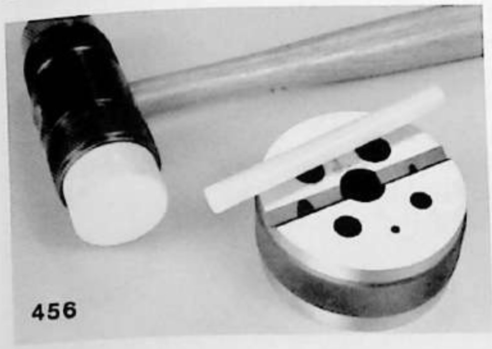
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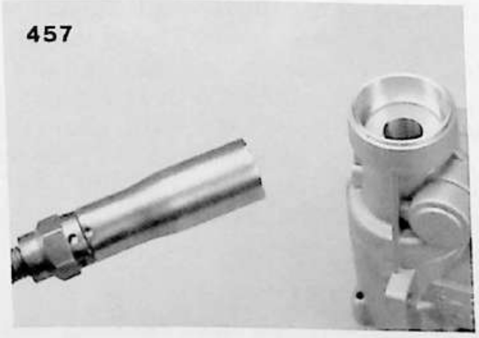
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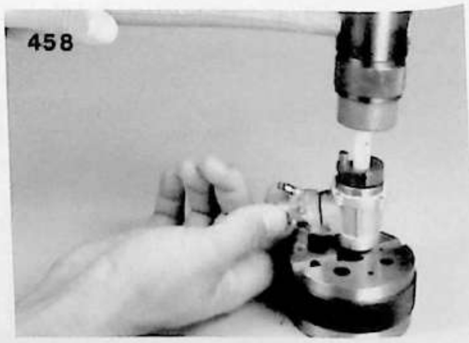
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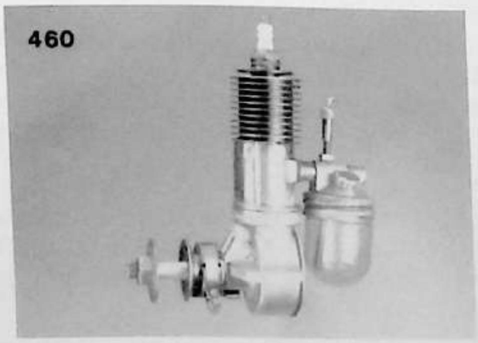
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CHAPTER FIFTEEN
AFTER THE CRASH

INTRODUCTION

Chapters Thirteen and Fourteen introduced topics about maintenance and disassembly that are part of any engine work you may encounter. Chapter Fifteen doesn't cover much new material but mainly emphasizes essentials shown in these earlier two chapters by repairing a Royal 40 that sustained some moderate crash damage. Most later chapters include only elements of these subjects and go on to show more advanced tasks.

THE CRASH

The discouraged modeler who brought this engine to me flew at a field with a reputation for radio interference on his frequency. While flying about three hundred feet high, the radio apparently malfunctioned causing a full-powered and nearly straight-down crash. The model went into wooded swamp land, and he spent many long hours searching. When the ship was finally located, he found the airplane was a total wreck, and the engine had buried itself eight inches into the ground. Surprisingly, the power plant sustained only moderate damage, because a lot of impact was absorbed by the motor mounts breaking and because the engine hit in soft marshy soil. A similar crash on a sunbaked field would have totaled the Royal too.

REPAIR ECONOMICS

You often find it cheaper to buy a new engine than to repair a wreck. An engine made completely from replacement parts costs much more than a new engine. This illustrates how expensive new replacement parts can be. If you buy a new engine, save the old one for spare parts, because modelers frequently sell or swap these. After a crash, make a few calls to your club's members to find out what used parts they might have before spending money on new parts.

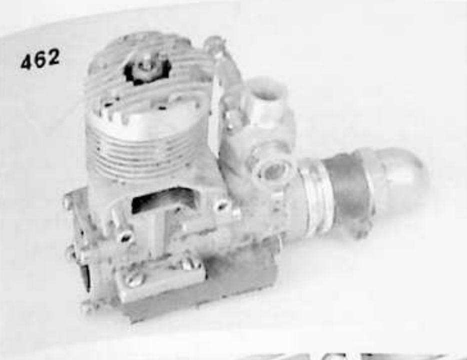
Let's decide if repairing this Royal makes economic sense. Photograph (462) shows broken muffler tabs, and a cracked carburetor mount appears in (464). No one in my club had a wrecked Royal, but an inexpensive new muffler and front housing would restore the engine to running condition. You'll usually get parts from the manufacturer or importer since dealers rarely carry a complete parts stock. We called Royal and had the two pieces (463) in only a few days.

THE REPAIR

This engine (462-463), while covered with grit, does not have hardened carbon and varnish like the Fox 35 in Chapter Thirteen, so we will clean the Royal in just a little different way. In many crashes an engine's interior stays clean, though the impact packs sand and dirt particles on exterior. We remove caked-on dirt before any disassembly; otherwise, these tiny abrasive pieces may find their way into the engine which unnecessarily complicates the cleaning job. First, stuff the intake and exhaust with paper toweling to keep the inside clean. Then, simply brush off the dirt particles, or like many engine mechanics, you can rinse the gritty engine under fast-running warm water. After cleaning off the exterior grit, remove the drive washer (465), crankcase (466), head, and backplate. Several hours of previous running had varnished the cylinder tightly into the block, and since the crash left the cylinder, piston and rod undamaged, we didn't try taking them from the block. A later chapter explains how to remove a stuck sleeve like this one. The cleaning operation concludes with a good rinsing in alcohol and an additional vigorous brushing (467-468). Besides cleaning residual dirt and fuel from the engine, alcohol removes water that may remain if you cleaned the exterior dirt by holding the engine under a faucet.

The most difficult part of this repair is removing the main bearings and installing them in a new crankcase; techniques similar to those shown in Chapter Fourteen work well. This engine has a removable crankcase that must be put back in the block and heated (469) for bearing removal which now proceeds as we explained in Chapter Fourteen (470-471) . You should look back there if these two photographs seem unclear. To install the front bearing, we heat the front of the crankcase (472), and then the bearing slides easily in place. A gentle press from a vise (473) seats the bearing. The rear bearing goes in exactly like the one in Chapter Fourteen (474).

The cleaned, repaired parts in (475) only need a complete oiling and reassembly (476-478) to become air worthy again. The refurbished Royal in (479) gave its owner some additional service and was eventually passed on to a new modeler. All this shows that even a moderately priced but carefully maintained engine like the Royal gives longer service than most flyers expect.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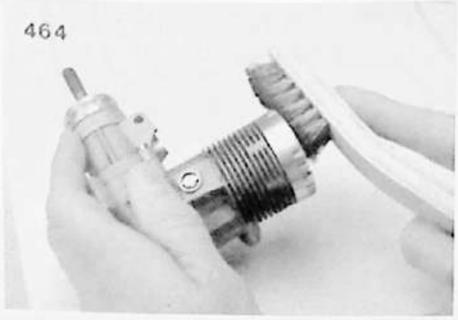
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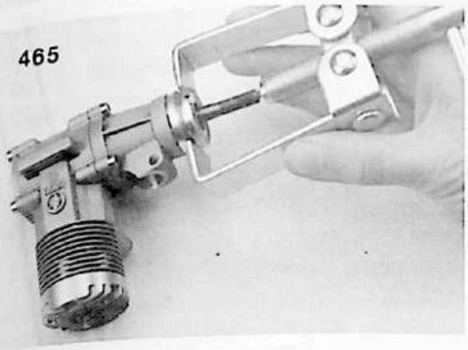
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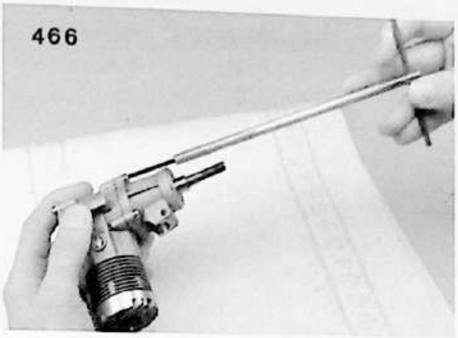
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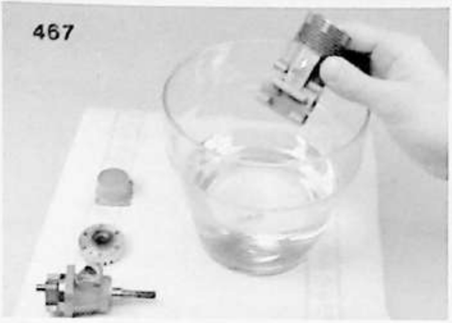
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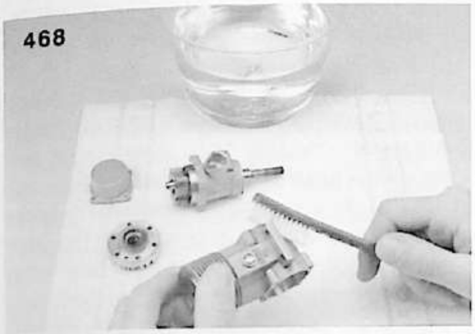
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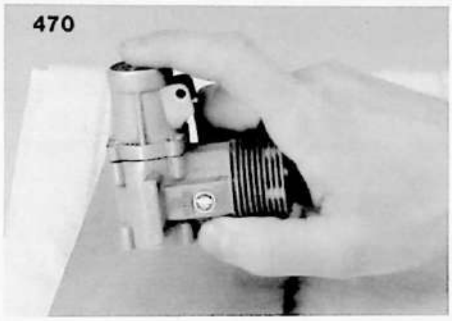
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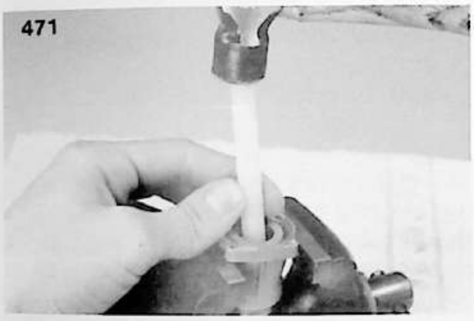
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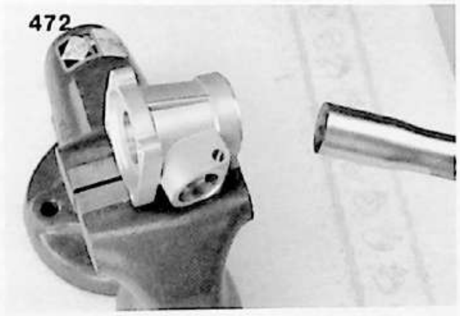
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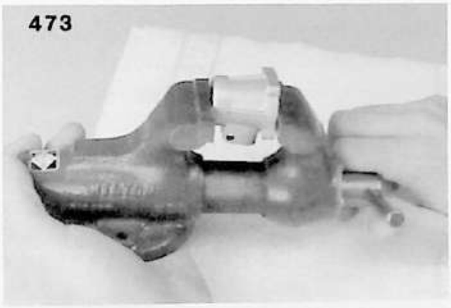
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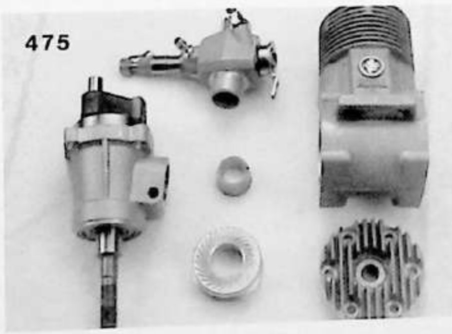
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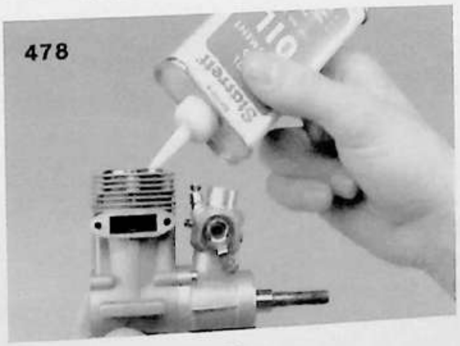

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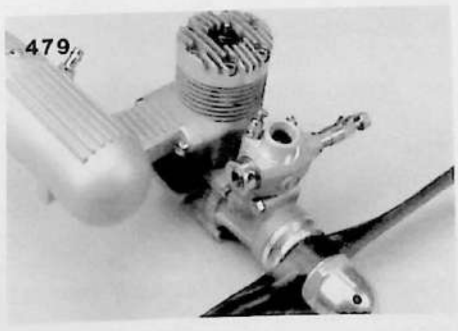
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OVERHAUL AND DEVARNISHING

INTRODUCTION

When an old, reliable engine becomes hard to start and lacks power, it may be varnished or badly worn and need an overhaul including a good devarnishing. Scrubbing, soaking in any common solvent, or even treatments with engine cleaner won't touch hardened varnish and carbon deposits on internal parts. Model engine mechanics remove this hardened varnish by scraping and sanding with very fine abrasive papers. This chapter explains this and suggests when to replace worn parts.

We chose a worn-out and badly varnished K&B ringed forty for our overhaul example, but most things shown work on nearly all engines. We want you to learn about overhaul, not just overhauling a K&B. After all, varnish comes off a four-stroke, diesel, or two-stroke piston the same way, and most other overhaul procedures work on all different engine types. Except for a valve job like the one in Chapter Seventeen, four-stroke and two-stroke engines are overhauled and devarnished about the same.

WHAT MAKES AN OVERHAUL NECESSARY

Some people express an engine's life in hours, and under controlled laboratory conditions examples from a production lot might wear at about the same rate. Since we do not operate engines in anything like a laboratory, identical engines wear at different rates - sometimes radically different. Modelers have complete control over engine temperature, lubrication, cleanliness, and operating speeds. These four factors greatly affect wear on the piston ring, piston, sleeve, crankshaft, rod, and main bearings. Since Chapter Six discusses lubrication and we explained earlier about overheating an engine, that information will not be repeated here. Now, let's take a minute to learn how cleanliness and RPM affect wear and overhaul frequency.

Look ahead to (545) and imagine an engine, running at a typical 12,000 RPM, with a piece of grit between the rod and shaft. You might expect the softer connecting rod bushing to wear faster, but sometimes the crankpin wears out first. Dirt particles, which are much harder than the crankpin, embed themselves in the soft aluminum rod or its bronze bushing. Then, the dirt particle, held firmly in the rod, cuts the crankpin. Machinists call this cutting action, "lapping". It happens at a high pressure because the piston exerts a strong downward force during the power stroke. If a flight lasts eight minutes, a piece of dirt embedded in the rod makes mile long scratch around and around the crankpin. A dirty engine has many such particles not just one, and they wear moving parts out in short order. Any adjacent surfaces moving against each other, including the [piston and cylinder], [piston ring and cylinder], and [crankshaft and crankcase] are subject to lapping when dirt is present. Filtering fuel and keeping the carburetor bore plugged when the engine isn't running, go a long way toward keeping the engine clean and extending its life. A model aircraft engine runs near the ground for extended periods and ingests small gritty dirt particles that give a lapping action in a running engine. An air filter like those on model car engines would decrease wear; maybe the engine manufacturers will provide them for aircraft engines in the future.

An experienced modeler knows the lower connecting rod bushing often wears more than the crankpin. This person probably would also find the wrist pin holes in the piston and the upper connecting rod bushing also have become oversized. This apparent wear is most likely caused by a hammering action, not by dirt grinding metal away. Before TDC and then during the power stroke, the piston pushes against the two pins. Operating an engine at high RPMs increases this hammering action and stresses the main bearings too. A ducted fan engine running more than 20,000 RPM lasts only an hour or two, while a clean well-lubricated sport engine, turning 10,000 - 13,000 RPM may run many hours before wearing out. Like dirt, operating speed also affects an engine's life expectancy and its overhaul frequency.

HOW DO YOU TELL?

How do you tell when dirt and pounding have taken their toll and the engine needs an overhaul? We can't give you a simple answer because some symptoms of wear and varnish also indicate other problems. For example: a formerly easy starting engine that no longer does may suffer from excessive wear, but a bad glow plug and many other things also cause hard starting. A worn out diesel will not start well or at all because the piston and sleeve no longer provide adequate compression for combustion, but fuel with the ether evaporated also makes a diesel hard to start. A noticeable loss of power in a two-cycle glow engine sometimes means it has worn out or become varnished, though switching to fuel with contaminated alcohol or less nitro-methane also reduces power. A four-stroker with carbon encrusted or worn valves displays these symptoms but the piston, rod and sleeve may still be serviceable. Then, only a valve job will be necessary. Any engine that becomes hard to start and that no longer produces power like it once did, MAY need a major overhaul including a good devarnishing.

The way in which hard starting and power loss occur is as important as the symptoms themselves. A clean well-lubricated engine wears out and accumulates varnish on its moving parts gradually. So, their symptoms, hard starting and power loss, become more pronounced as time passes. An inexpensive but well cared for sport engine could give two hundred flights [forty or fifty hours of running] before needing an overhaul. Some high priced engines may last five hundred flights. Again, let us point out that a modeler who lets his engine overheat, uses inadequate lubrication, or doesn't keep the engine clean, will find he needs an overhaul in far fewer flights. Let's consider two extreme examples. A new, ringed engine that becomes over lean and heats up excessively during a break-in will warp and ruin a piston ring in less than a minute. Once a modeler brought me an ABC two-stroke engine that was accidentally run on four-cycle fuel. Recall that four-cycle fuel has less oil than two-cycle fuel. Chrome plating peeled off the cylinder liner during the first twenty seconds of the ill attempted break-in ruining the piston and liner. When you have some doubt about how badly the parts are worn, disassemble the engine and remove the varnish. As we just mentioned, this procedure frequently restores power and easy starting, or you may discover worn parts and will want to replace them.

AN OVERHAUL

An overhaul begins with a good cleaning and by collecting the necessary tools. Look at Chapter Thirteen to see how nicely a Fox 35 cleaned up, and do the same things to your engine because there is no reason for working with a sticky, dirty engine. Then, gather tools like those in (480). The long white nylon punches help remove tightly fitted or stuck parts. Those punches are available through a gunsmith supply company like Brownell's Inc., Montezuma, IA 50171. If you don't want to buy them, pieces of wood dowel rods that are available in any hardware and most hobby shops make good substitutes, though wood doesn't hold up like nylon. We'll not bother explaining what the other tools do here since that will become obvious.

Initially, we want the engine disassembled to the degree shown in (488). Begin by pulling off the crankcase assembly (481), backplate (482), and head (483). Use a container for screws and small parts, otherwise they will vanish forever. The partially disassembled engine appears in (484). Varnish and carbon collect on the cylinder wall above the piston at TDC so it will not pass through the cylinder there, and that means the cylinder liner and piston must come out of the block as a unit. If you try to take the piston out first by pushing it through the top of the sleeve, the piston and ring may be scored and the ring broken. Often the piston and cylinder assembly just pulls out, but if the liner sticks in the block, the following method usually breaks it free. The bottom of the liner is exposed in the bypass area as indicated by the arrow in (485). We'll punch the liner there and jar it lose. The helper holds the top of the block at an angle on a paper pad so only a small part of its outer circumference touches the paper (486). With the block cocked, the liner will be slightly above the pad with room to move down when we punch the liner as in (486). Once started, it can be forced farther by inserting two screwdrivers under the liner flange, arrow in (487), and gently prying up against the block. If gentle force on the screwdrivers doesn't work, heat the block to expand it slightly and soften varnish that lies between the block and liner, and then try prying it up again. The engine's subassemblies appear in (488).


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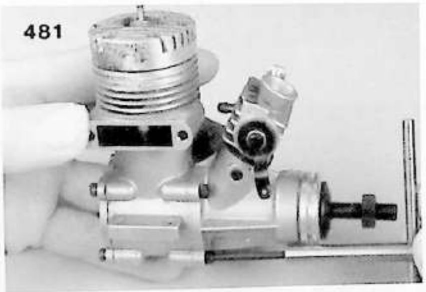
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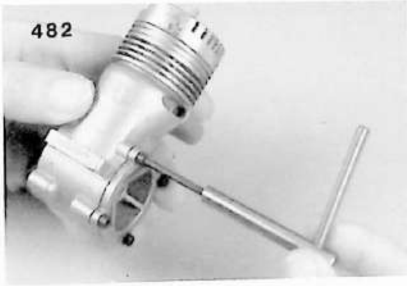
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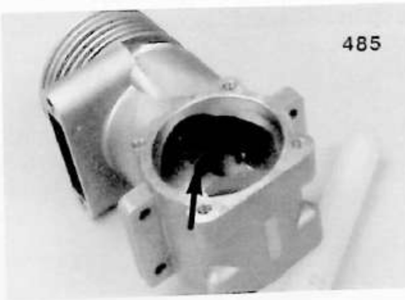
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K&B's model 4011, which we are overhauling, and their model 6550 61 cubic inch engine have unique crankcase units. Most ball bearing engines have a press fit between the bearing assemblies and the crankcase while the shaft slips smoothly but easily into the bearings. K&B press fits the bearings in the crankcase, but also provides a heavy press fit between the bearings and shaft. That requires a different disassembly method than given in Chapter Fourteen and we'll show it now.

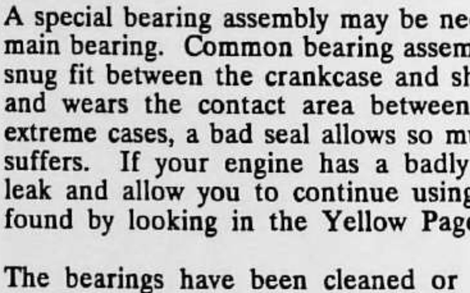
A K&B front end comes apart in the following way. After removing the carburetor (489) and thrust washer (490), the crankcase assembly looks like (491). Photos (492-493) show how to remove the crankshaft by putting the case assembly and block back together, heating the main bearing area, placing the engine on a paper pad, and striking the crankshaft end with a plastic hammer. The shaft and rear main bearing fit so tightly that they usually come out together (494).

Soak the bearing assembly in alcohol and let it dry. Then, hold it between your fingers and spin the shaft smartly (495). With a clean, dry bearing, the shaft should spin smoothly for several seconds before stopping. If the shaft does not spin that long or you feel any roughness, the bearing most come off the shaft for additional cleaning and possible replacement. Our bearing was a little "rumbley" and had to come off. Since the steel crankshaft and bearing assembly expand the same when heated, a torch won't help get them apart so we carefully force the bearing off in the following way. Notice the step near the front of the shaft (494). Drill a hole in a wood block so the shaft rests on that step as photograph (496) shows. Use a light plastic hammer and two nylon or wood dowel rod punches (497) to knock the bearing from the shaft (498). Finish the crankcase disassembly by heating the front main bearing area (499) and driving that bearing out with a nylon punch and plastic hammer (500).

The following common methods to clean and test ball bearing assemblies work with any engine not just a K&B. Soaking the bearings overnight in alcohol or a lacquer thinner dissolves or at least softens varnish deposits. After that, scrub out stubborn varnish from both sides with a tooth brush and some alcohol (501). If you can see that the balls or tracks they ride in are rusted or pitted, replace the assembly. Our rear bearing was rusted and had to be replaced. Sometimes, a bearing passes this visual test but is still unserviceable, so make one final test. Put your little finger through the bearing, spin it rapidly and see if it spins smoothly for several seconds before stopping. Any roughness or binding means you should replace it.

A special bearing assembly may be needed to stop fuel from leaking around the crankshaft and through the front main bearing. Common bearing assemblies normally found in model engines do not seal the crankcase chamber. A snug fit between the crankcase and shaft near the arrows in (502) makes that seal. When dirt enters the engine and wears the contact area between the crankshaft and crankcase, fuel flows through the front bearing. In extreme cases, a bad seal allows so much leakage that the crankcase does not pump as it should and performance suffers. If your engine has a badly worn seal and loses fuel this way, a special sealed bearing will stop the leak and allow you to continue using the worn parts. Sealed bearings are available nearly everywhere and are found by looking in the Yellow Pages under Bearings.

The bearings have been cleaned or replaced and we are ready to reassemble the crankcase. This procedure requires two wooden children's blocks (502) or short lengths of two by four. The rear main bearing slides easily onto the crankshaft until it encounters a slight increase in the shaft's diameter where the two parts have a press fit (503). The two arrows in (501) point to the bearing's "inner and outer races". Be sure the blocks (503) support both of them or bearing damage may occur in the next operation. A sharp blow from a plastic hammer forces (504) the bearing and flywheel together. Insert the crankshaft into the crankcase until the bearing will go no farther (505). Put the crankcase in the wood block you made earlier, heat the rear bearing area (506), and strike the flywheel sharply (507). Next comes the front main bearing. Heat the front bearing area, slide the bearing over the crankshaft and into the seat as far as possible (508). While the bearing appears to be completely in, photograph (511) shows it needs to be driven farther. I use a simple hollow wooden punch (509) for driving in front bearings (510). The overhauled front end appears in (512). Test the bearing alignment by spinning the shaft smartly. It should take several seconds to stop. If the bearings bind, they are probably not seated completely and need the operations shown in (507 and 510) repeated with a little more force.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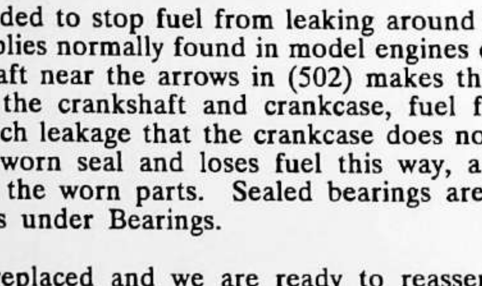
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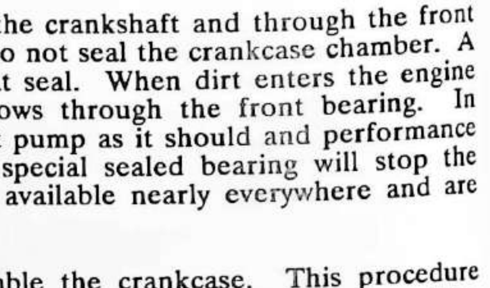
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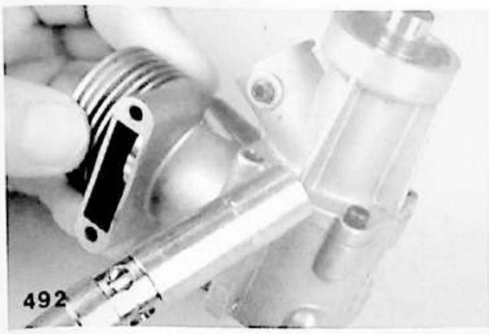
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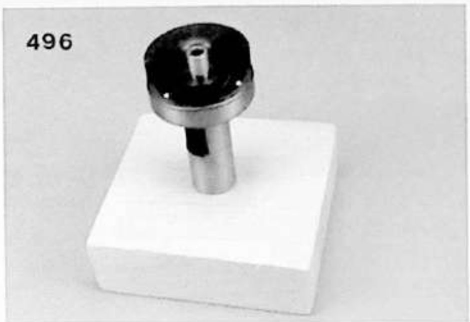
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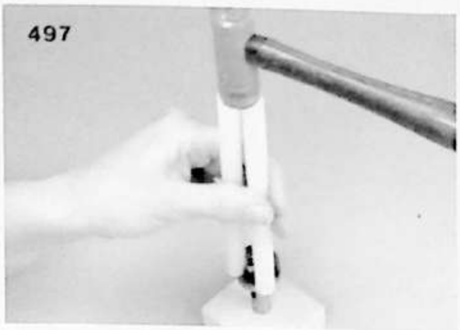
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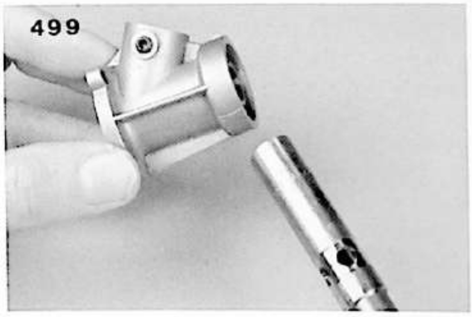
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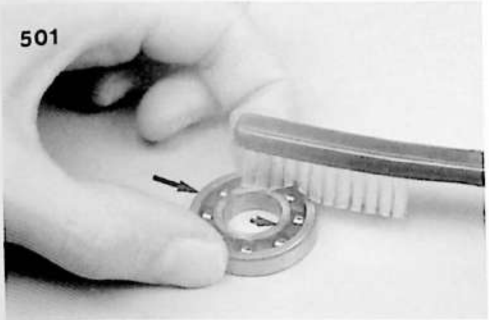
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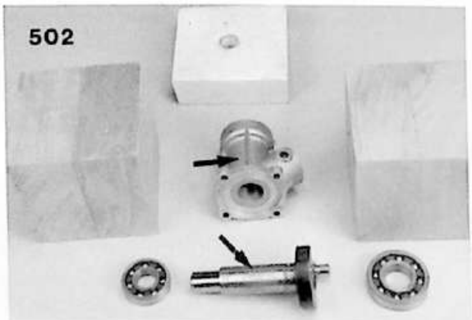
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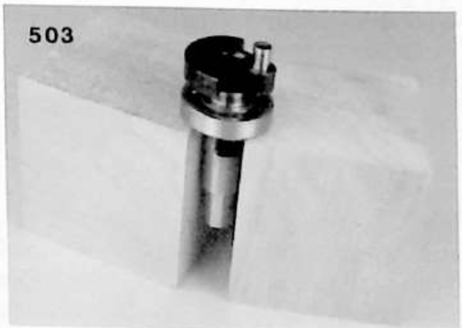
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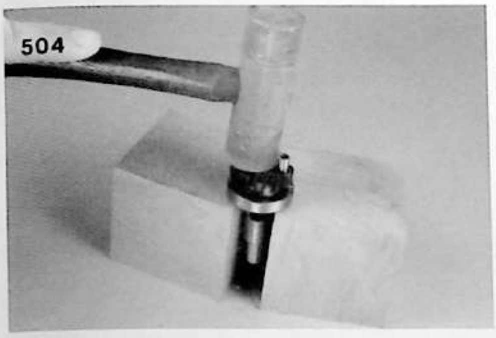
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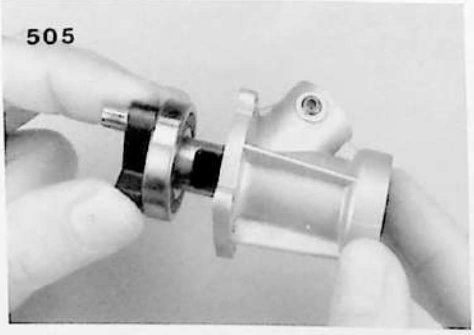
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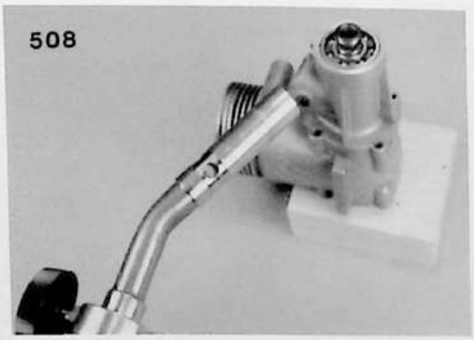
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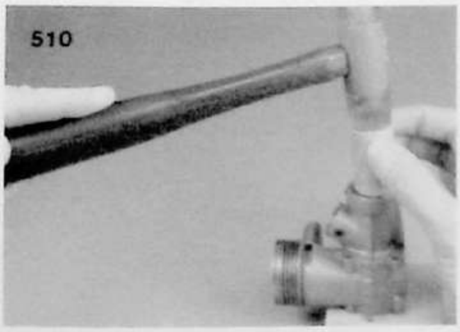
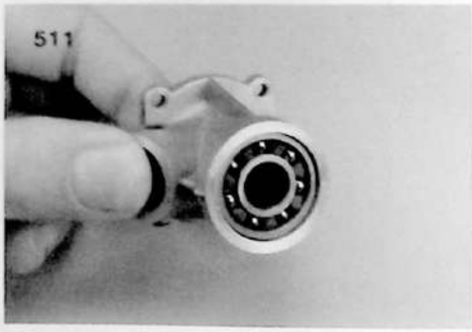
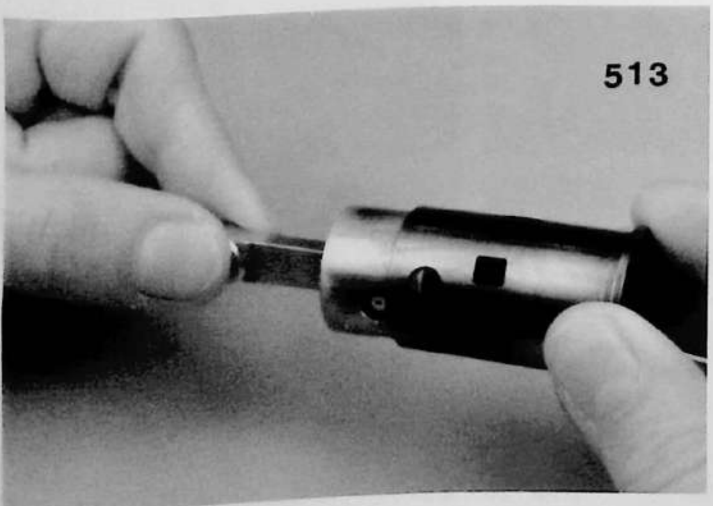


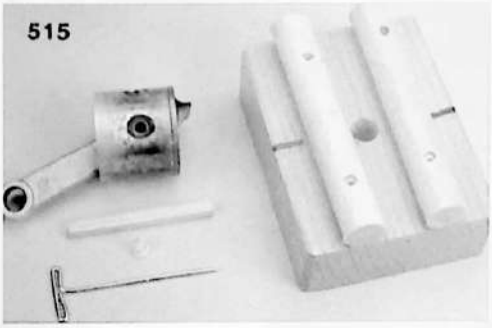


Next, let's take the piston and cylinder assembly apart. Begin by pulling the piston and connecting rod from the cylinder liner (513). Then, pry the Teflon wrist pin pads out with a pin (514). Other engines keep the wrist pin from scraping the cylinder wall with a single coil spring called a circlip. Look ahead to Chapter Twenty-One for details on removing it. When a wrist pin becomes varnished or stuck, an easily made apparatus (515) simplifies its removal. Notice the hole in our block gives the pin a place to go, and black marks show the hole's location when the piston rests on the block and covers the hole. A mechanic aligns the wrist pin and black marks and then drives the pin out (516) with a hammer and small wood punch. Soaking the disassembled parts overnight in alcohol or lacquer thinner (517), removes loose varnish and softens the rest, making the remaining steps a little easier.

During a major overhaul both the piston and cylinder liner are replaced, except with a ringed engine like this K&B. Then, you should install a new ring and piston, but we'll show how to clean up the piston for those who may only want a ring replacement. Remove the piston ring and scrub out the groove like you learned in Chapter Fourteen. Now we clean all carbon varnish deposits, clearly visible in (518), off the piston and cylinder assembly with fine sanding papers until these parts appear as in (541). The 320 to 400 grit 3M Tri-M-ite Wetordry paper used on the piston top (519) and 600 grit needed for the other cleaning operations (520) are available from most hobby shops and any auto body supply company. Sand one half the piston by rotating it in a strip of 600 grit paper (521) until a shine appears and all traces of varnish are removed (522), but do no additional sanding or the piston may become undersized even with these fine grit papers. Next, do the other half (523) of piston and then the wrist pin, which cleans up nicely in the same way (524). A narrow Wetordry strip, glued to and wrapped around a cotton swab or 1/16" dowel rod (525), cleans holes in the piston (526) and connecting rod (527). Use rotary, not in and out motion, because the paper's natural spring exerts enough pressure to remove the varnish, while a sawing motion could make the holes in these soft metals out of round or oversized. The outside of the cylinder cleans exactly like the piston (528). To clean the inside, carefully remove the carbon deposits at the top with a number 11 blade chucked in an X'acto knife. Then sand the inside with 600 Wetordry leaving no vertical sand scratches, because a cylinder wall scored in this way does not seat the new ring as well as one with circular scoring.

The K&B has a separate block and crankcase while the OS 48 Surpass in Chapter Eighteen incorporates the two parts into a single unit. Engines featuring a separate block have no moving parts contacting it, and though this part needs devarnishing, it never needs replacing unless the screw threads become stripped. Sand varnish from the area that contacts the liner (529). After wiping the block and liner clean and dry, the parts should slip together with light to moderate hand pressure (530) while a tighter fit usually means some varnish remains. Varnish finds its way into the screw threads so they should be cleaned out. We recommend a tap glued in a short dowel rod (531) because a normal tap handle doesn't have a sensitive feel. Using this tool to clean the block's threaded holes (532-533) concludes this section on devarnishing the engine. So far, we have cleaned the engine like in Chapter Thirteen, replaced the rear main bearing and piston ring, and devarnished the internal parts.

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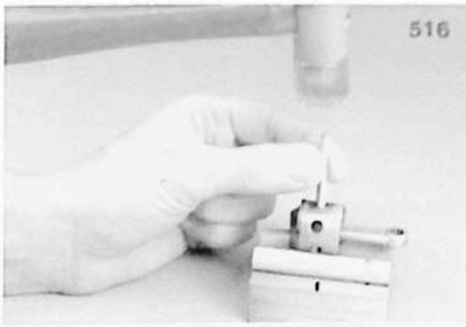
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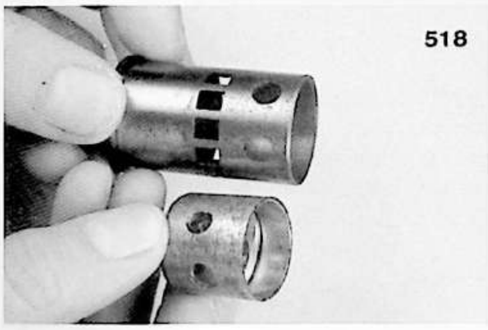
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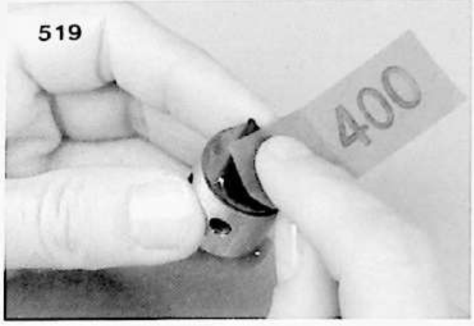

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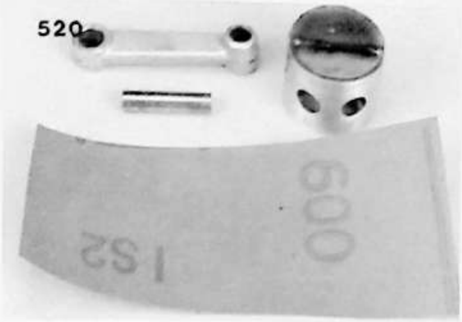

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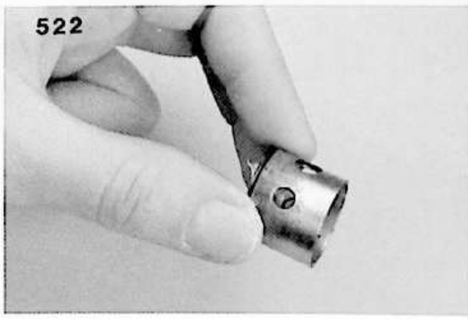
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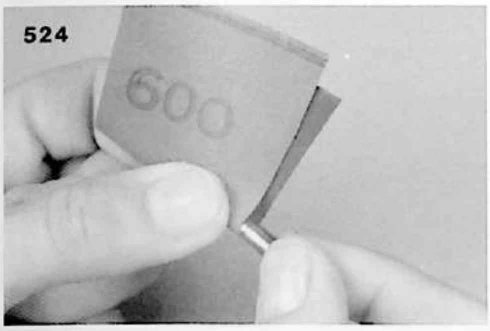

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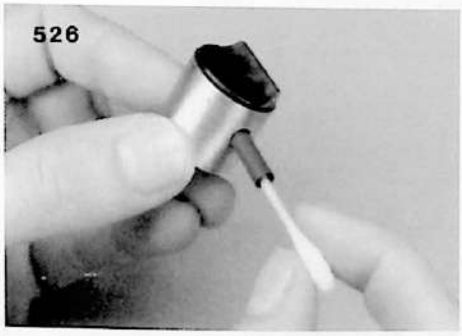
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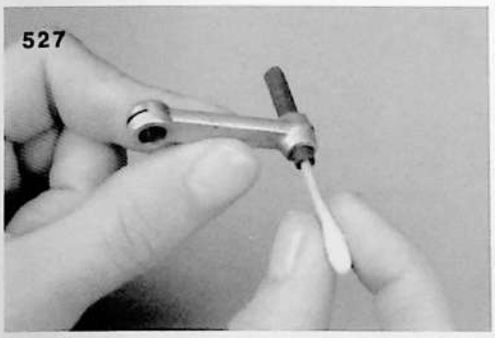
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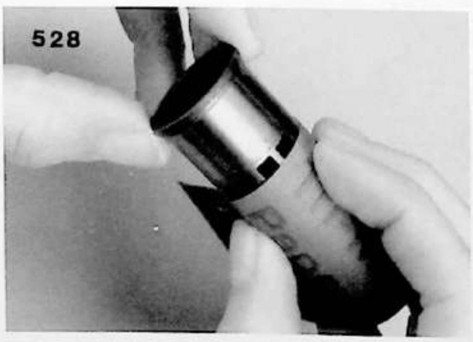
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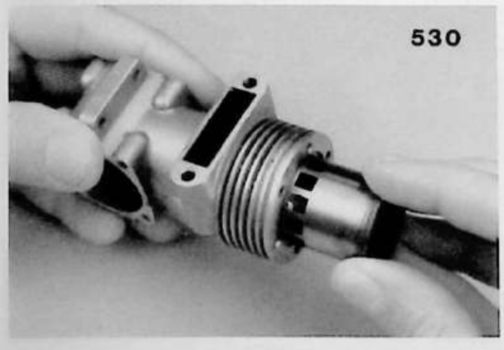
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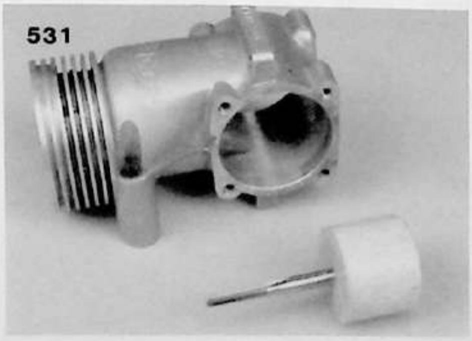
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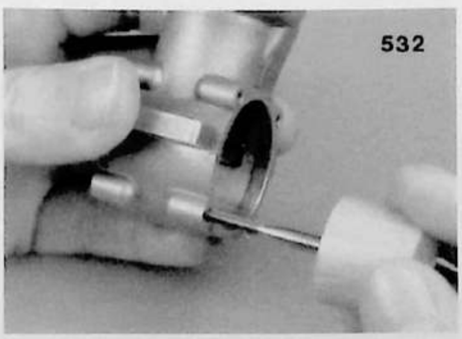
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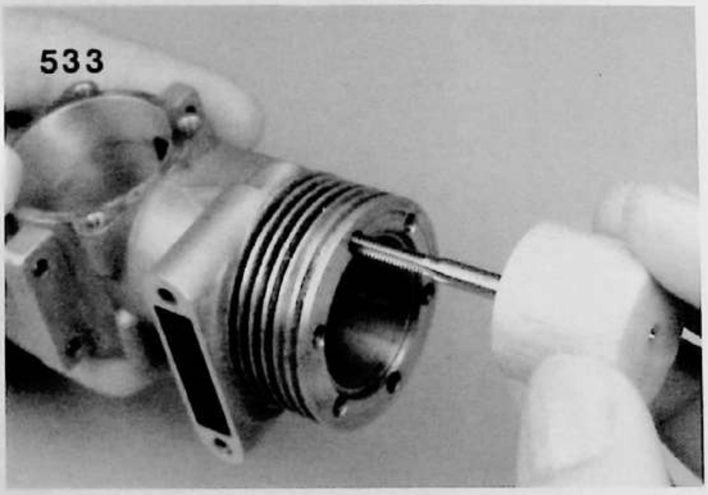
During the next step, small amounts of fine abrasives from the Wetordry paper remaining on the parts can be removed with alcohol (534), though some experienced mechanics prefer water and dishwashing detergent because it floats the abrasive away a little better than alcohol. Put any devarnished parts in a container of alcohol or soap and water (535) and agitate the container so the liquid moves repeatedly over the parts. This floats away most of the abrasive. Many engine mechanics have an air compressor and blow off any liquid and remaining abrasives. Others recommend boiling the parts in water and dishwashing detergent; nothing cleans more completely. We realize you probably do not have a compressor and are not interested in boiling detergent, so an alternate method that works almost as well follows. Hold the parts under very-hot fast-running water, dry them, and test all small holes with a cotton swab (536-537). If the cotton becomes dirty, repeat the swabbing until the cotton comes out clean. Finally, wipe down each part with a paper towel (538-540). The towel should come off unstained, showing that the parts are perfectly clean and dry (541-542).

Only reassembly remains. Install the piston ring as shown in Chapter Fourteen, assemble the piston and rod assembly, and push the piston into the bottom of the sleeve. That last operation takes a little care, and if you have never compressed a ring into a cylinder liner, review the subject in Chapter Fourteen. From here on, the engine reassembles easily. Insert the piston and cylinder assembly into the block (543-544), and then install the crankcase assembly (545-546). Test the dry assembly by turning the crankshaft slowly (547). A ringed engine should turn completely over smoothly and easily. A non-ringed engine will only turn easily near BDC because the piston and sleeve fit tightly near TDC. Oil both rod ends, the shaft and both main bearings like photos (548-551) show. Also, drop oil on the piston top and rotate the crankshaft until oil coats the cylinder wall. Then, finish assembling the engine (552-553). We do not put the muffler on until after the engine is mounted in an airplane, but clean the threaded holes at this time (554). After doing all this, the old K&B never ran better.

A FINAL OBSERVATION

I've known modelers unable to afford replacement parts and after only devarnishing an engine, they often got much better performance because an engine looses significant power moving varnished parts against each other.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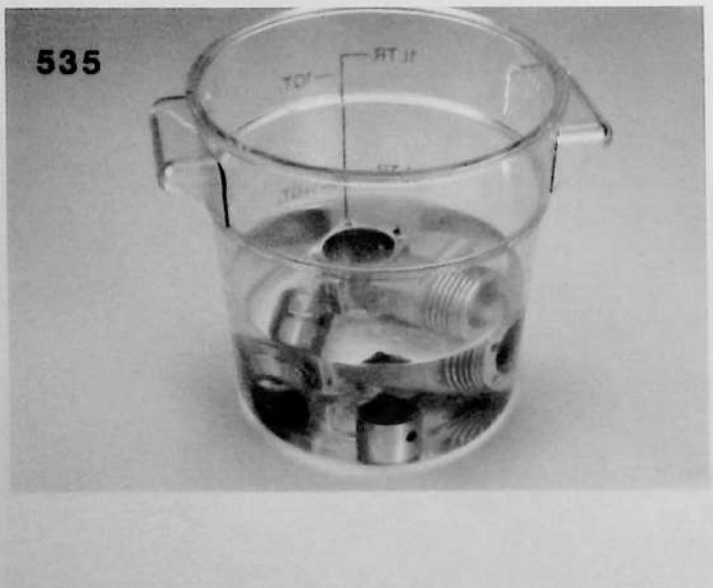
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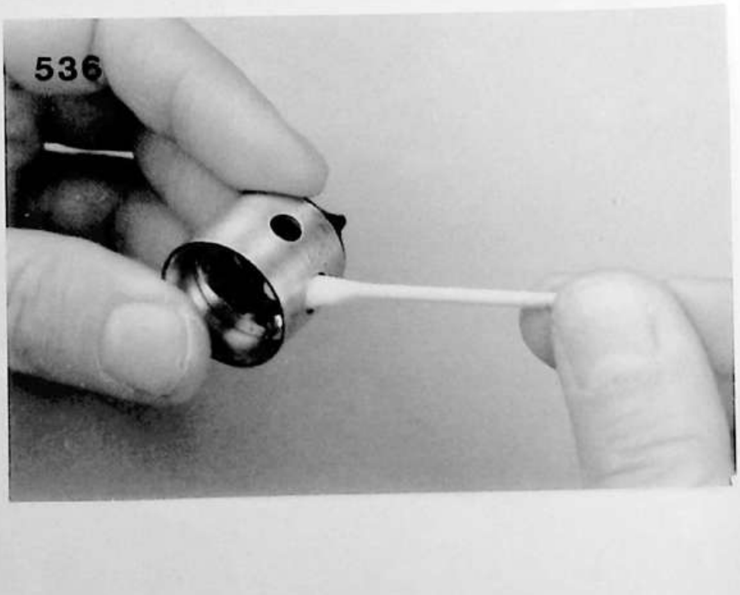
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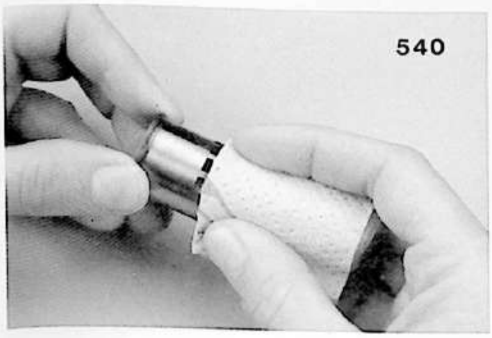

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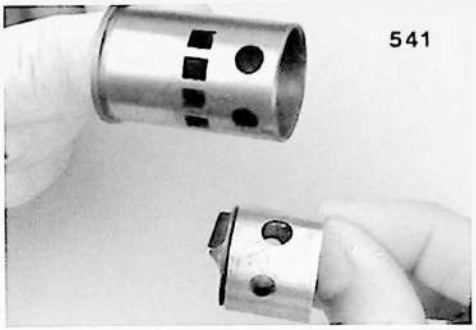

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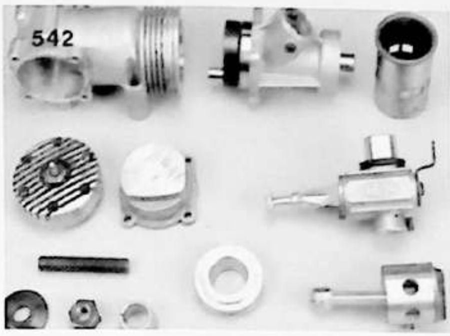

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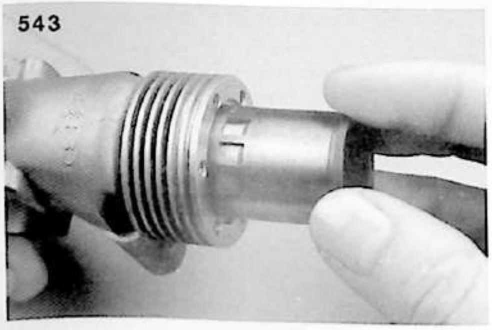

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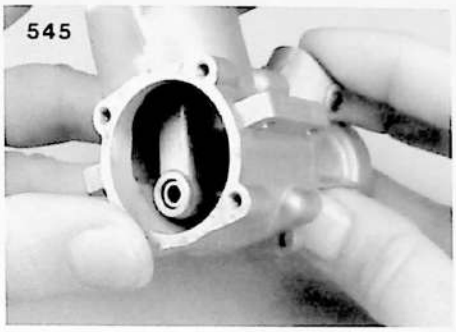

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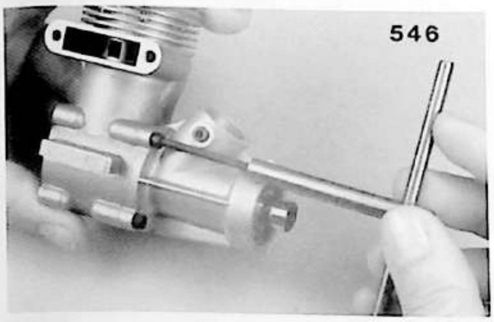

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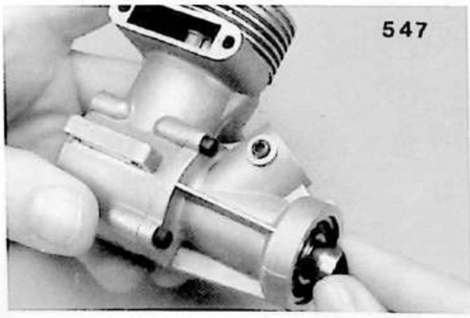

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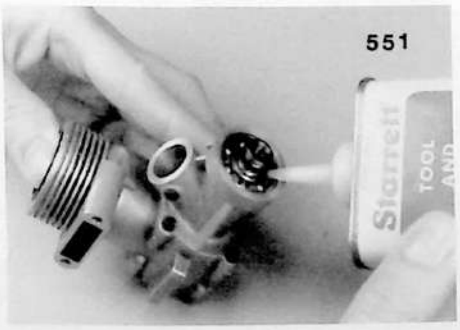

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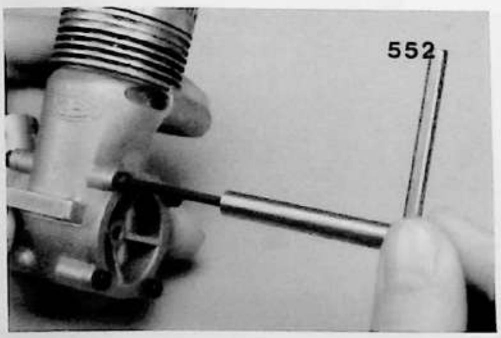

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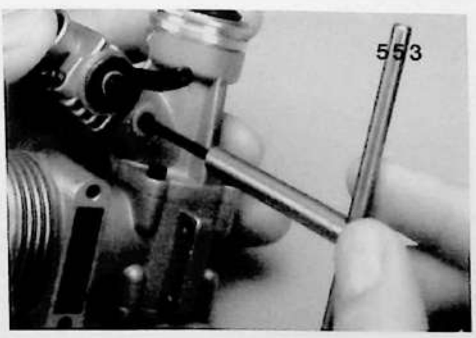

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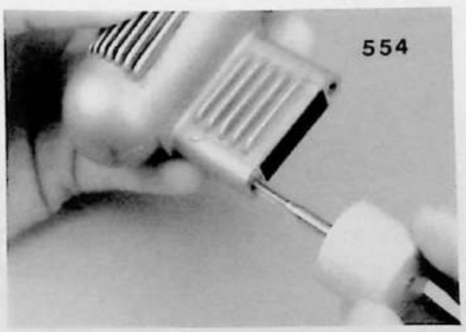

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CHAPTER SEVENTEEN
ADJUSTING ROCKER ARMS AND GIVING A VALVE JOB

INTRODUCTION

Chapter Fourteen presented some common how-to-do-it methods that are similar for many different engines and we did not repeat them every time an engine was disassembled. For example, techniques for removing a piston ring only appear there and nowhere else. This chapter continues in that vein with two four-stroke procedures, adjusting valves and a valve job. After showing them here, they aren't repeated in the chapters about OS, Enya, and Saito four-strokers.

ADJUSTING VALVES

Valves in four-stroke engines provide another opportunity for combustion mixture leakage and the gross overheating it causes. During the power stroke both valves must be completely closed, otherwise gasses passing through even a slight leak will burn and erode the valves and their seats. The springs in (555) partially seat the valves, but expanding combustion gasses force them into their seats to a much greater extent, and nothing must inhibit either factor. Let's see how engine manufacturers do this. The arrow in (556) points to a pushrod holding an intake valve open on the cutaway engine positioned in the mid intake stroke. The repositioned engine in (557) shows the relationships those parts have during a power stroke. Then, both pushrods must be retracted, exerting absolutely no upward force on the rocker arms, or the pushrods will hold the valves open causing them to burn and erode. Look in the next three chapters and notice the complex gears and cams that operate the valves. Even a novice model engine mechanic must appreciate that collective normal wear of these many parts will eventually change the rocker arm's free play and need adjusting. The arrow in photo (567) clearly highlights adjusting screws and lock nuts on the rocker arms. These screws should be reset occasionally to keep the rocker arm's free movement correctly set.

Rocker arm play is set with two metal strips called "feeler gages" that have different thicknesses. These come with Enya, Saito, and large OS engines. Since small OS four-strokes are sold without the gages and used engines do not usually have the gages either, they must often be purchased separately. OS markets an inexpensive valve adjusting tool kit (558-559) that includes feeler gages with their thicknesses marked millimeters. For those who want to buy an American feeler gage set, photographs (560-561) show how thick OS's gages are in inches, .002" and .004". Shortly, we'll explain why the thicker one can be .005" or even .006" without hurting anything. A properly set valve train will have at least .002 inches clearance between the valve stem and rocker arm but not more than .004" to .006". That means the .002" gage fits between these two parts as in (577), and the larger one does not (578). For these reasons, the .002" gage is called a "go gage" and the larger one a "no-go gage".

Before any adjusting, the shaft must be rotated until the valves close, and both pushrods are at their lowest positions. Most engine instructions tell you to turn the shaft a quarter turn beyond where compression starts. While this usually works, we suggest something a little more accurate. Correct valve and pushrod orientations occur with the piston at TDC between the compression and power strokes. A four-stroker has another distinctly different TDC between the exhaust and intake strokes, but engine designers make no effort to have the valves ready for adjusting then. You can easily find both TDCs after removing the rocker cover (562). We attached a wood piece (564) that points straight up at TDC, so you can see what happens to the valves as the engine moves over TDC between the exhaust and intake strokes. The engines in (564) and (567) are late in the exhaust stroke with their exhaust valves depressed and still open. A few degrees of crankshaft rotation later (565) and (568), the valves appear closed and the piston has moved very close to the TDC between the exhaust and intake strokes. Shortly after that (566) and (569), the intake valve opens. Reset the engine back to TDC though it is the wrong one. Some engines have a mark on the propeller washer that lines up with line on the block (563) at TDC. If your engine does not have these lines, scribe them now (570). Rotating the shaft one complete revolution sets the engine to the correct TDC for adjusting valves (571). For future adjustments, rotate the propeller counter clockwise until you feel compression and continue until the lines on the washer and block are opposite each other.

After setting the engine at TDC between the compression and power strokes, depress one valve (572) to release any compression in the cylinder. Then, push both valve stems down several times to be sure they move freely because if they stick, the adjustments will not be accurate. A head with sticky valves must come apart, and whatever causes the sticking needs to be fixed. We'll say more on this subject later.


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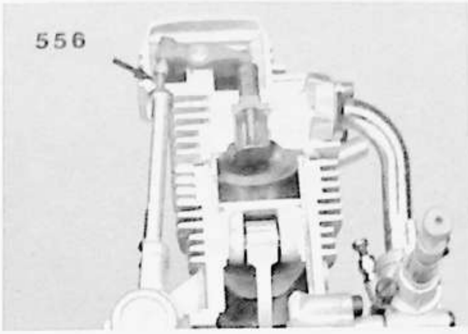
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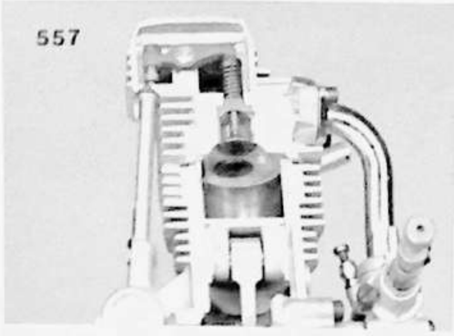
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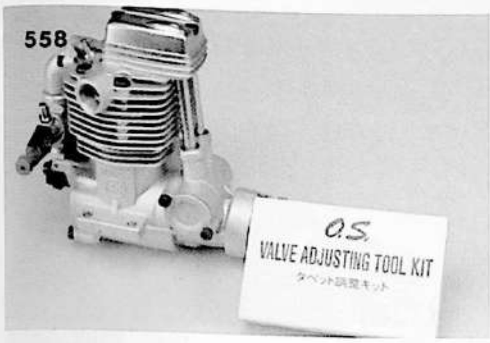

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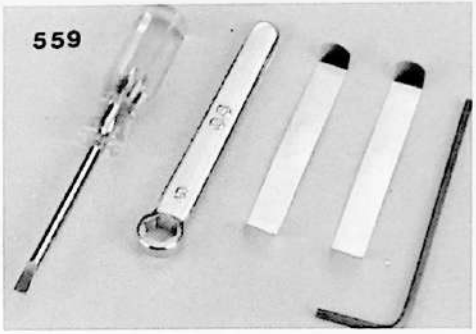
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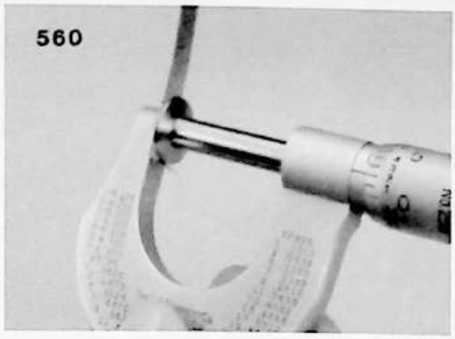
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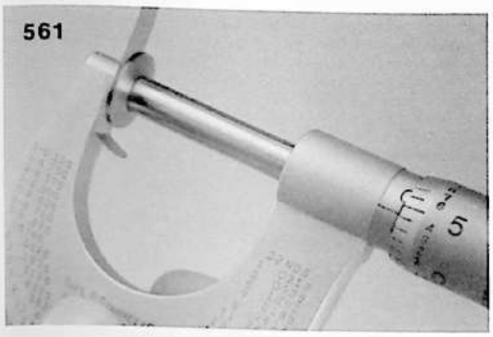
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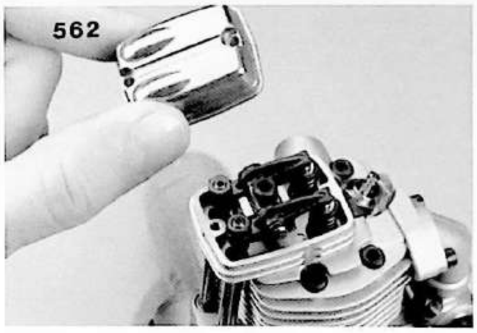
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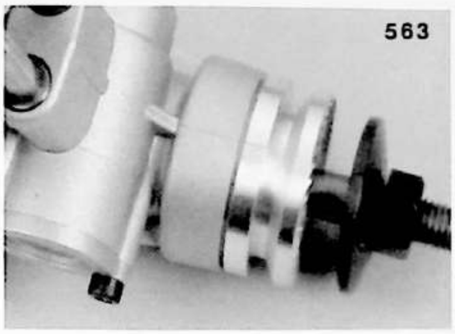
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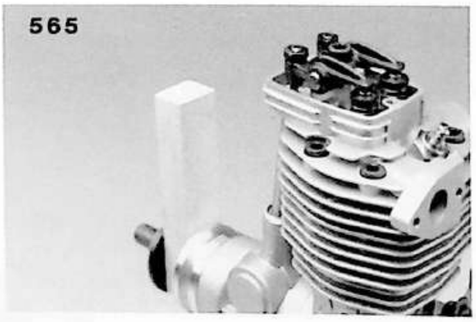
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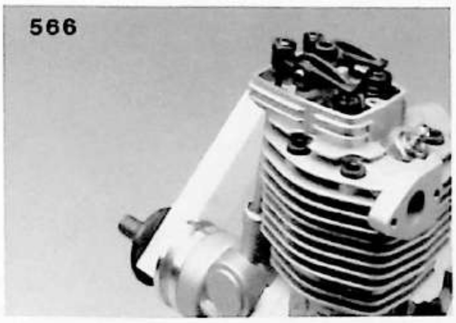
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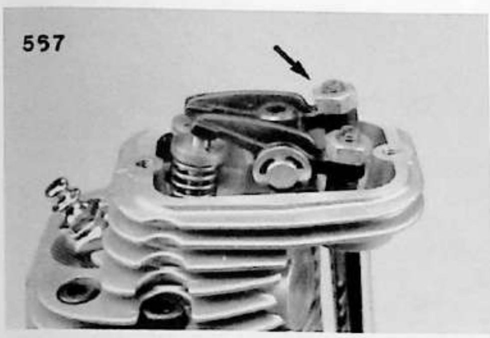
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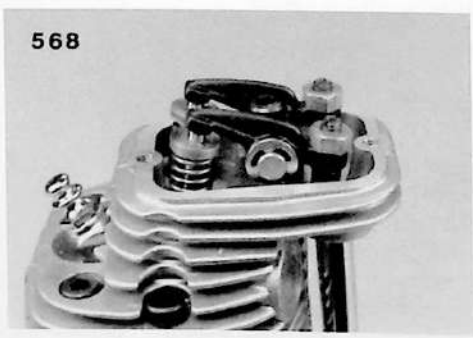
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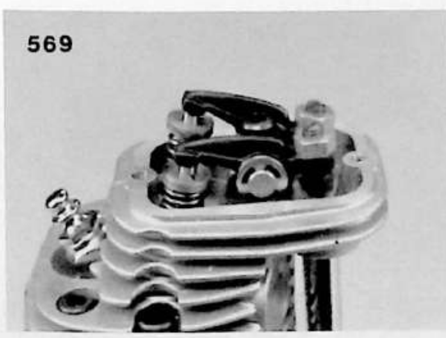
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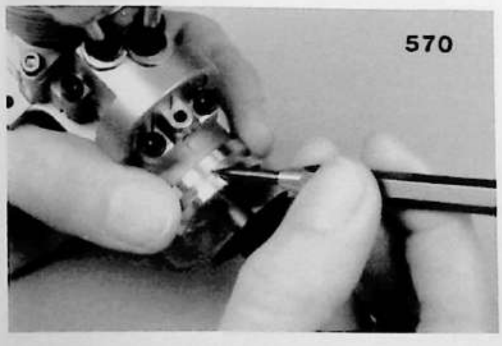
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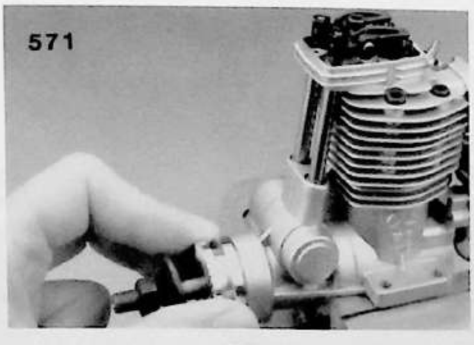
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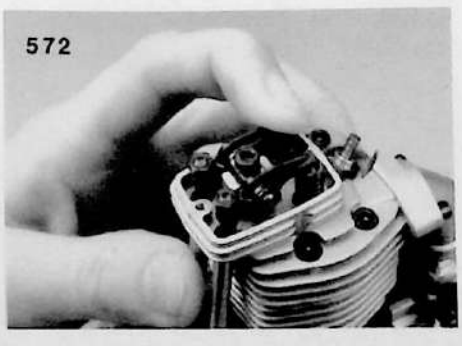
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Now, you have enough background to make valve adjustments, but always do that with the engine at room temperature. Loosen the lock nuts (573) and back the adjusting screws out about a turn (574). After sliding the go gage between the rocker arm and valve, tighten the adjusting screw until the rocker and valve stem lightly contact the gage (575). An inexperienced mechanic often over tightens them because adjusting screws exert tremendous leverage; he may not even know it happened. A valve set this way will not close completely and quickly burns up. So, use the light touch and sensitive feel this delicate operation requires by lightly turning the Allen wrench between the thumb and index finger as in (575). Now, we lock the screw. When you think the screw is correctly set, note the position of the Allen wrench's short arm, hold it in that location and tighten the locknut (576).

Next, we do three checks. First, after removing the gage, grip the rocker arm between the thumb and index finger and gently move it up and down. You should feel a slight movement limited at either end by a click when the rocker contacts the valve stem or pushrod. If that doesn't happen, try resetting the adjusting screw. For the second test, slide the go gage between the rocker arm and valve stem (577). It should enter almost effortlessly and pull out with a detectable but slight resistance. These two tests show whether the valve train has too little play; the third check tests for too much play. The no-go gage should not fit between the rocker arm and valve stem (578). An unskilled mechanic forcing the gage in will depress the valve, and that doesn't take much force. You should force a no-go gage once just to see what we mean.

Let's make a final observation about valve adjustments. *If you are going to err, have too much play not to little.* With too much, the valves don't stay open as long as they should, but that doesn't hurt a thing and affects performance so little you won't even notice a power loss. For this reason the no-go gage may be a little large as we mentioned earlier. Too little or no play in the valves quickly burns them and their seats in the head, and that results in an expensive repair.

CARBON, STICKY VALVES, AND A VALVE JOB

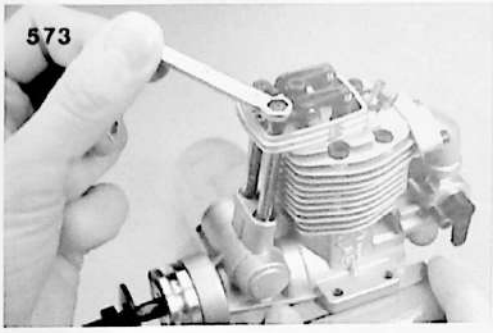
The tiny valves and their seats in the head operate at high temperatures and pound together 8000 times a minute or more. Considering this, they hold up surprisingly well but still occasionally need maintenance. After taking the head off, we service valves about the same on all four-stroke engines in the following ways.

Any fuel creates carbon that forms deposits in the combustion chamber and especially on the exhaust valve stem indicated by the arrows in (580). Begin the valve job by scraping carbon off the valve with a small X'acto knife and a number 11 blade. Carbon deposits come off the head with 320 Tri-M-ite Wetordry, but leave the valve seats unsanded.

Valve seats and the valve rim that they contact are cleaned and reformed together with any grit abrasive paste in the 600 to 1000 range (582). Pastes like this, called lapping compounds, consist of silicone carbide or aluminum oxide powder mixed with grease. Since aluminum oxide decomposes in heat and breaks down faster than silicone carbide, we'll choose it because any residual will damage the engine less than silicone carbide. Brownell's Inc. in Montezuma, Iowa stocks these abrasives.

Corroded valves and valve seats are lapped as follows. Attach the valve to a short dowel rod with any thick CA glue (579-580); then polish the stem (581) with 600 grit Tri-M-ite Wetordry. Place a pin-head size drop of lapping compound at two or three places around the valve seat (582). Keep compound out of the valve stem bushing in the head, or the next operation could badly wear them both. Turn the valve a complete revolution (583) to distribute compound but do not press hard. Then, rotate the valve a quarter turn and return it to its original position several times while pressing with only moderate force. Remove the valve and check for low spots on both the valve seat and the valve itself. Lapped areas will exhibit a good shine, but low, unlapped areas will not. If the seat had a high spot and the valve was rotated complete revolutions, the high spot would polish the entire valve circumference including any low spots. When the entire seat and valve circumference shine, remove all compound (584) with a cotton swab and then clean the head thoroughly using methods we explained in the last chapter.

Now, the valves seal better, and the cleaned, decarboned valve stems won't bind in the head, but the rocker arm assembly (585) may be varnished. That inhibits valve movement. Disassemble the rocker assembly like photograph (586) shows. Rockers from other engines may disassemble differently, but getting them apart should not be problem. Devarnish the rocker arm holes (587) and rocker arm shaft (588) like the connecting rod bushings in the last chapter. The devarnished pieces appear in (589), and the parts from the first photograph in this chapter have been reassembled in (590). Shortly, we'll show how to do that for each major engine type.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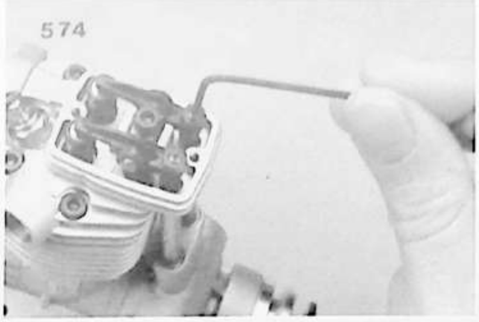
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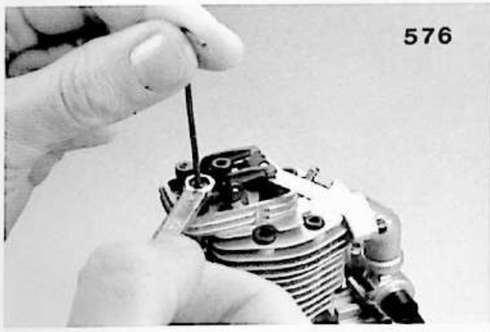
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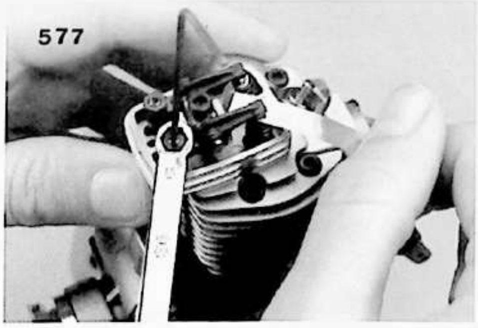
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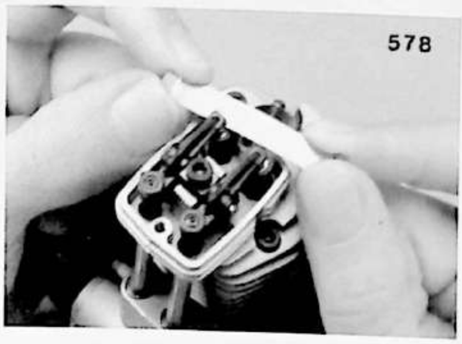
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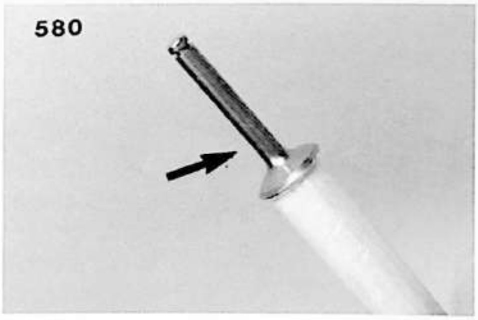
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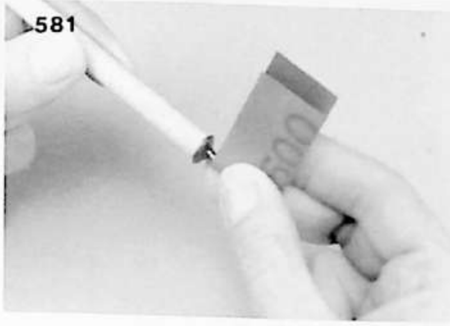
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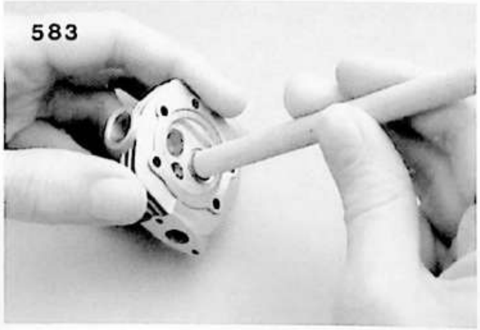
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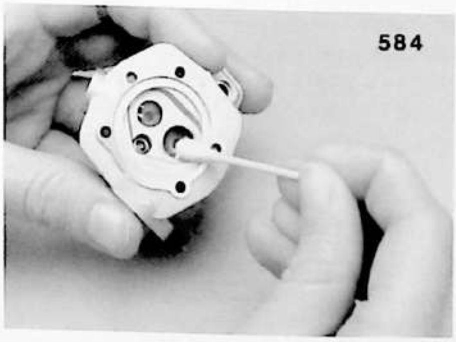
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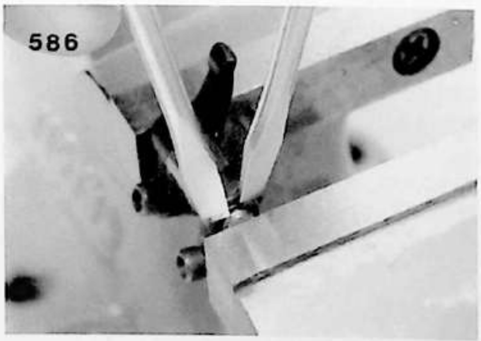
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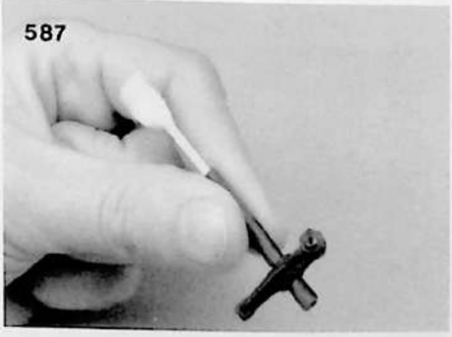
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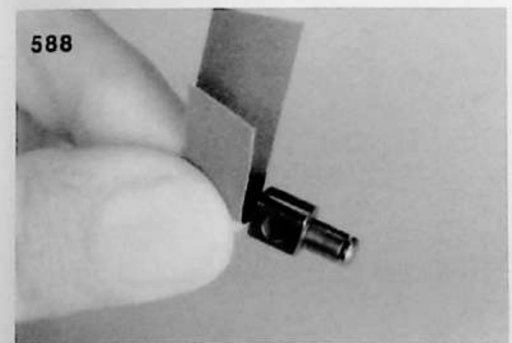
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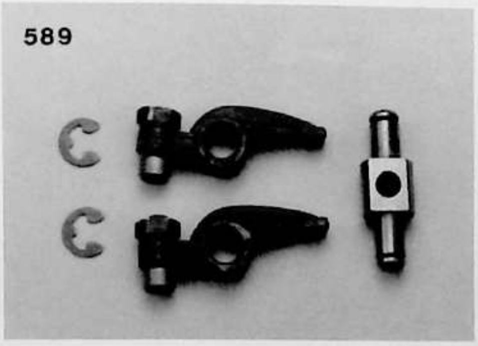
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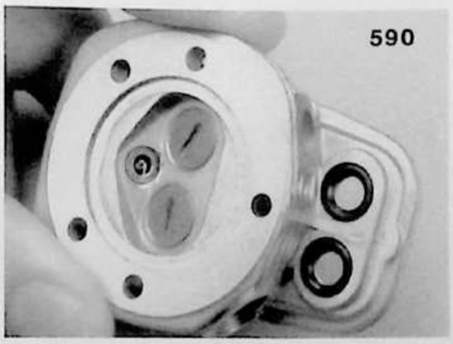
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INTRODUCTION

We want you able to maintain and service any popular four-stroke engine, and that means disassembling them should be second nature. Learning this might seem like a huge job because many different designs exist and OS, Enya, and Saito's valve driving mechanisms have little in common. However, single-cylinder four-stroke engines by an individual manufacturer are nearly identical except for size. After reading chapters eighteen through twenty, which show how to take apart an OS 48 Surpass, Enya 53, and Saito 50, you should be able to disassemble any single-cylinder four-stroke engine by these manufacturers. Multiple cylinder four-strokers are made by attaching cylinder assemblies from single-cylinder engines to a common crankcase. For example, a Saito 90 Twin, consist of two 45 cylinders on a common crankcase. So, these three chapters also provide a basis for taking apart multiple-cylinder engine designs.

One procedure in this chapter applies equally to four-strokers and many two-stroke engines. The two-stroke Royal and K&B 40s we discussed in earlier chapters have a separate block and crankcase that makes these engines easy to take apart. Other two-stroke engines like an OS SF, K&B 61, ASP 46, and most four-strokes combine the block and crankcase in a single casting. Since it performs both functions, the part is called either a block or a crankcase. Usually, the one piece unit complicates disassembly. If your engine has this feature, the discussions about photos (614-618) and (651-655) show how to get the unit apart and back together.

GETTING THE HEAD OFF AND APART

We'll begin with two suggestions. A four-stroker has many small, easily-lost pieces, so before removing anything, find a container with a screw lid. Our photographs show a glass dish, but a peanut butter jar would be better. In my experience, any pieces that aren't put in something like this will get lost, never to be seen again. Then, you'll wait several days for replacements - probably even longer. While our sparkling new 48 Surpass (591) did not need cleaning, most engines should be cleaned up using the special four-strokes method that appear in Chapter Thirteen. After doing these things, we can begin the disassembly.

Before you can remove all the head screws, several small parts must come off. Four screws attach the carburetor and intake manifold to the block and head (592). Unscrew them, remove the carburetor and manifold, and set these small parts in the container (593). Also, take off the rocker cover (594). The rockers partially hide one head screw [arrow in (599)]. Some modelers, not knowing about this fifth head screw, remove the other four and damage the head trying to pry it off, so remove the rocker arms (595-596) and pushrods (597) before taking off the head. The small parts in (598) should also be put in the peanut butter jar. After removing all five head screws (600), lift the head off (601) and pull out the pushrod tubes (602). The engine is now separated into its two main sub-assemblies, the block (603) and head (604).

Of these two sub-assemblies, we'll take the head apart first. OS four-strokes all have soft aluminum head gaskets (604) that tend to stick, and are easily ruined if you try to remove them. Unless the gasket appears damaged, just leave it in place. Let's move on to the valves. We displayed a valve assembly (605) so you can learn the names of two very small but important parts. The C clip, called a "valve keeper", rides in the "retainer", against which the valve spring pushes. As you can see, the spring must be depressed before a keeper will come out. An 1/8 inch plywood piece (606) holds the deeply-recessed valve faces, shown in (604), against the seats. Otherwise, the valve, keeper and retainer move down together when the spring is depressed (607), and the keeper cannot come out of the retainer. With the wood in place, use a scriber or small screwdriver to push down the retainer and then pull the keeper out with a long-nose pliers (607). The retainer, being under heavy spring tension, will fly off if the scriber slips. For that reason and many others, anyone working on engines should wear safety glasses. Incidentally, lost retainers seem to hide themselves well, so take the following precaution. After removing the keeper and setting it down, put the index finger of your free hand on the valve stem end to stop the retainer if it should spring free, and then carefully let the retainer up. Next, the springs come off (608) and the valves slide out easily (609). These pieces appear in (610).

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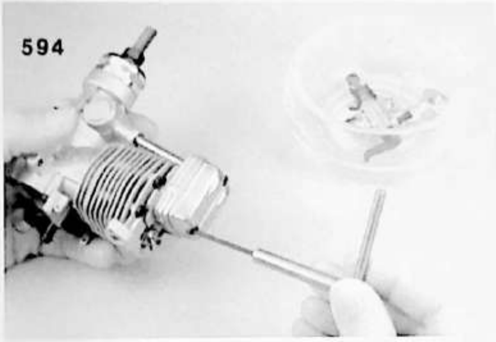
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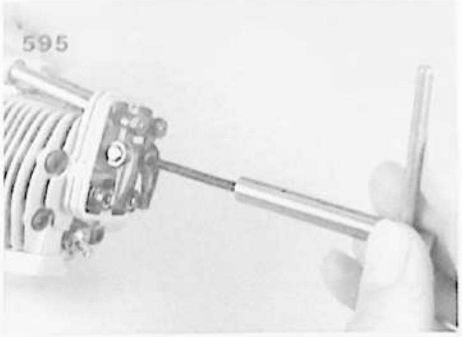
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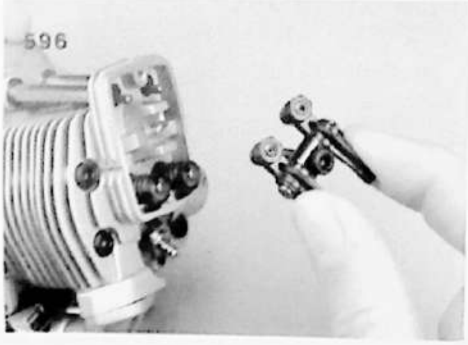
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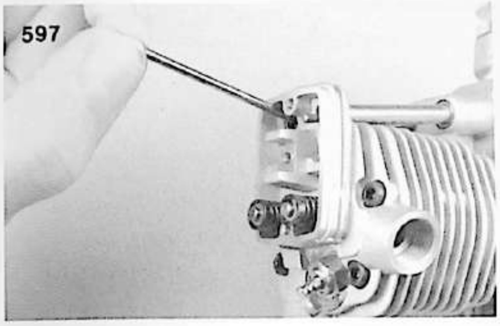
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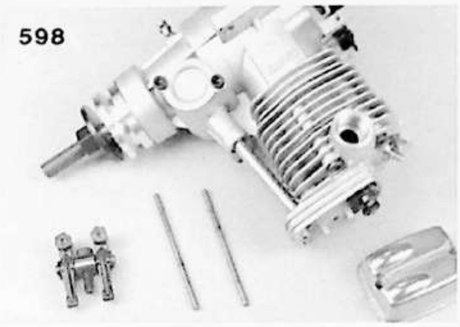
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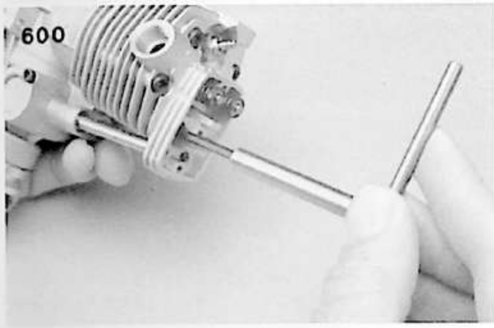
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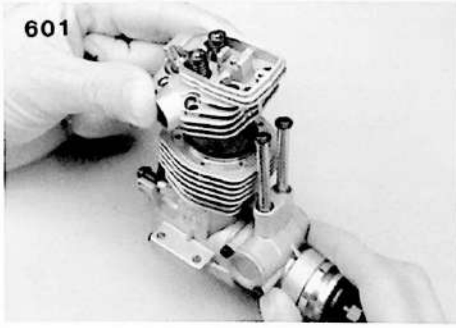
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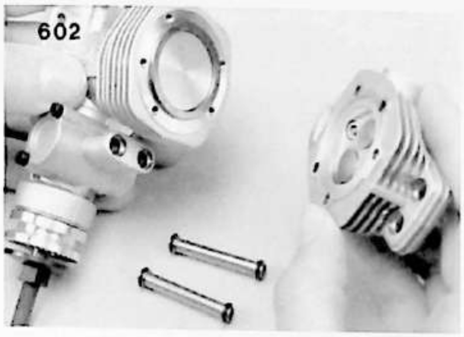
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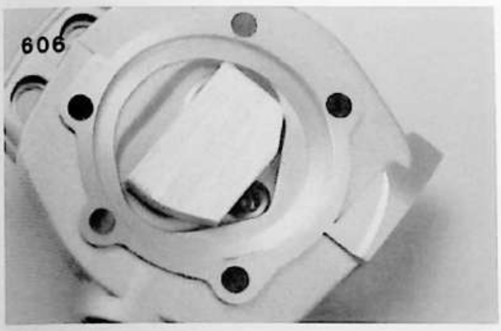
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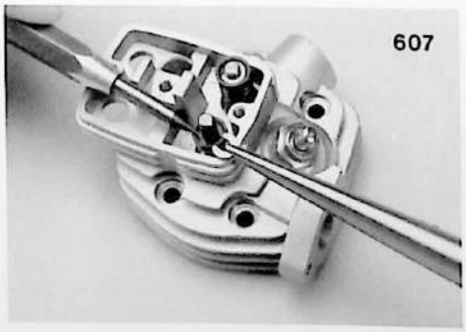
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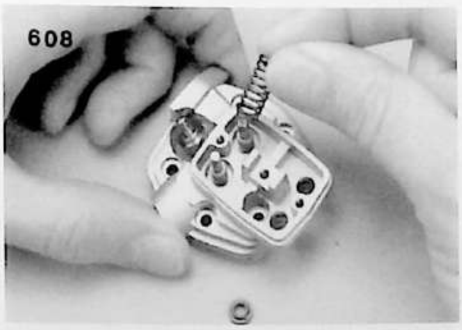
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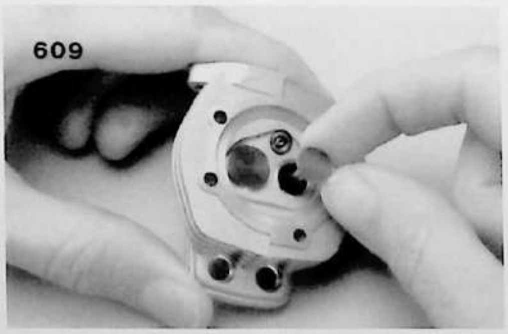
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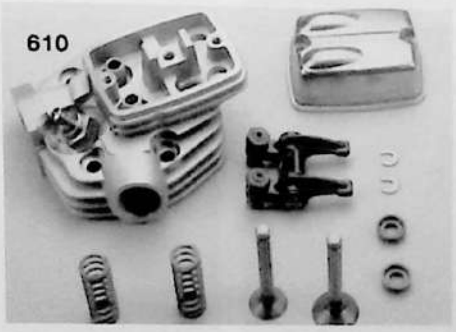
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DISASSEMBLING THE BLOCK

The cylinder liner is the first major part we take out of the block, but before doing that, let's remove the lifters since nothing holds them in and they become lost too easily. Valve lifters (613), visible in (611), are jarred from the block by striking it sharply against your hand (612-613) or against a paper pad. Next, the cylinder comes out. As we have already mentioned, many other engines with a one piece block including some two-strokes also use this procedure. A one piece block does not provide enough room to pull the connecting rod off the crankpin, so the liner comes out while the piston assembly remains. If a wood rod won't push the cylinder liner out (614), try the method for removing a stuck sleeve that appears in Chapter Sixteen. After moving the sleeve enough for a good grip (615), pull the sleeve out completely (616).

Often, getting the piston and rod assembly off an OS crankpin presents a challenge, because the piston and rod are separated in the block by fishing the wrist pin out through a small hole (617). A special tool called an "easyout" sometimes frees a stuck wristpin. The tool was designed to remove a broken screw from a threaded hole by wedging itself into another hole drilled down the screw axis by a mechanic, who can then turn the screw by rotating the easyout. Wrist pins normally have a hole through their axis. Varnish that holds the wrist pin in the piston usually break loose when an easyout is inserted in the wrist pin hole and rotated. If these things fail, a somewhat destructive method always works. Loop a flexible wire saw under the connecting rod and saw it in half. Normally, the piston and rod will come out (618) without resorting to an extreme method like that. Remove the piston ring using the methods that appeared in Chapter Fourteen.

At this point an inexperienced mechanic might be tempted to remove the crankshaft, but the cam must come out first or both parts will surely be ruined when the hammer strikes the shaft. After taking the cam cover plate off (619), the cam is easily pulled from the block (620). Now, remove the crankshaft using the methods shown in Chapter Fourteen.

The next job, getting the cam bearings out, has a reputation for being tough, but one of the ways we show will work for you. Make wood pieces like those in (621). Then, heat the bearing cover (622), hold it as (623) shows, and strike the work bench hard. In most instances the bearing pops out (624). The cam bearing pressed in the block comes out just like the rear main, with moderate heat and impact. After heating the cam bearing area (625), strike the block sharply against a paper pad (626), and the bearing will be jarred loose (627).

Let's see how a bearing puller works and if one can be made that will remove cam bearings. A heavy slide on a puller moves on a shaft with a striker plate at one end. You can see both parts in (637). The shaft's other end attaches to the bearing, and a mechanic slides the weight sharply against the striker plate to jar the bearing out. Small bearings, pressed in blind holes, present a nasty problem to tool manufacturers because they cannot devise an easy way to grab the bearing. The hard-to-reach cam bearing buried in the block serves as a perfect example. I asked a creative flying buddy, Mark Spencer, if he could come up with a functional puller. Mark thought to grind (628) flat head 2-56 screws so their heads could be slid under the inner race (629). A look at photograph (635) gives a better idea of how he ground the screw heads. One screw goes through the bearing and its head slides under the inner race (629). That leaves enough room in the bearing to insert the second screw. Pieces of 1/16 and 3/32 inch wire tightly fill the remaining area (630) and keep the screws in place during the remaining steps. The screws and wires slide into the end of the puller, and a set screw in the puller clamps them solidly in the shaft (631). The plywood ring in that shot prevents burnt fingers after we heat the bearing cover up (632-633). By moving the slide rapidly down the shaft so it hits the striker plate


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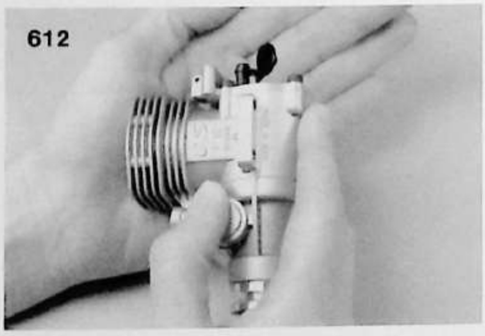
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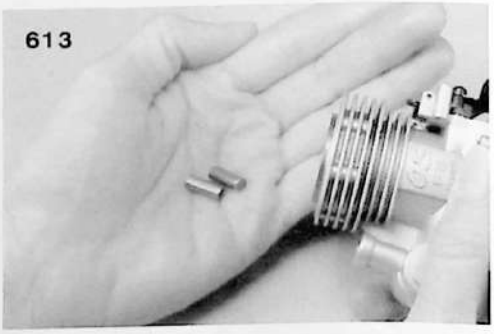
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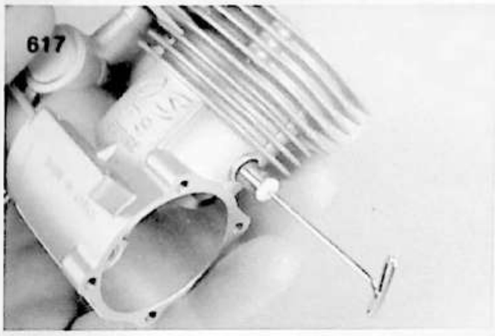
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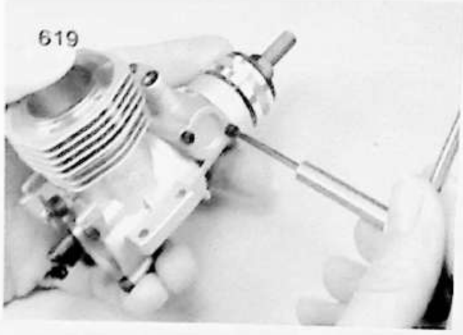
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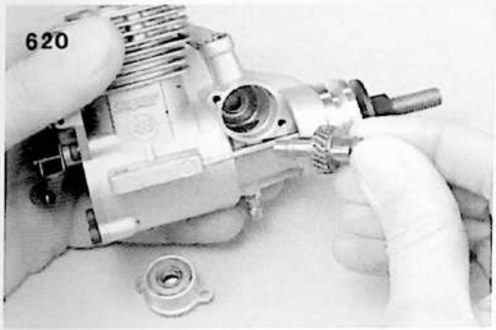
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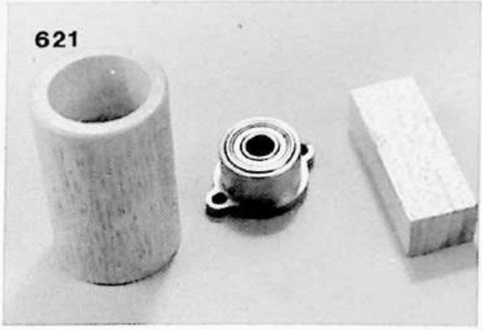
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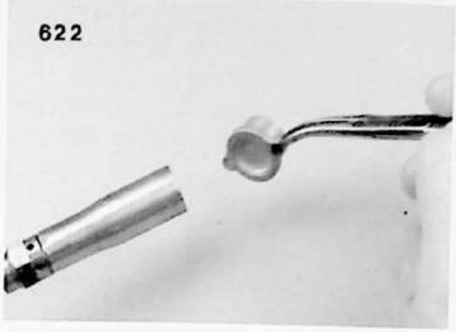
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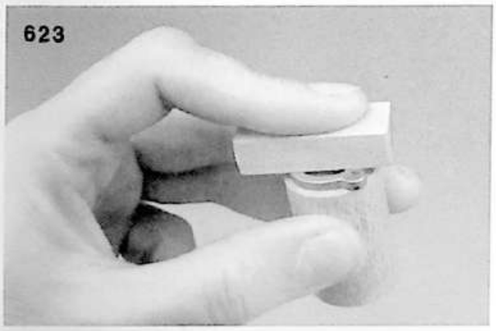
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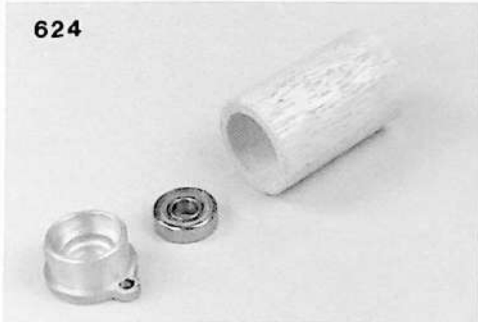
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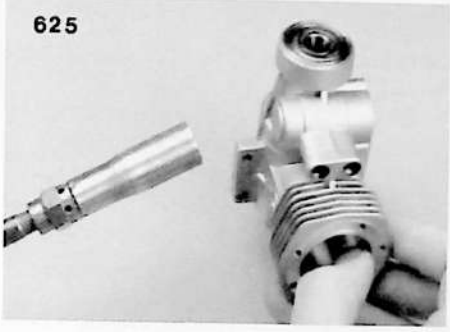
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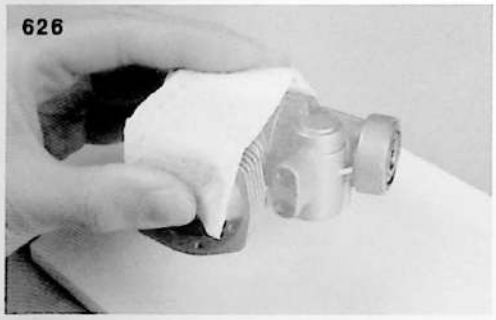
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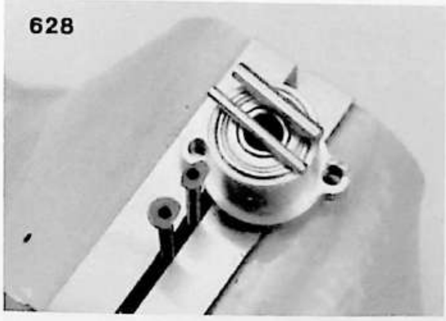
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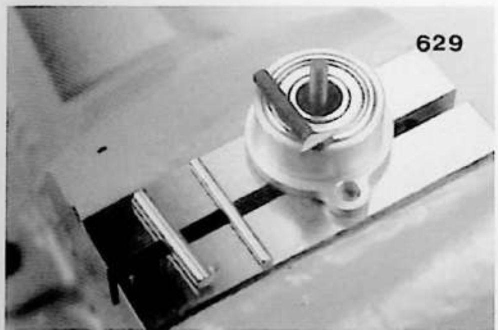
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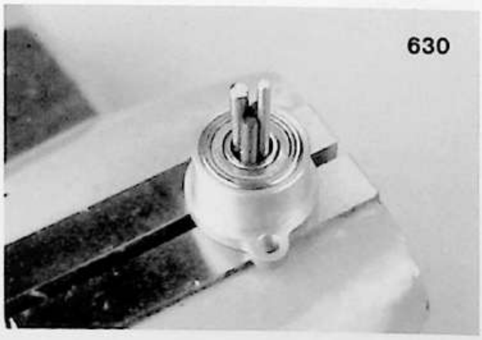
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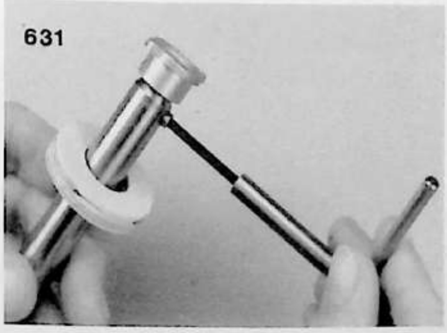
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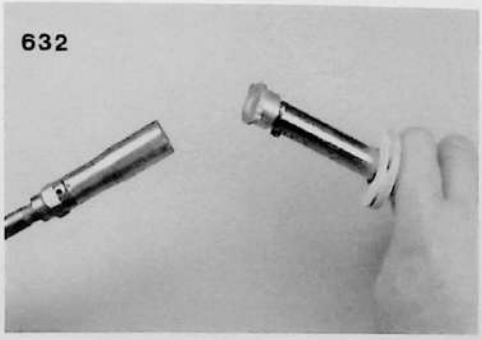
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sharply, the most stubborn bearing comes out (633-635). Mark's puller easily removes the other bearing, which lies deep in the block. We use tweezers to insert the screws and wires in the same order as before (636), and tighten the set screw through a pushrod hole (637). With a little heat (638) and a smart blow of the slide against the striker plate (639), the bearing comes out without a hitch.

To complete this engine's disassembly, the main bearings come out as we explained in Chapter Fourteen and the rockers come apart using methods presented in the last chapter. Now you can remove varnish, replace broken parts, or do whatever other task made the disassembly necessary.

REASSEMBLY

An OS four-stroke goes back together in about the reverse order it comes apart, beginning with all four ball bearings and the crankshaft. Chapter Fourteen explains how the main bearings go in, and that should be done now. Put one cam bearing on the camshaft, heat the bearing cover (640), and push the bearing into the cover (641). Let everything cool down so these parts can be handled during the next operation. With the block clamped in a vise, heat the cam bearing area (642), and start the bearing into its seat as photograph (643) shows. Then, pull out the camshaft, insert it in the cover, and finish seating the bearing by pushing it with the shaft and cover (644). You could seat the bearings farther with a hammer and nylon punch, but we've rarely found that necessary because OS's aluminum housings expand enough to accept the bearings. The crankshaft must be in place before the final cam installation, so remove the camshaft, check Chapter Fourteen, and put the crankshaft into the block according to those directions.

Some mechanics find the camshaft installation a little tricky because the gears must mesh perfectly, or the resulting incorrect valve timings will not let the engine start, much less run. The camshaft's punch mark must point directly under the pushrods with the crankshaft at TDC (649). Do this by first rotating the crankshaft so the marks on the crankshaft and block line up (645), and tape the shaft (646) so it doesn't move during the next operation. Slide in the camshaft (647) until the gears just begin to mesh with the punch mark located like photograph (648) shows. As you continue to push the camshaft farther, it rotates slightly moving the punch forward to its final position (649). After oiling the region (650) screw the cam cover in place.

Getting the piston and sleeve assembly out of the block was difficult because of the hard-to-remove wrist pin, but the pieces go back together easily. First, follow the piston ring installation instructions, which appear in Chapter Fourteen, and then slip the rod over the crank pin. Put the piston into the cylinder leaving the wrist pin holes exposed, and insert the cylinder and piston into the block (651) until the holes in the block, piston, and wrist pin line up as the arrow in (652) shows. Sometimes, after getting the piston in position, a little prodding with a piece of wire brings the connecting rod into alignment. When all the holes line up, the wrist pin slips into place (653) and you can push the sleeve completely in (654-655). After installing the valve lifters (656), oiling the moving parts (657-660) completes this phase of reassembly.

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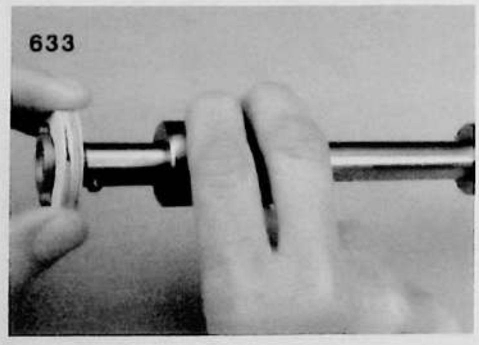

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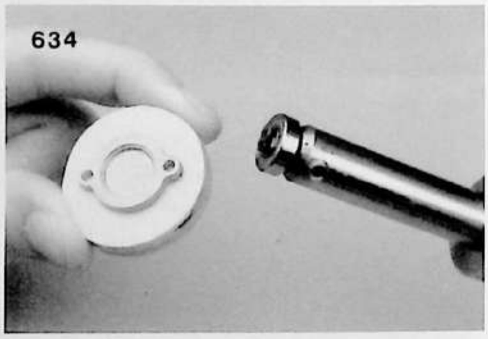

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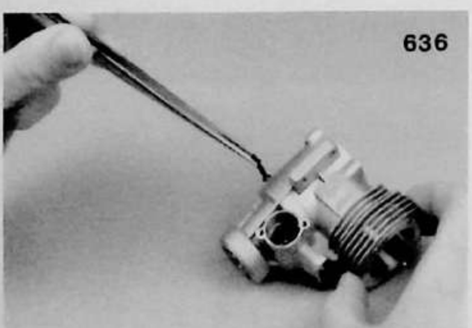

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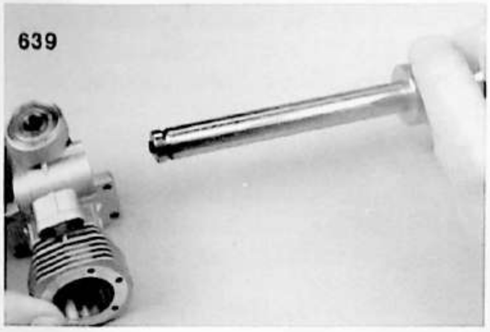
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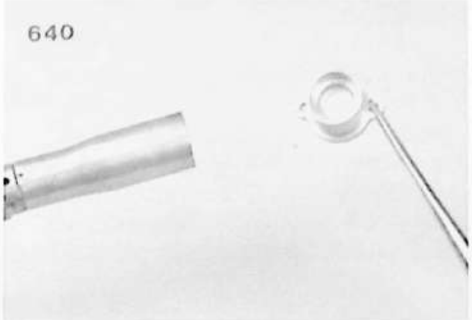
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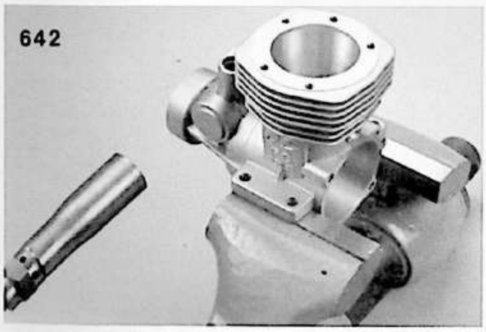
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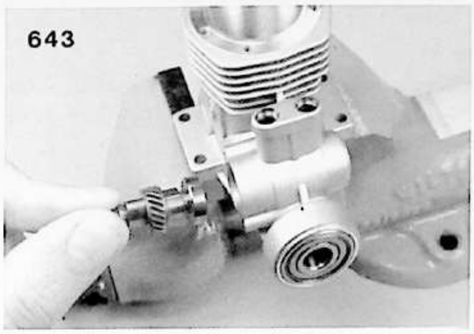
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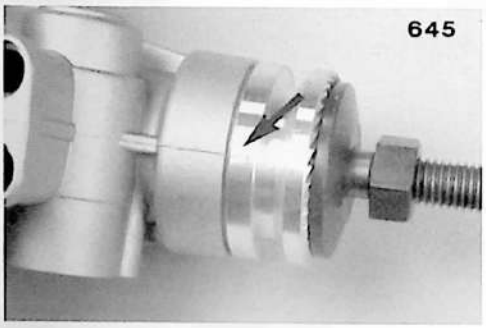
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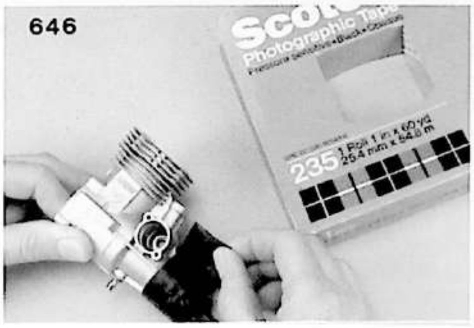

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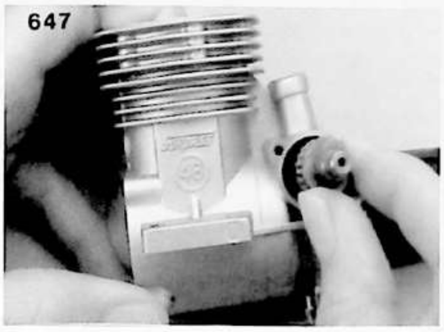
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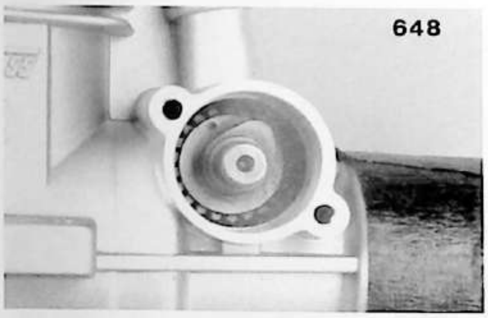
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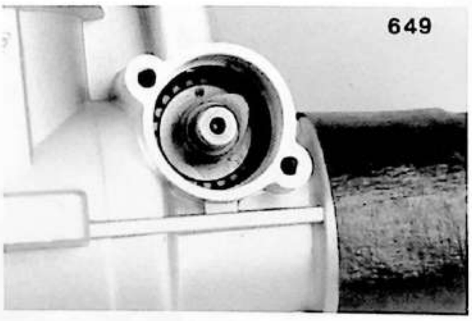
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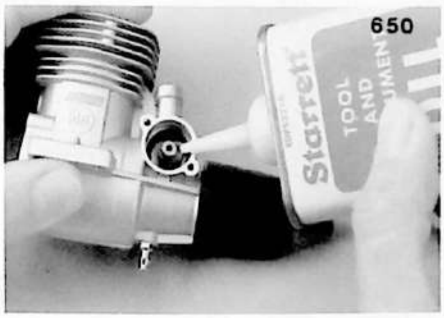

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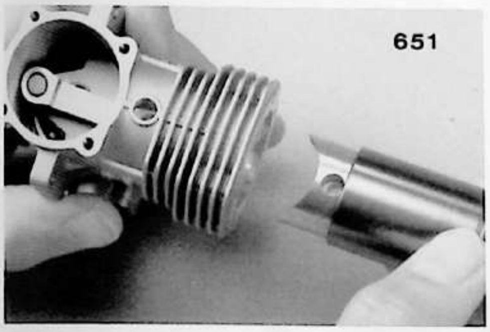
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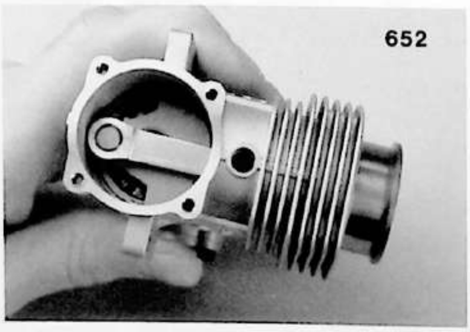
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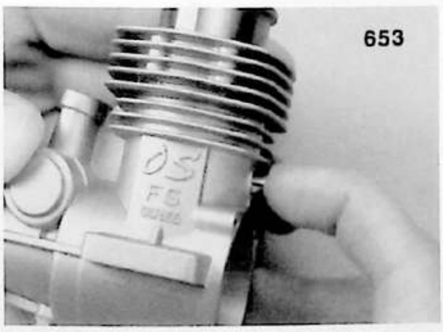
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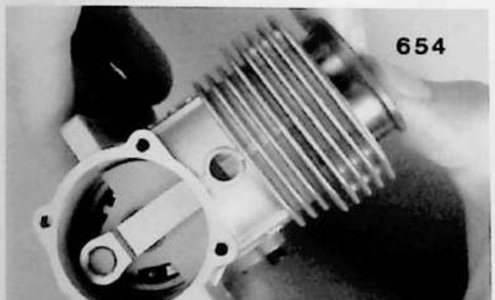
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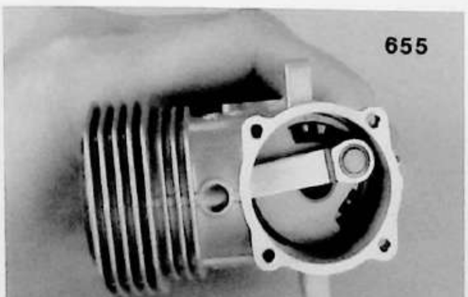
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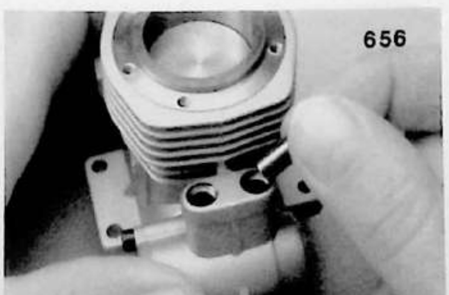
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Now, with the more difficult part of the job behind us, let's finish reassembling the Surpass. Put the rocker arm assembly together at this time. The head reassembles simply enough except for the valve keepers, which require the wood piece shown in (606). The keeper installation appears in (661-662). Next, oil the valve stems from both ends (663-664), and install the pushrods (665) and rocker arm assembly (666). Adjust the valves according to the directions in the last chapter and complete the reassembly.

FILLER PHOTOGRAPHS

The models in (669-671) are all powered by OS four-strokes, which are similar in design to the 48 we just took apart. Pete Mathis built the 60 powered Kavilier. A 120 twin pulls Mitch Koring's Aero Master, and I installed a Surpass 70 in an Astro Hog.

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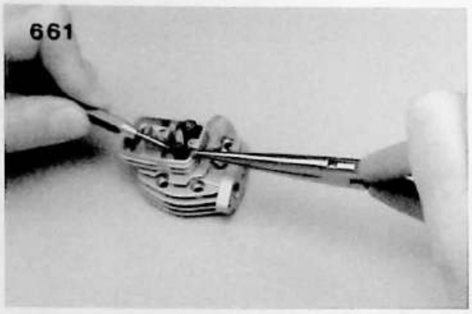

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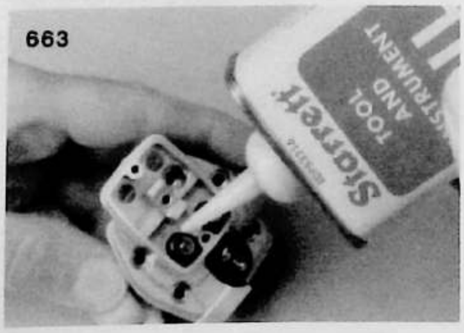

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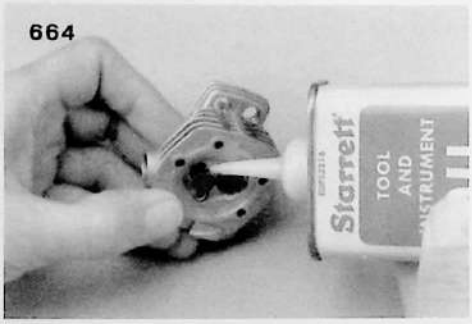

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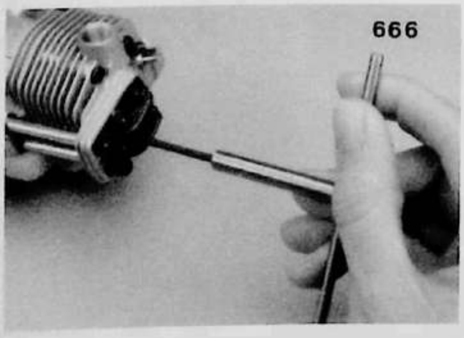

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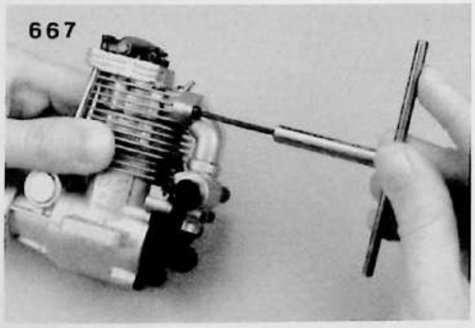

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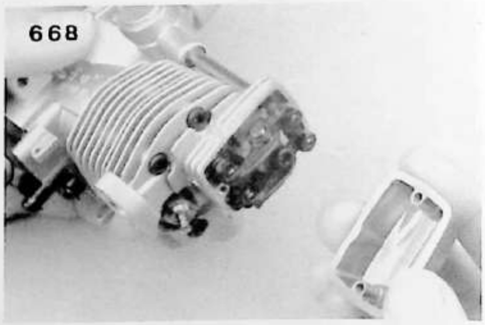

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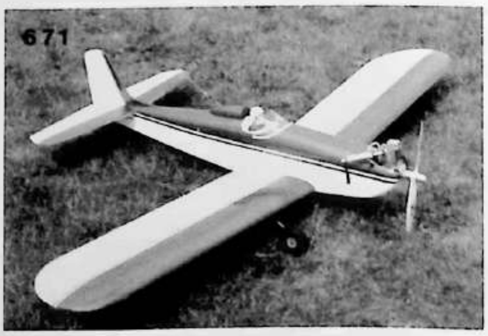

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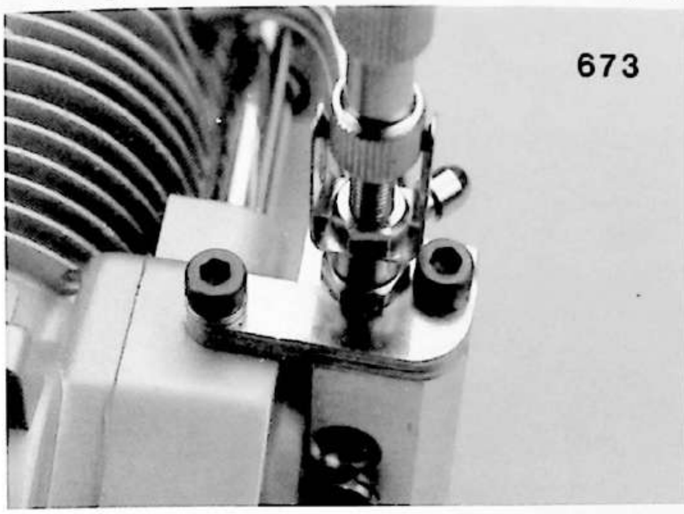
INTRODUCTION

This second chapter in a three chapter series explains how to take an Enya 53 four-stroke engine apart and put it back together again. Enya four-stroke owners will need to know these things for an overhaul or repair. Many steps in the Enya procedure are similar to those for the OS, but we decided not to reference the OS chapter. A complete Enya sequence appears here, except common maintenance procedures that were covered in Chapters Thirteen, Fourteen and Seventeen. While this complete approach saves you time flipping pages between the OS and Enya chapters, you'll notice some duplication between them.

GETTING THE HEAD OFF AND APART

We'll begin with two suggestions. A four-stroker has many easily-lost pieces, so before removing anything, find a container with a screw lid. Our photographs show a glass dish, but a peanut butter jar would be better. While our sparkling new Enya 53 (672) did not need cleaning, any used engine should be cleaned up using the special four-stroke method appearing in Chapter Thirteen. Now, let's begin disassembling. Before you remove all the head screws, several small parts must come off. Two screws and a pair of metal mounts attach to the carburetor and timing gear housing (673). Remove the screws (674), carburetor mounts (675) and carburetor (676).


672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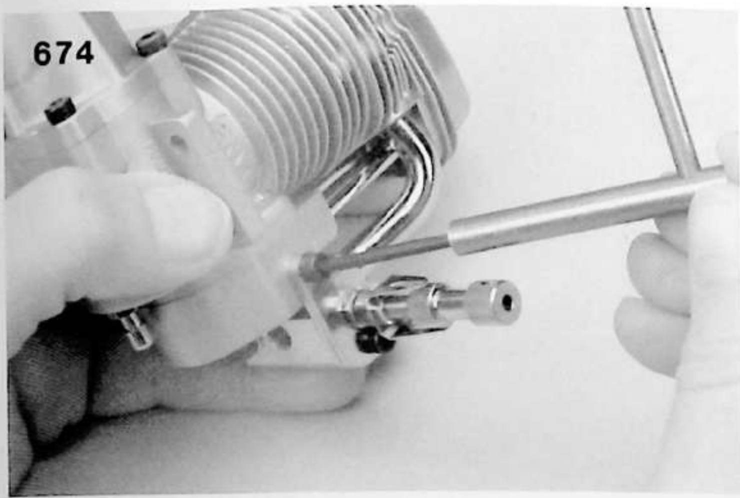
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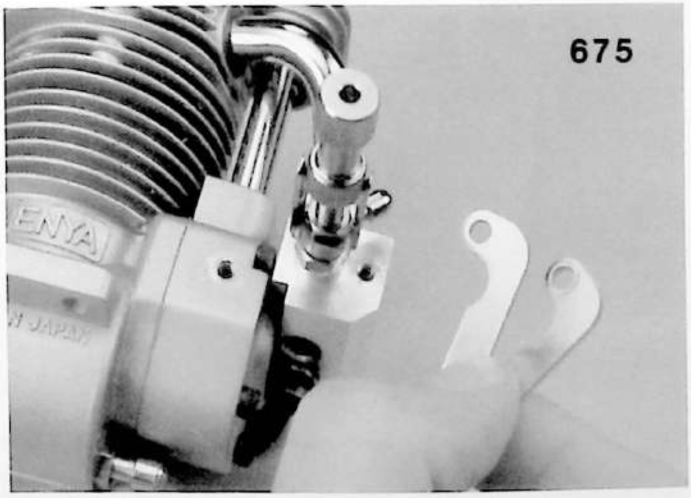
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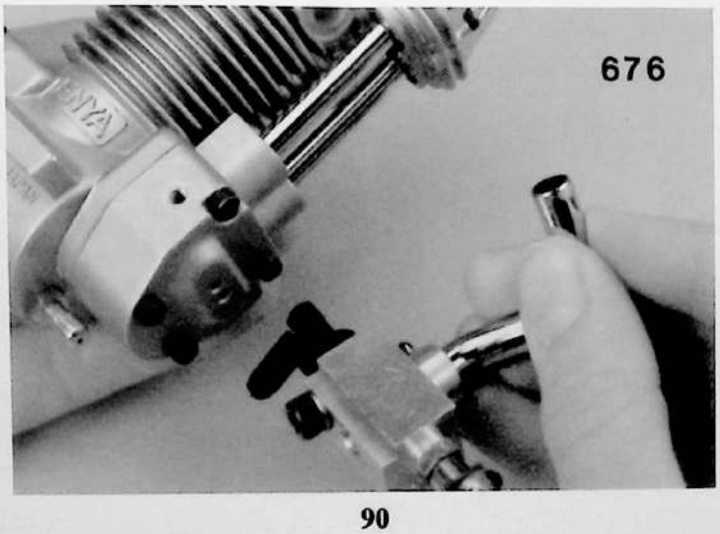
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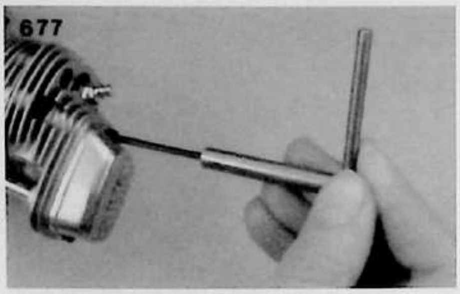
Now, take off the rocker cover (677-678). The 53 has been partially disassembled as (679) shows. Set all small parts in the container. Loosen the rocker arm lock nuts (680) and back the adjusting screws out a turn or two (681). The rocker arm screw, shown by the arrow in (682), also serves as a head bolt and must come out at this time. Remove the pushrods (683), four remaining head screws (684), head and pushrod tubes (685). The engine is now separated into its two main sub-assemblies, the block and head.

We'll take the head apart next. Enya four-strokes all have soft aluminum head gaskets [see the arrow in (686)] that tend to stick and are easily ruined if you try to pull them off. Unless this gasket appears damaged, just leave it in place. Let's move on to the valves. The head close-up (687) shows some very small but important parts, and you need to know their names. Enya calls the semi-circular pieces "valve keepers" and the small disk in which they ride, a "keeper seat". As you can see, the spring must be depressed before the keepers will come out. A 1/8 inch plywood piece (688) holds the deeply-recessed valves, shown in (686), and seats together. Otherwise, the keeper and keeper seat move down together when the spring is depressed instead of the way (689) shows. When that happens, the keepers will not clear the keeper seat. With the wood in place, use a scriber or small screwdriver to push down the keeper seat (689) and the keepers will normally fall off the valve stems. The keeper seat, being under heavy spring tension, will fly off if the screwdriver slips. For that reason and many others, anyone working on engines should wear safety glasses. Incidentally, lost keeper seats seem to hide themselves well, so take the following precaution. After the keepers drop off the valve, put your free index finger on the valve stem end to stop the keeper seat if it should spring free. Then, carefully let the keeper seat up. As an alternative, hold the head over the small parts container and, while keeping the valve against its seat, depress the keeper seat (690). The keepers will drop into the container. Next, the springs come off and the valves slide out easily. All the head pieces appear in (691).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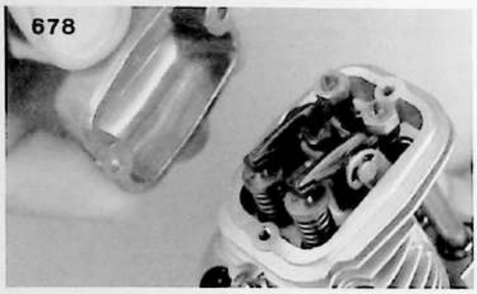
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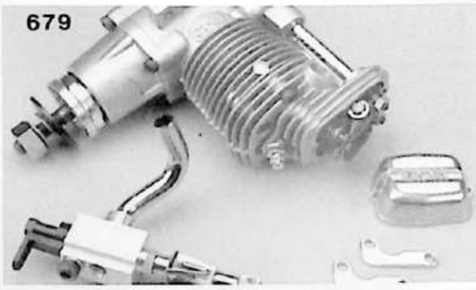
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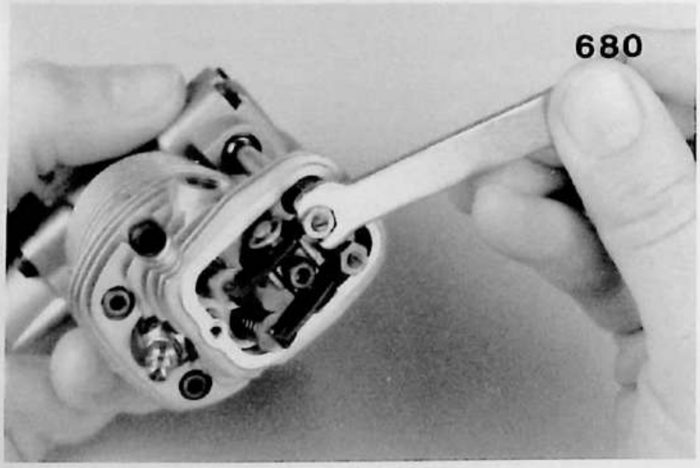
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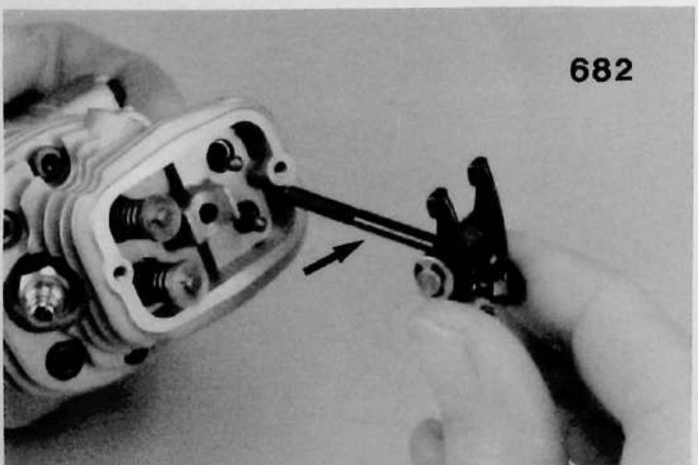
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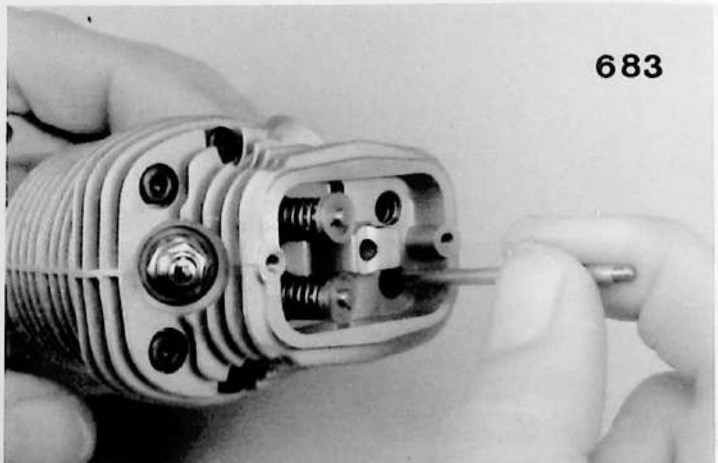
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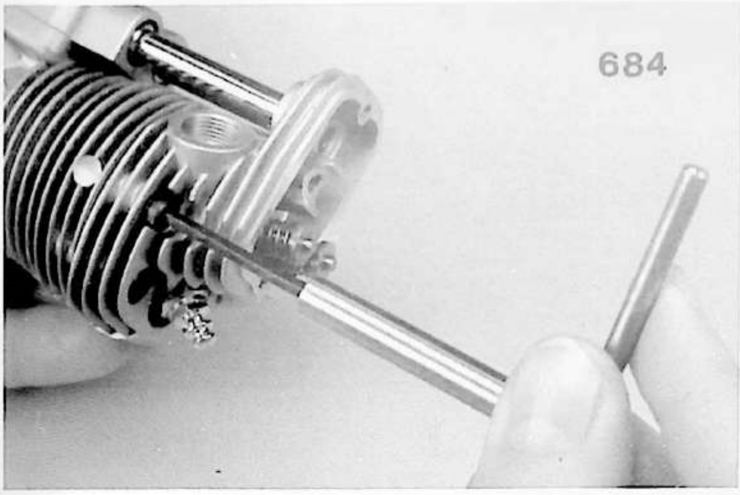
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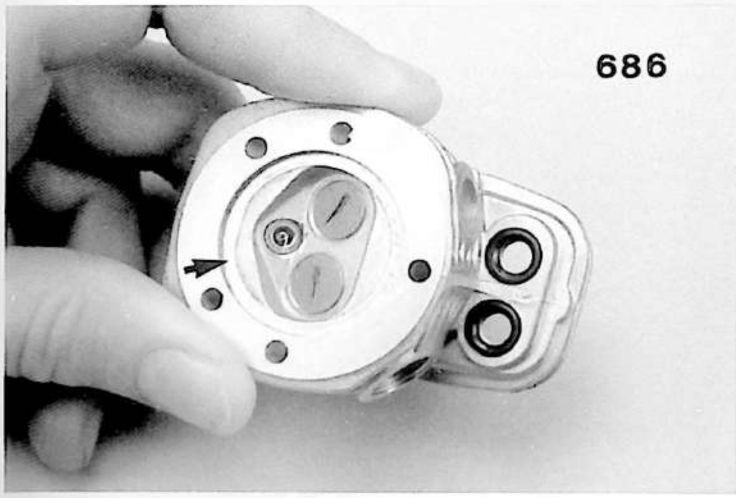
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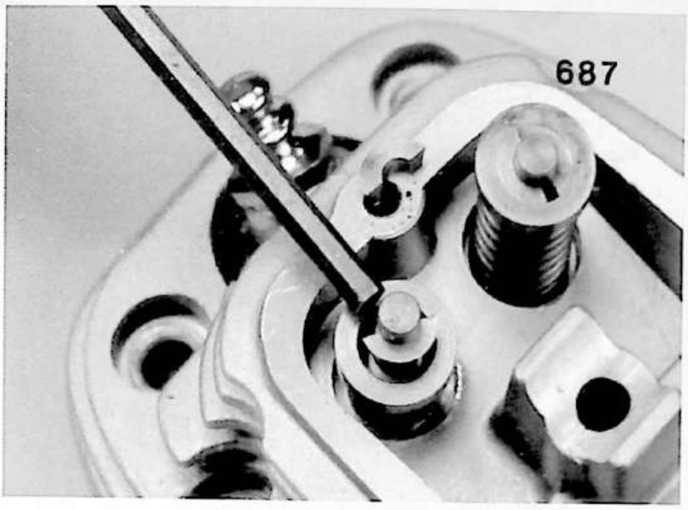
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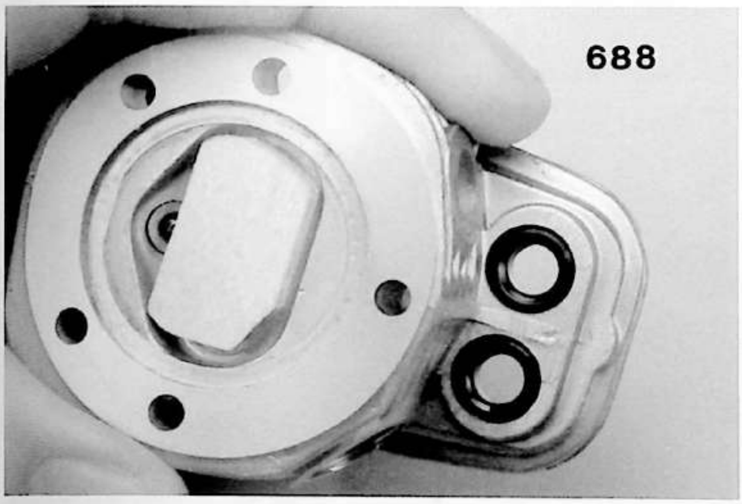
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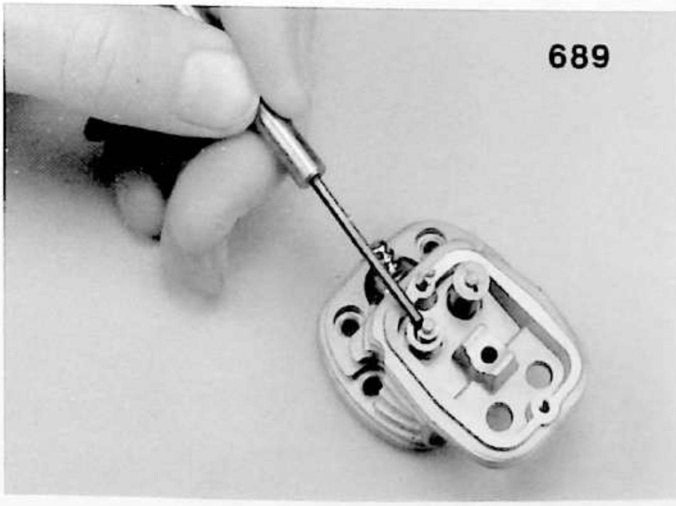
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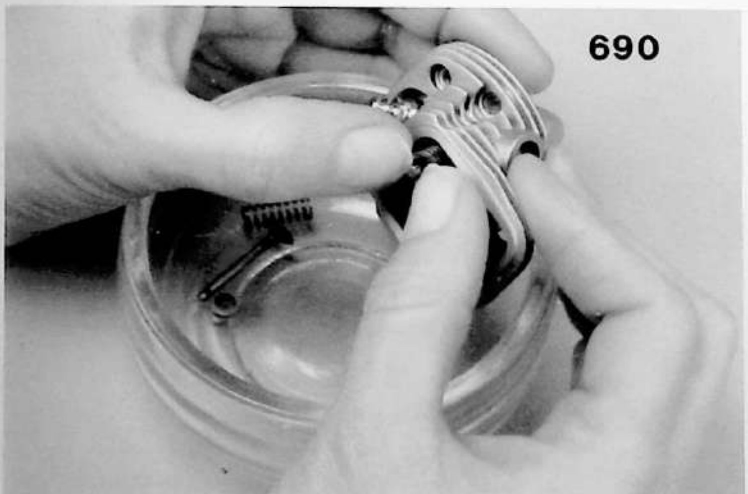
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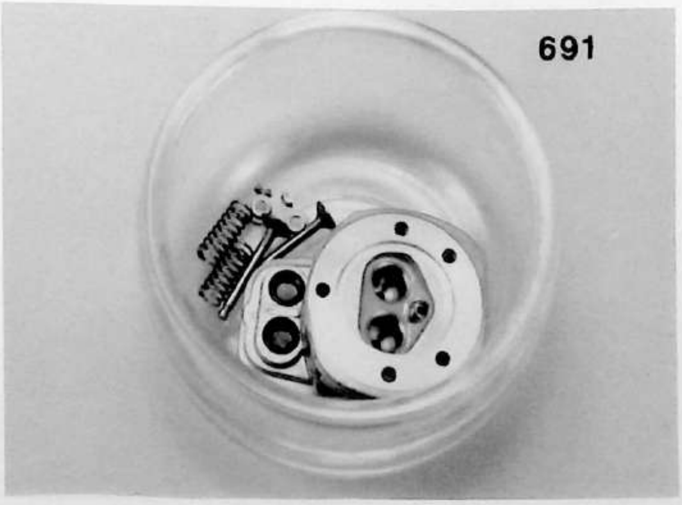
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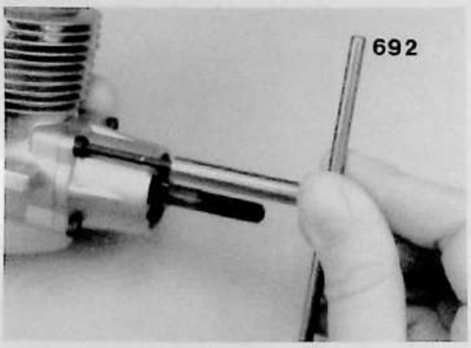
DISASSEMBLING THE BLOCK

The crankcase and cylinder assemblies come out in the following order. First, remove the four crankcase screws (692) and pull the case assembly free (693). Next, the piston and cylinder come out as a unit. If a wood rod won't push the cylinder liner out (694), try the method for removing a stuck sleeve that appears in Chapter Sixteen. After moving the sleeve enough for a good grip, pull it out (695). Then, pull the piston from the bottom of the cylinder liner (696). Remove the piston ring and take the wrist pin out using methods that appeared in Chapter Fourteen. Finally, pry out the "O" rings (697).

Now, the gear mechanism comes apart. Take the four timing gear cover screws out (698) and pull the block and cover apart (699). Be careful not to break the fragile paper gasket shown by the arrow in the last photograph. If the gasket sticks and doesn't break when the pieces separate, just let it stay. The timing gears and valve lifters come out easily (700-702). Next, we'll remove the timing-gear shaft (703) by striking it from the rear with a light plastic hammer (704) and pulling it out (705). Normally, the timing-gear shaft bearings stay in place. If there is some reason to remove them, they come out exactly like the rear main bearing shown in Chapter Fourteen. If that doesn't free the bearings, refer to section about the special bearing puller in the last chapter.

Enya four-strokers feature a front main bearing retaining clip (706) that comes out with a special tool (707). You can buy it at any auto parts store. After taking the clip off, the main bearings come out almost as we explained in Chapter Fourteen. The engine shown there has a block and crankcase cast in a single piece while an Enya features separate pieces. That difference makes only a single change necessary. After getting the crankshaft out (708), put the block and case back together before removing the rear main. The rockers come apart using methods presented in Chapter Seventeen. Now you can remove varnish, replace broken parts, or do whatever other task made the disassembly necessary.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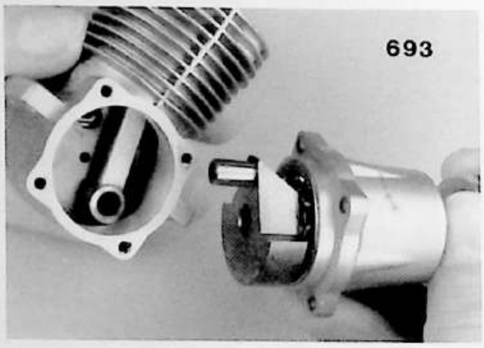
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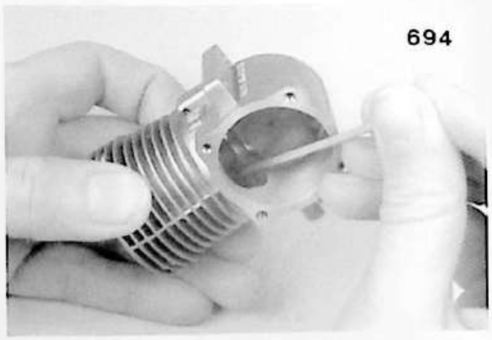
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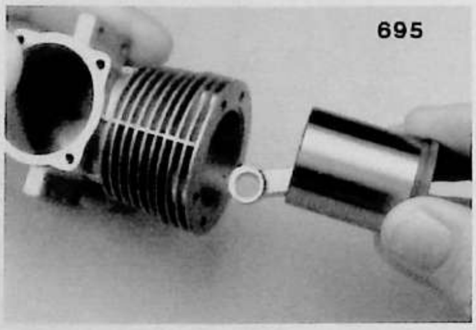
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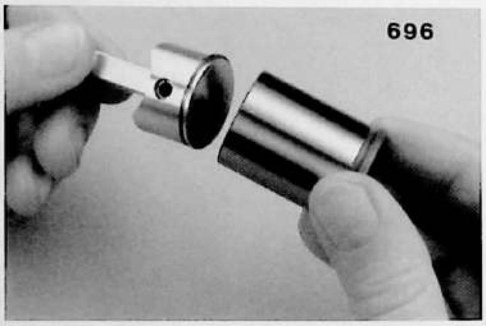
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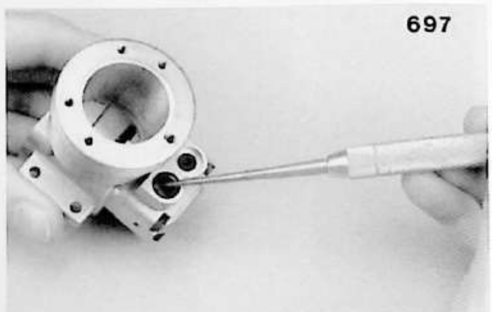
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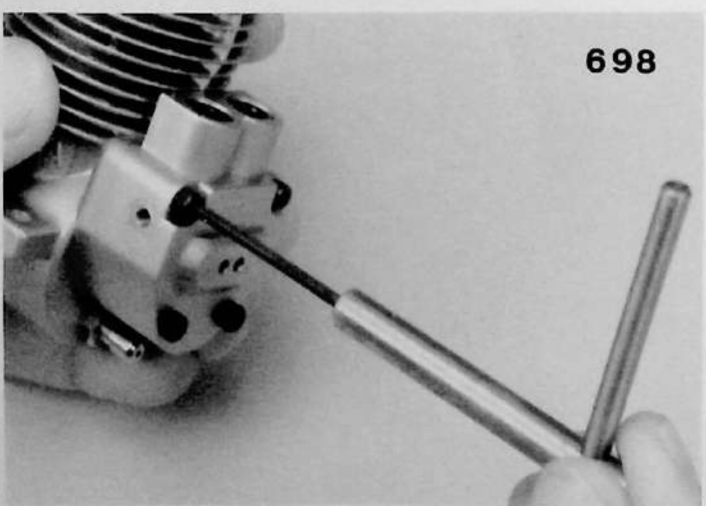
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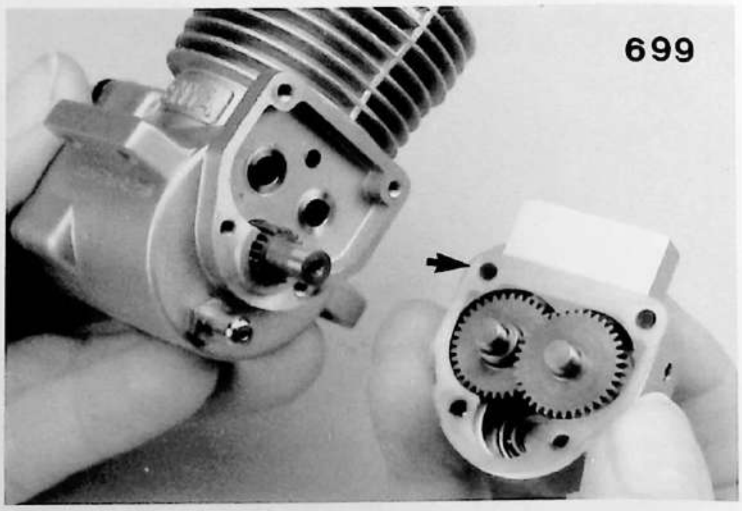
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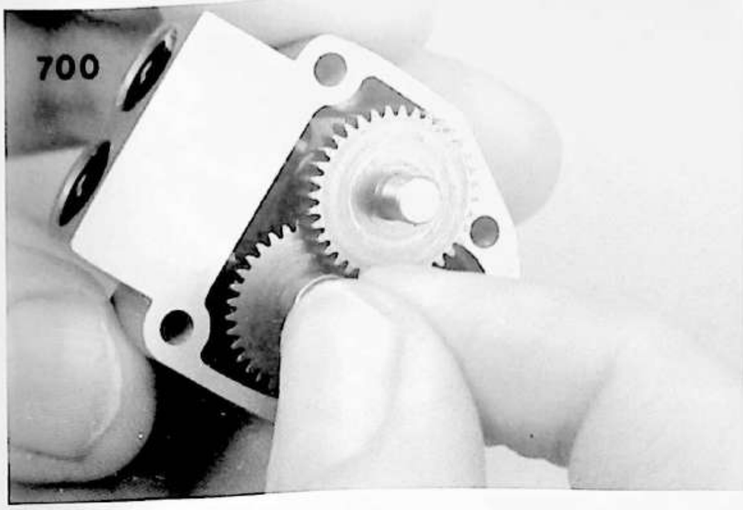
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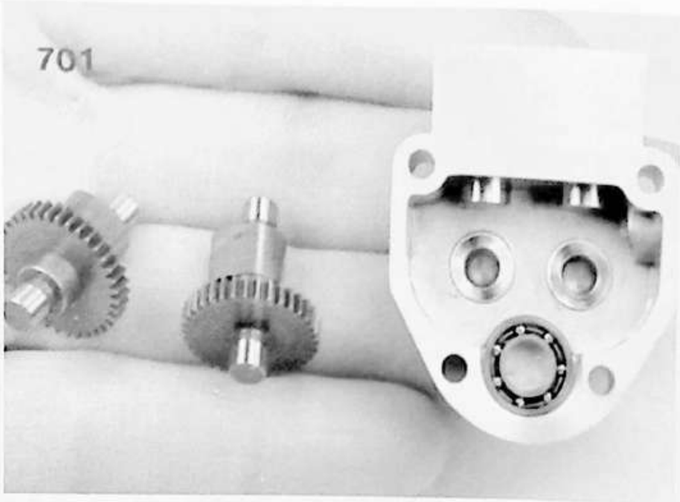
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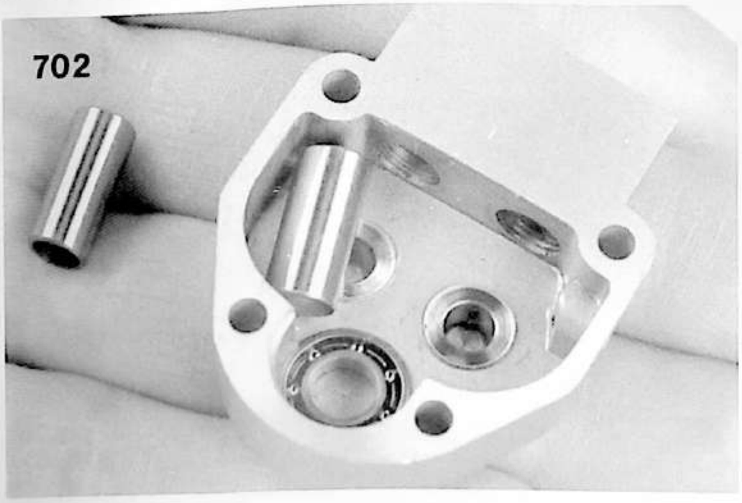
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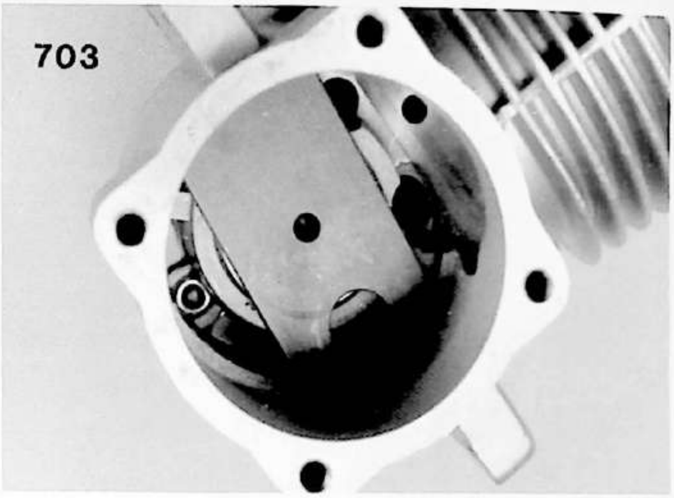
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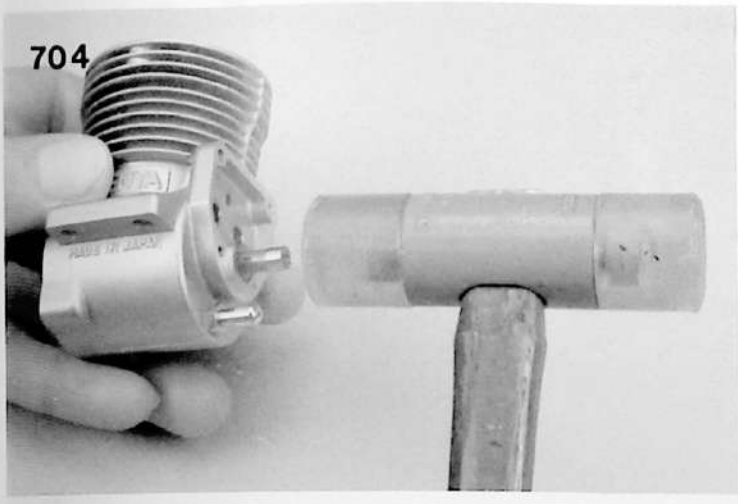
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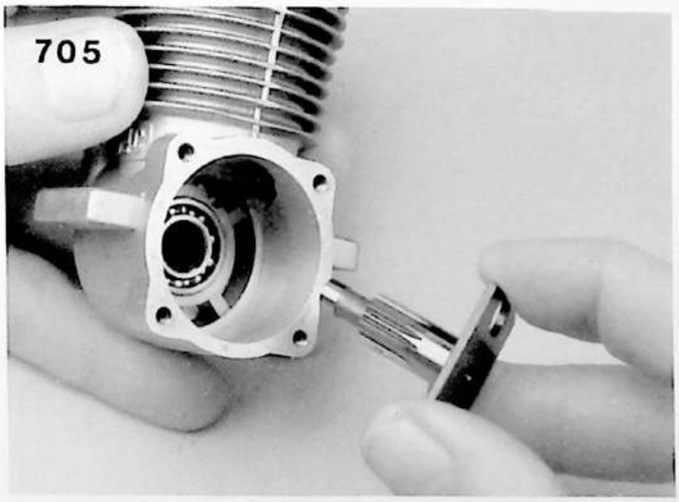
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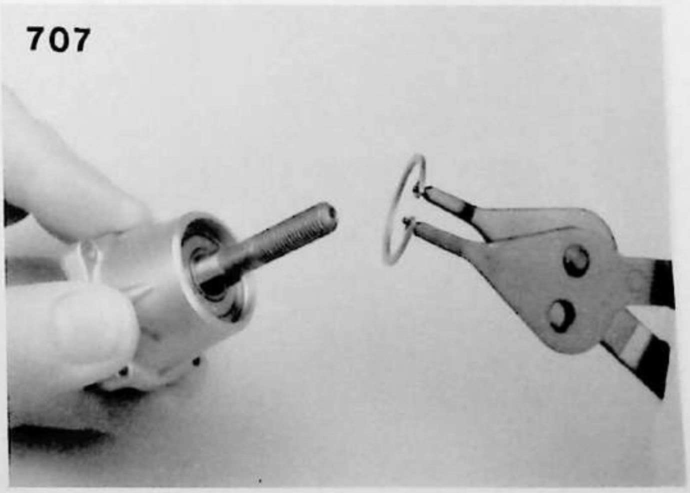
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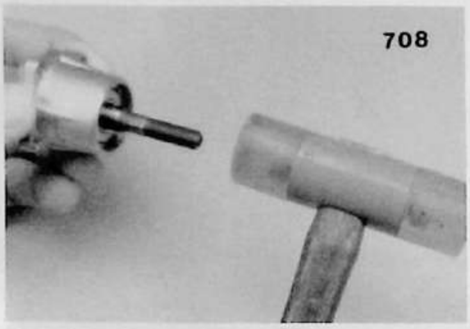
REASSEMBLY

An Enya four-stroke goes back together in about the reverse order it comes apart, beginning with the block and crankcase assemblies. Oil the timing gear bearing (709) and put the timing-gear shaft in by hand (710) as far as it will go. Then, a light blow on the front of this shaft with a plastic hammer and nylon punch seats it in the bearing. Follow the piston ring installation instructions and start the piston into the sleeve (711-712). If you haven't already done so, check Chapter Fourteen because those operations are more involved than these two photographs show. Insert the piston and sleeve assembly into the block (713) and set them aside for now. Chapter Fourteen explains how the main bearings go in, and that should be done at this time (714-715). After oiling the crankpin and lining up the holes in the connecting rod and timing-gear shaft, install the crankcase assembly (716). Attaching the crankcase screws completes this phase of the reassembly.

Some mechanics have difficulty installing Enya's timing gear mechanism because the gears are not interchangeable and they must mesh perfectly. There are two timing gear locations on an Enya block, a left one and a right one. To avoid confusion in this discussion, left and right refer to directions with the engine viewed from behind. In (721) you will notice the front [right] cam goes all the way to the gear face, and the rear [left] cam does not. The timing gear with the cam that doesn't go all the way to the gear face lifts the intake pushrod. As you look at the engine from the rear, the intake timing gear is always in the left position. Reference dots on the timing gears and short lines on the timing shaft, shown by arrows in (718), must be correctly aligned. The timing-gear shaft's two reference lines should point up during the timing gear installation. The tooth marked by a dot on the intake timing gear must lie between the teeth indicated by the left line on the timing-gear shaft (719). After putting in the intake timing gear, drop the exhaust timing gear in place (720-721). Notice the exhaust timing gear references also line up correctly in that shot. Installing the timing gear cover, (723-725), proceeds routinely. After dropping oil down the valve lifter holes, complete the block reassembly by installing the lifters (726) and "O" rings (727).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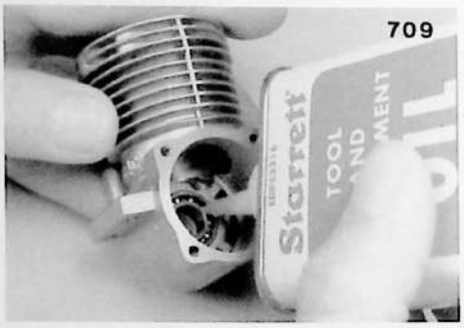

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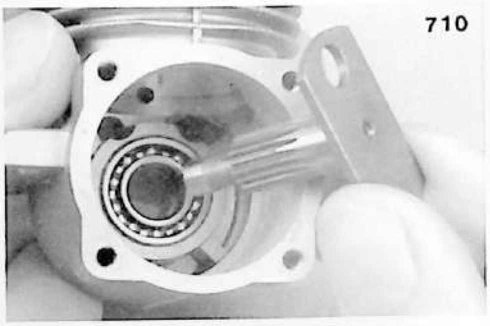
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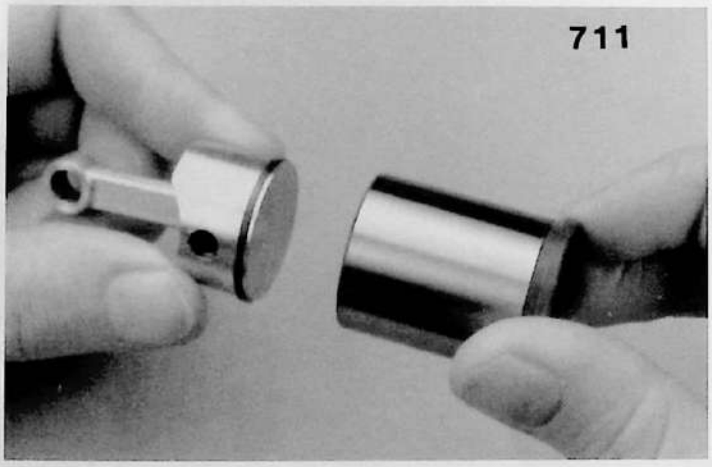
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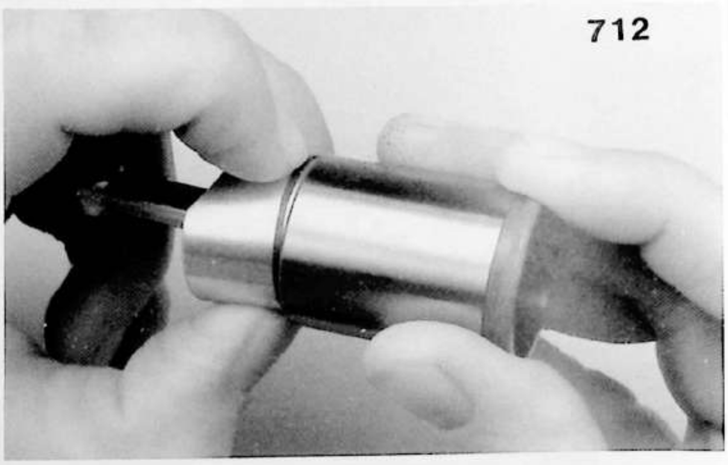
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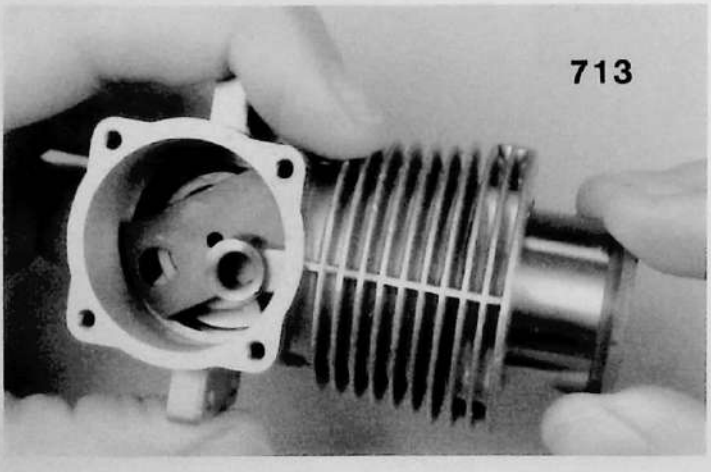
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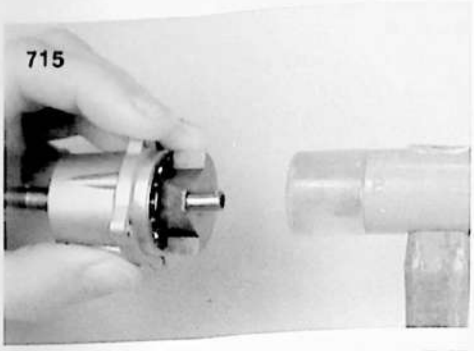
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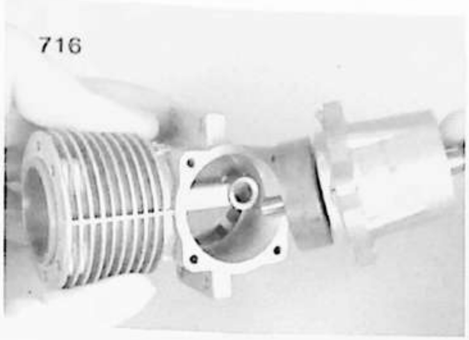
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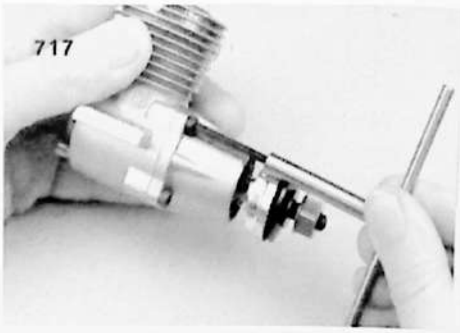
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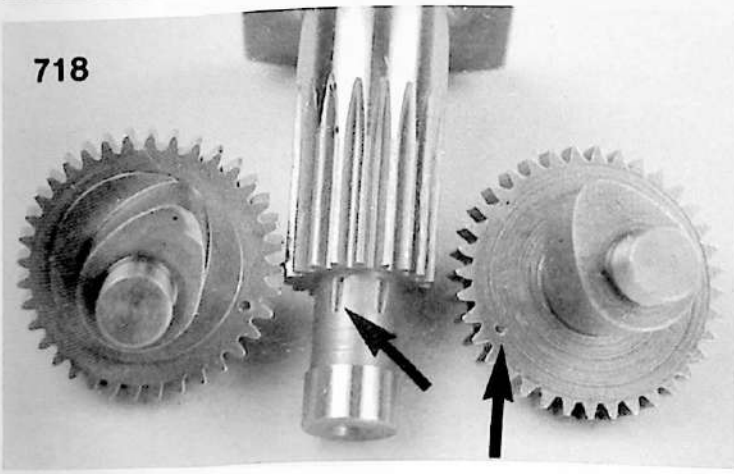
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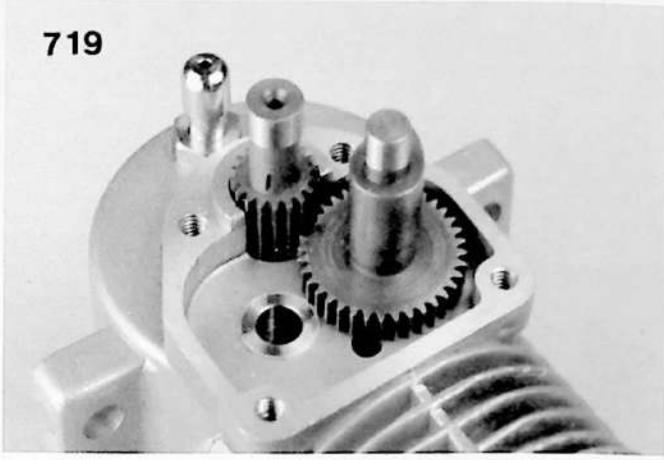
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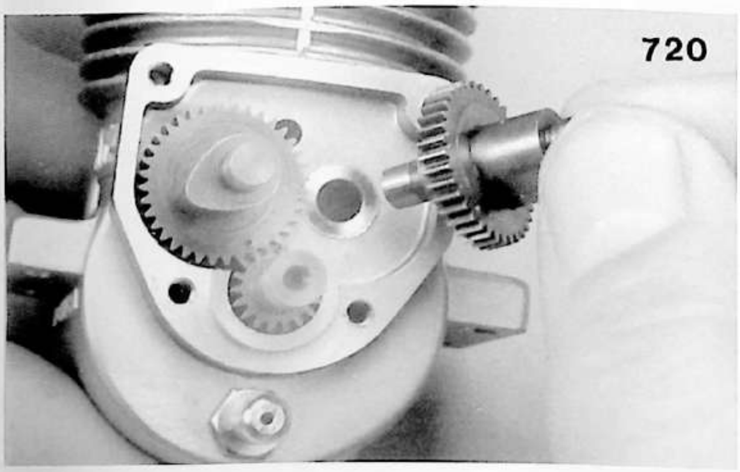
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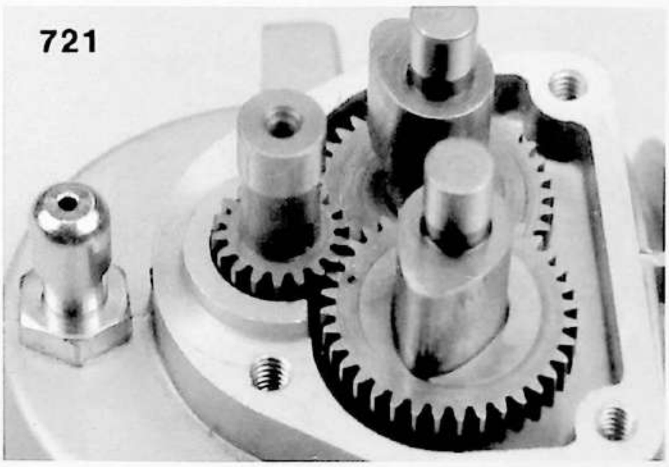
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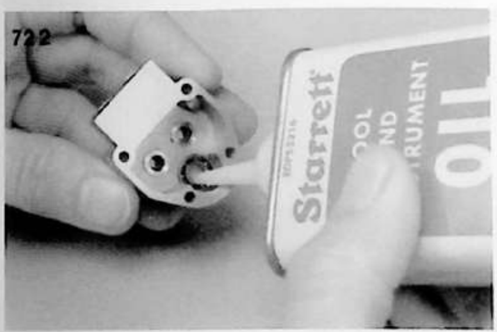

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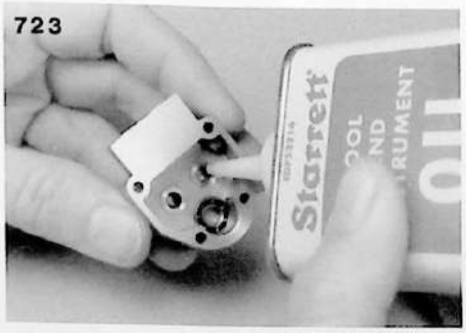

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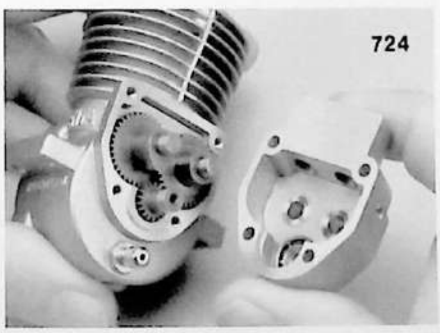
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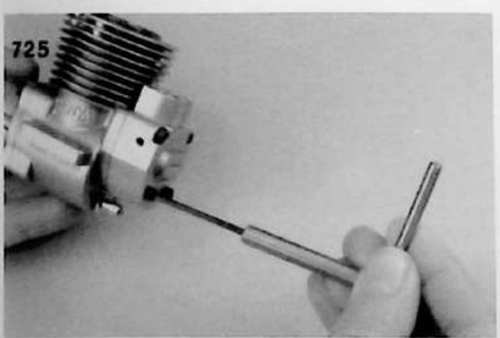
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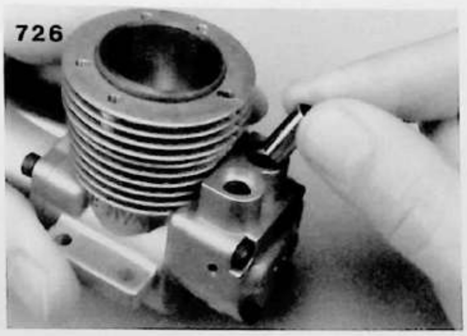
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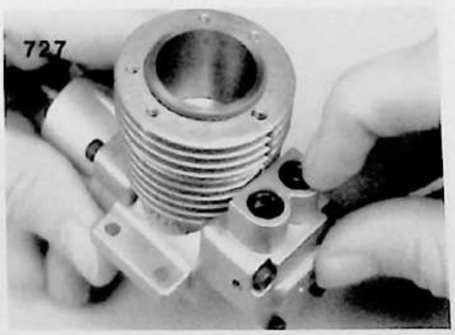
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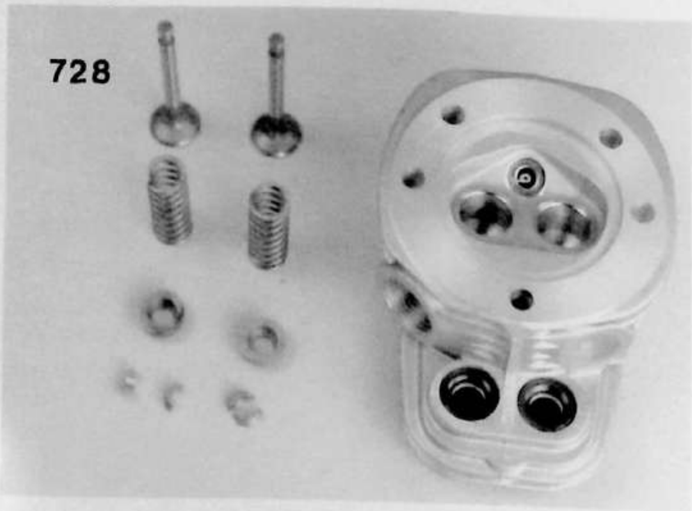
Most parts in (728) go back into the head easily, except the two-piece split-ring valve keepers, which take a special method. Incidentally, larger OS four-strokes also have split-ring keepers and you'll need this method for them too. Slide the valves into the head and put the springs over the valve stems. Set the head upright on your workbench with the plywood piece (688) in position. The next operation requires a rocker cover screw, some different size washers, a 2mm Allen wrench and long-nose pliers (729). Install the rocker cover screw and two washers so they depress the valve spring as photograph (732) shows then slide the keeper seat on the valve stem. Split keepers cannot be safely moved by a bare hand, so pick them up as photographs (730-731) show and set them in the keeper seats (732). We tease the keepers into the valve stem groove with a pencil (733) and, using a long-nose pliers, lift the keeper seat up until it engages the keepers (734). While holding the keeper seat in this position, slowly loosen the rocker cover screw and let the spring assume its normal position (735-736). The same method gets the other valve in place. Next, we'll complete the head by oiling the valve stems from both ends (737-738) and depressing the valves several times to spread the oil (739).

Now, with the more difficult part behind us, let's finish reassembling the Enya. Attach the pushrod tubes and head to the block (740-741). Put the rocker arm assembly together at this time. Then, drop in the pushrods and screw the rocker arm assembly in place. Adjusting the valves according to the directions in the Chapter Seventeen and attaching the rocker cover (742), carburetor, and a few other small parts leaves our Enya ready to run (743).

728



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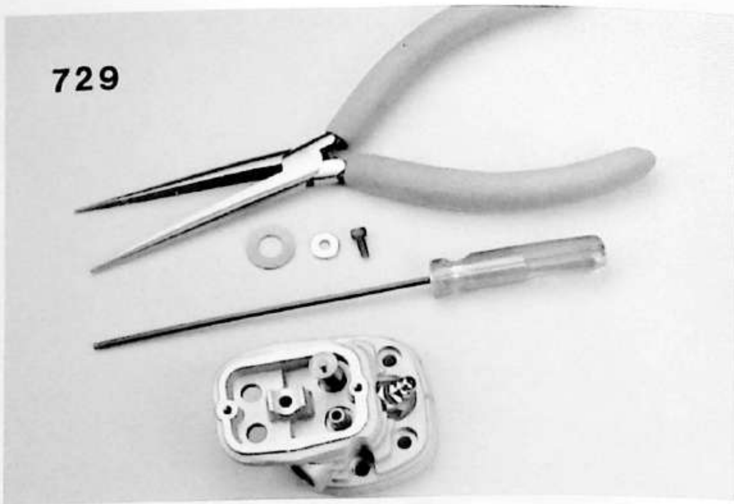

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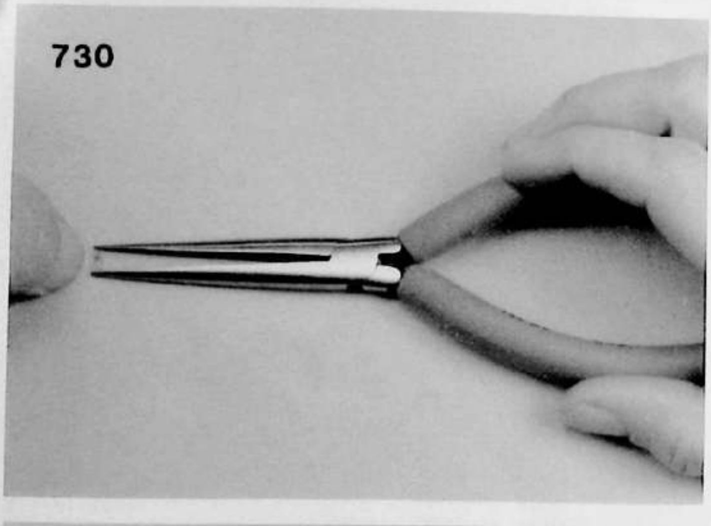

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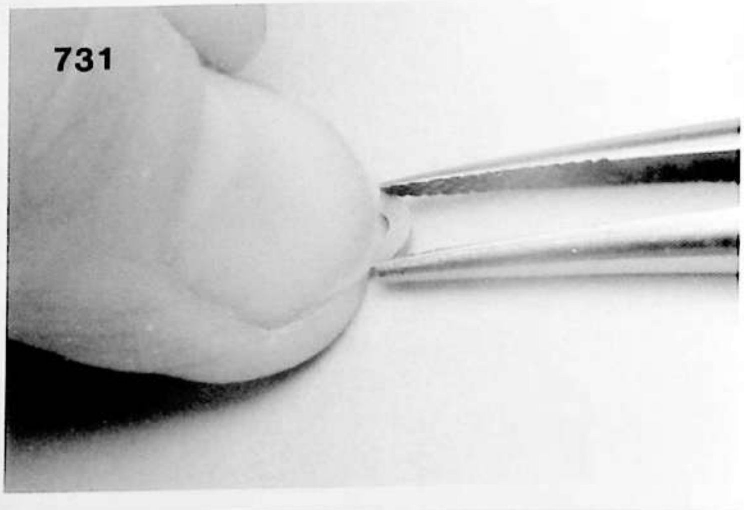

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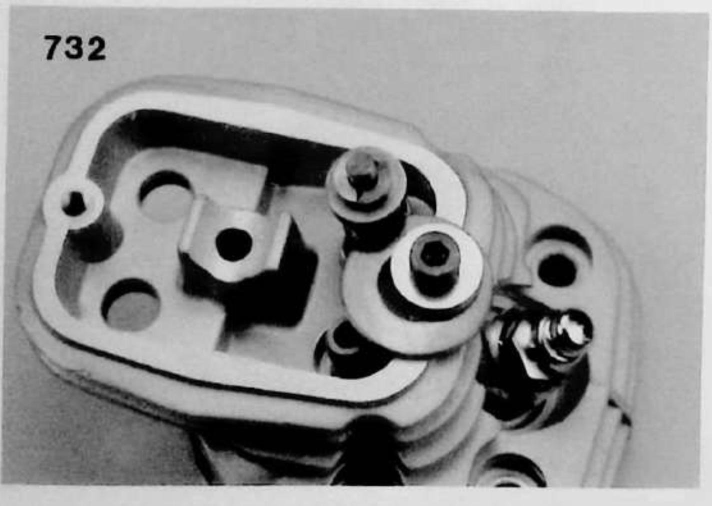

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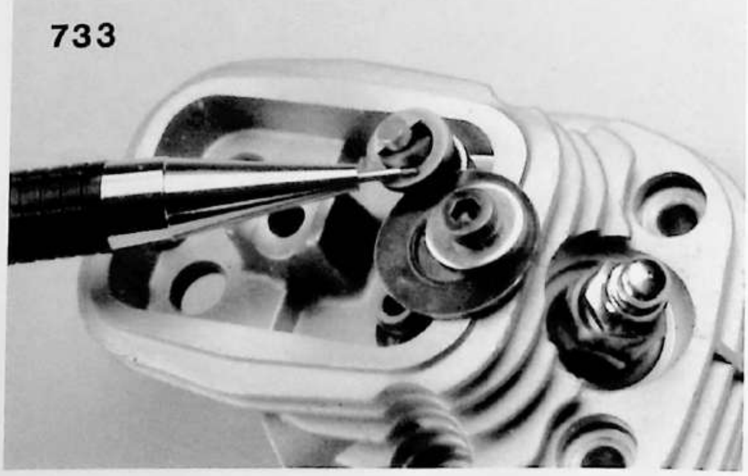

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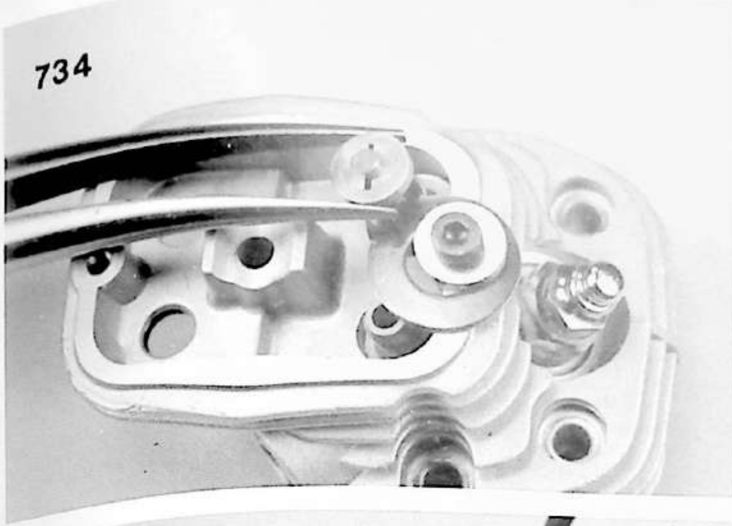

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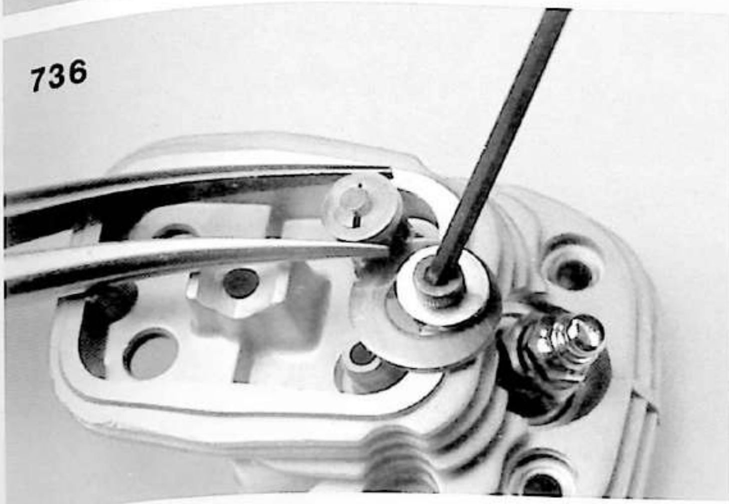

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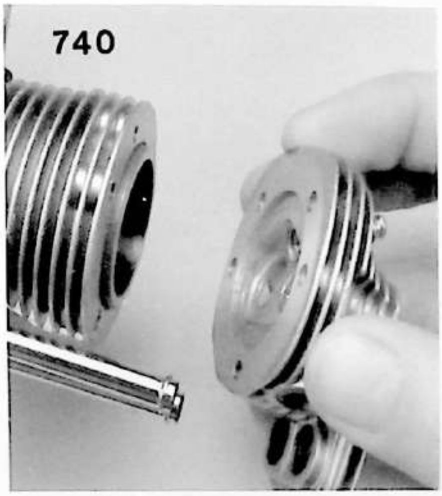

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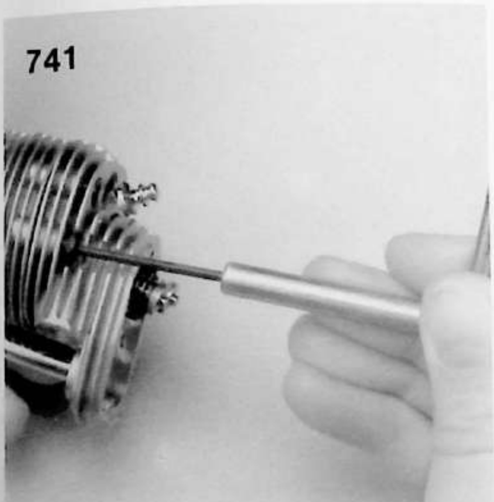

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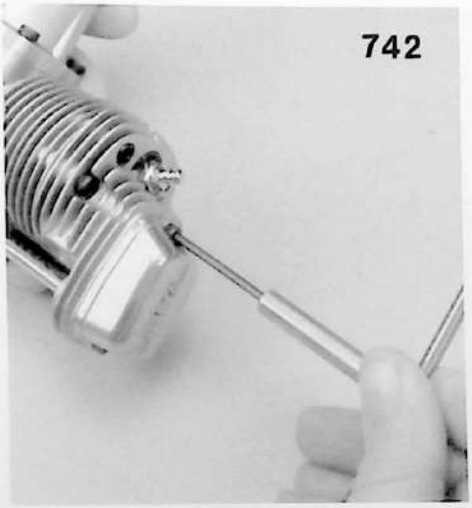

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CHAPTER TWENTY
SAITO FOUR-STROKE DISASSEMBLY

INTRODUCTION

Chapter Twenty completes our four-stroke disassembly coverage by showing how a Saito 50 comes apart and goes back together. Most engines have removable heads, and many also feature separate cylinder liners, however Saito designs engines very well but in their own way. Saitos have three major sub-assemblies, the cylinder/head (772), timing gear (773), and block (774). Since our earlier explanations do not apply to engines made this way, a complete Saito disassembly and assembly appear here except for maintenance procedures that apply to nearly all engines. These common procedures include things like cleaning and piston ring removal. You can find them in Chapters Thirteen, Fourteen and Seventeen. Anyone who must repair or overhaul a Saito needs the information included those three chapters and this one.

DISASSEMBLING THE CYLINDER/HEAD

We'll begin this section as we did in the earlier four-stroke chapters with two suggestions. A four-stroker has many small, easily-lost pieces, so before removing anything, find a container with a screw lid. Our photographs show a glass dish, but a peanut butter jar would be better. The second suggestion is to clean your Saito using the methods that appear in Chapter Thirteen. After doing these things, let's begin the disassembly.

Before you can remove the cylinder/head, several small parts must come off. The single screw, being removed in (744), attaches the carburetor and backplate. Once the screw is out, the carburetor and intake manifold separate from the head (745). In photo (746) the small pieces rest safely in the container before they have any chance to get lost. This initial small parts removal continues with the intake manifold "O" ring (747), backplate (748) and rocker covers (749).

Now is a convenient time to scribe reference lines on the propeller drive washer and block, since a Saito does not have factory scribed lines. Put two fingers on the rockers and turn the engine over (750). At some point you'll feel the exhaust valve close and immediately after that the intake valve opens. In the short interval between these events the piston reaches TDC. Let's do that with a little more accuracy. Put the Saito in a vise, turn the engine over, and watch the valves. The open exhaust valve (751) closes (752) and a very short time later the intake opens (753). Turn the shaft until the rockers assume the positions shown in (752) and scribe the references (754).

A few things remain, and then the cylinder/head can come off. Refer to Chapter Seventeen if you do not understand the difference between a four-stroke engine's two TDCs. Then, use the scribed reference lines to find TDC between the compression and power strokes, which is the correct orientation for removing the rocker arms. The arrow in (755) points to a rocker arm locknut and adjusting screw. Loosen the lock nut, unscrew the adjusting screw about a turn, and unscrew the rocker shafts as that photograph shows. Then, the rocker arms and pushrods (756) come out. Photograph (757) shows the engine and the small parts just before we take the cylinder/head off. Saito attaches the cylinder/head to the block with four very tight screws. A rugged "L" shaped Allen wrench (758) breaks these screws loose, but they must then be unscrewed several turns. A less rugged ball wrench, which can be tilted (759), speeds the screws out after you loosen them with the "L" wrench. Now, the cylinder/head and block separate (760), and the pushrod tubes come out (761).

Let's remove the valves. We displayed a valve assembly in Chapter Eighteen (605) so you could learn the names of two small but important parts. The "C" clip, called a "valve keeper", rides in the "retainer", against which the valve spring pushes. As you can see, the spring must be depressed before a keeper will come out. A large dowel rod (762) holds the deeply-recessed valves against the seats. Otherwise, the valve, keeper and retainer move down together when the spring is depressed (763). Then, the retainer does not clear the keeper and you cannot get it out. With the wood in place, use a scriber (763) or small screwdriver to push down the retainer. Pull out the keeper with a long-nose pliers (764-765). The retainer, being under heavy spring tension, flies off if the scriber slips. For that reason and many others, anyone working on engines should wear safety glasses. After setting the keeper down, put the index finger of your free hand on the valve stem end to stop the retainer in case it springs free. Carefully let the retainer up. Next, the springs come off and the valves slide out easily.


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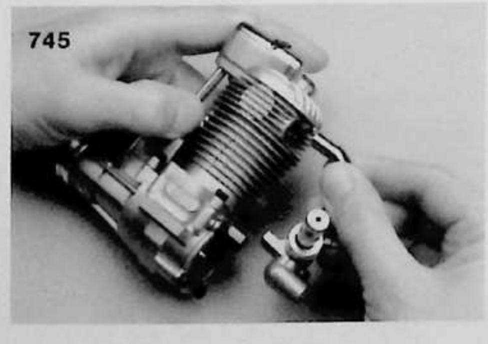
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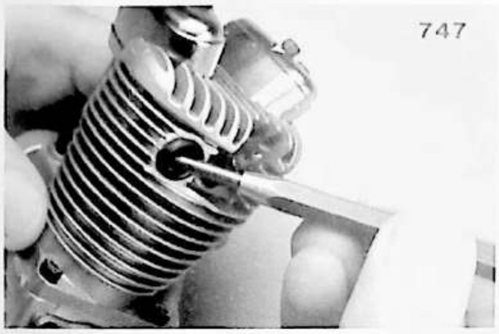
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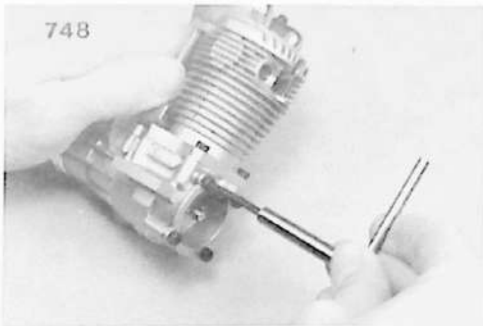
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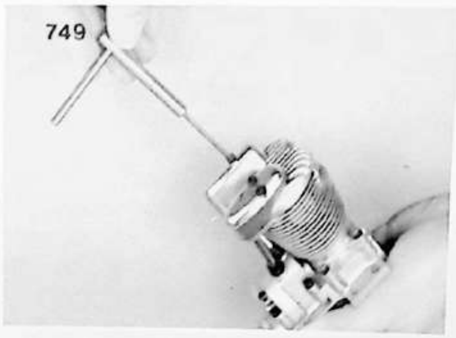
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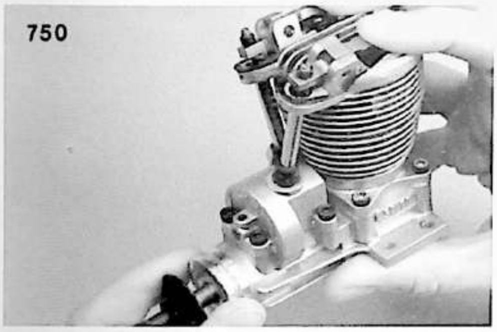
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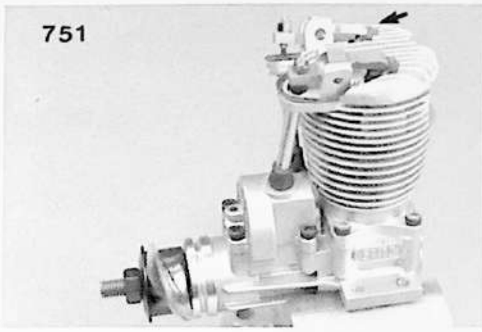
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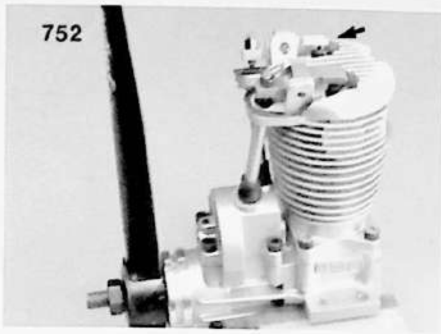
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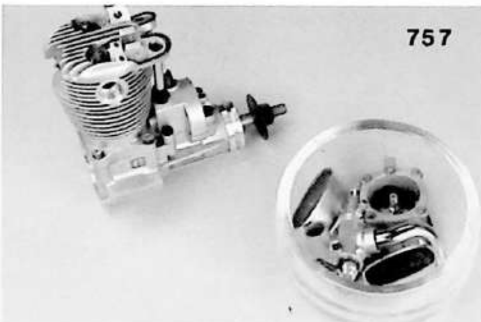
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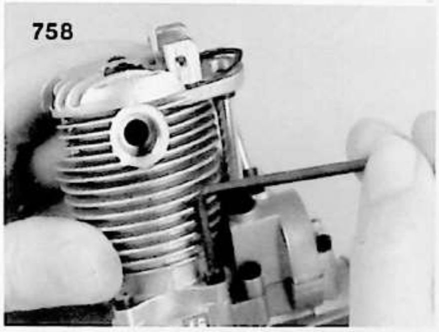
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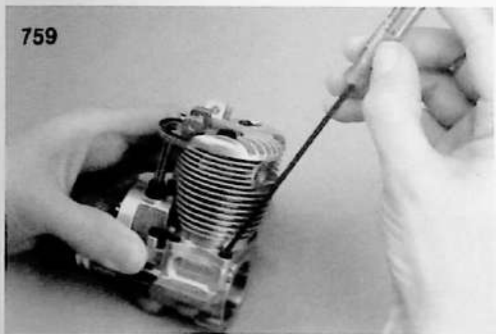
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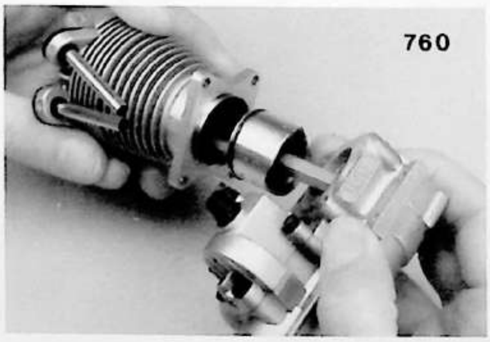
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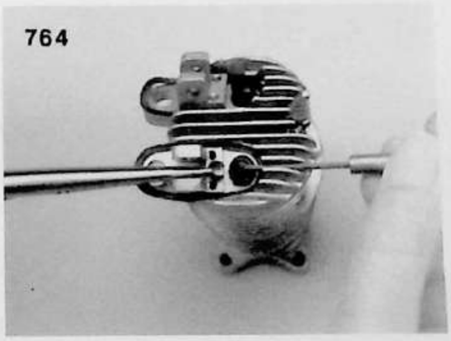
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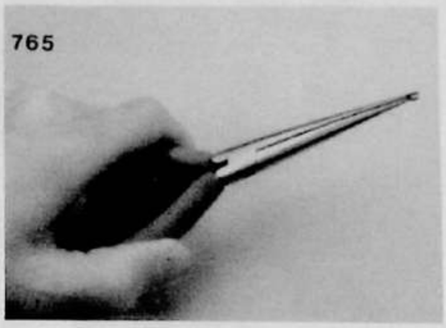
DISASSEMBLING THE BLOCK AND TIMING GEAR ASSEMBLY

Take the piston and rod off the crankpin and set them aside, but not in the small parts container where they could get banged up. I keep a folded rag on my workbench for this. The timing gear housing comes off next by simply removing four screws (766) and lifting it from the block (767). The valve lifters in (768) drop out when the gear assembly is turned upside down. A 1.5 mm Allen wrench removes a single set screw (769) that holds the timing gear shaft in place. Then, the shaft pulls out (770) releasing the gear (771). The arrow in (771) points to a Teflon spacer; remove it before continuing. So far, these efforts have left the cylinder/head (772) and timing gear units (773) completely disassembled, but a little work on the block remains. Take apart the piston, rod, and ring using the methods that appeared in Chapter Fourteen, and the block looks like (774). Chapter Fourteen also shows how to remove the crankshaft and main bearings. Now you can fix whatever made the disassembly necessary.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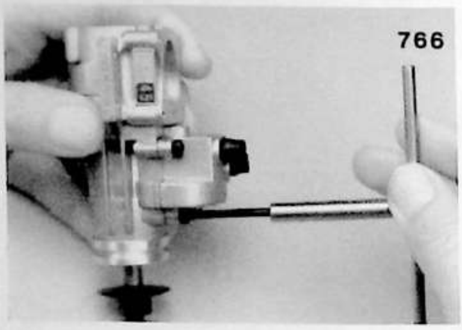
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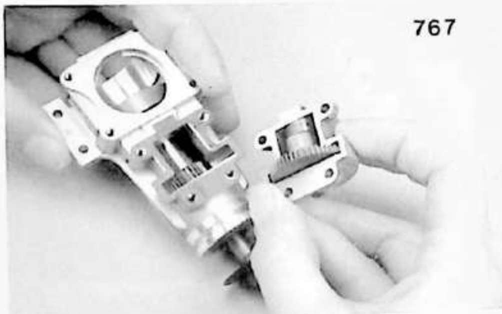
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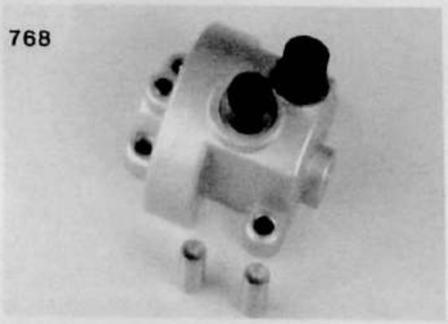
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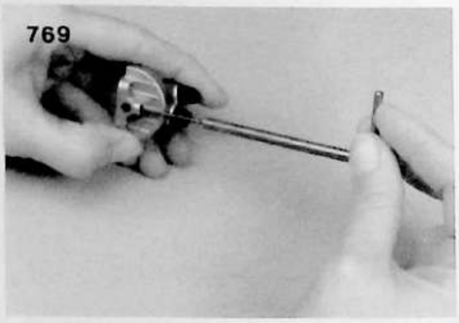
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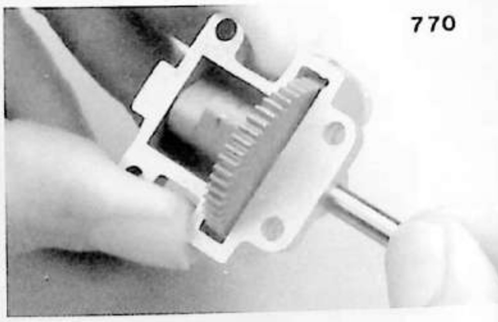
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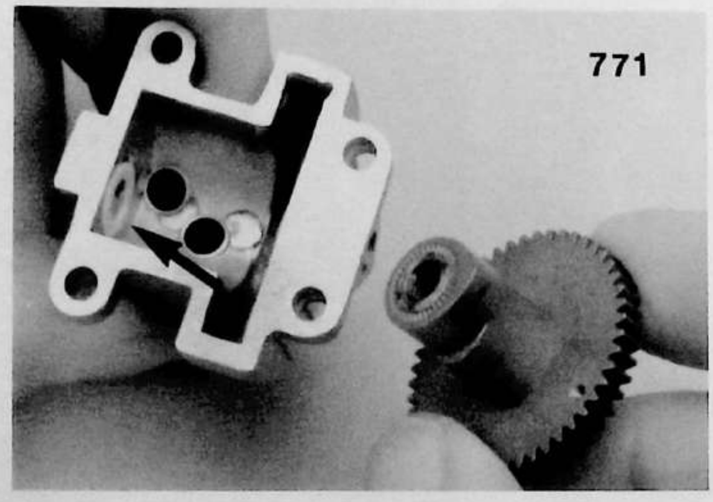
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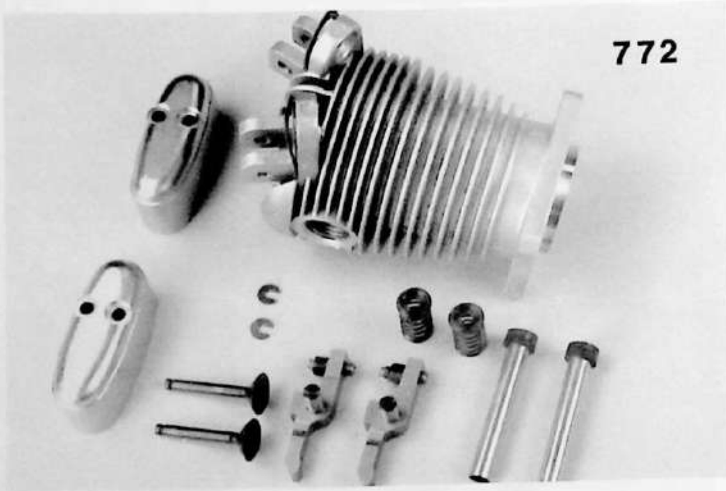
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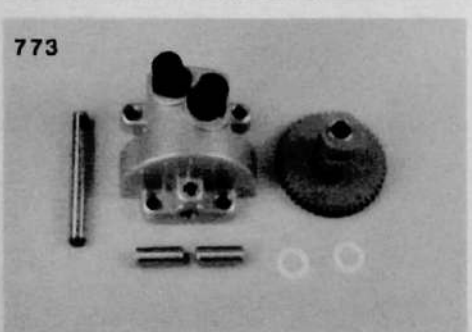
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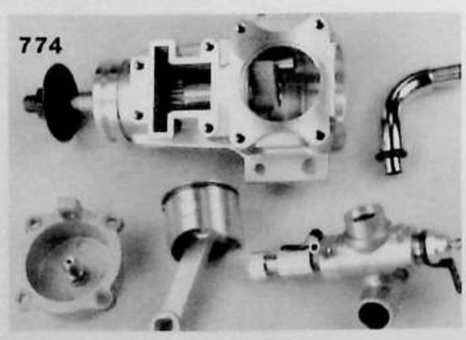
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REASSEMBLY

Most engines go back together in about the reverse order they come apart, and the Saito is no exception. Saito reassembly begins with the block, main bearings, and crankshaft. Chapter Fourteen explains how these parts go together and covers the next step, wrist pin, piston, piston ring, and rod assembly. Set the piston assembly aside until we are ready for it.

Like other four-strokes, the timing gear assembly and valve installation command some careful attention. An oil spot on the housing (775) holds the Teflon spacers (776) in place until we put in the timing shaft. The crankshaft gear has a roll pin between two gear teeth (777) that mesh with a marked tooth on the timing gear (778). After rotating the crankpin to its highest position (779), lay the timing gear on the shaft (780) so their teeth mesh in that manner. With a little care the timing gear cover will go on (781) without disturbing the Teflon washers. Next, a wire or small Allen wrench aligns the holes in the Teflon washers, timing gear and housing (782), after which the timing gear shaft can be inserted (783). Tighten the set screw on the timing gear shaft. Oil the timing gear mechanism through the valve lifter holes (784), and then the lifters can go in (785). Photos (762-765) where taken during disassembly, but shots of the valve installation are similar, and that job should be done now. This completes the hardest reassembly tasks.


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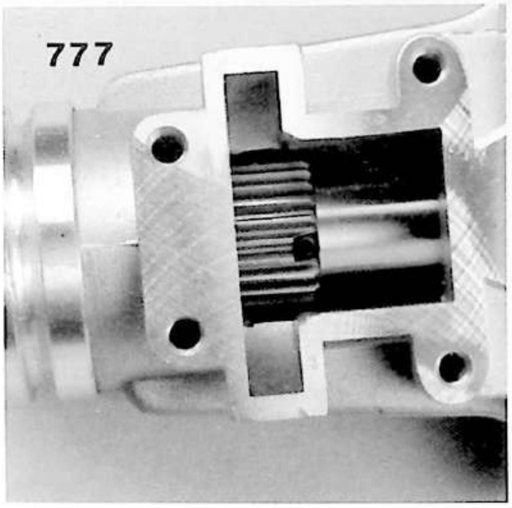
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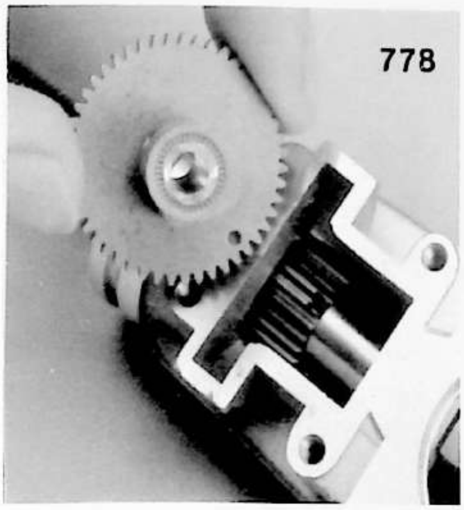
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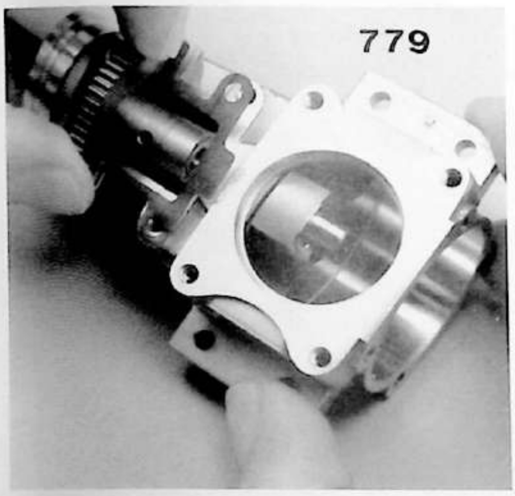
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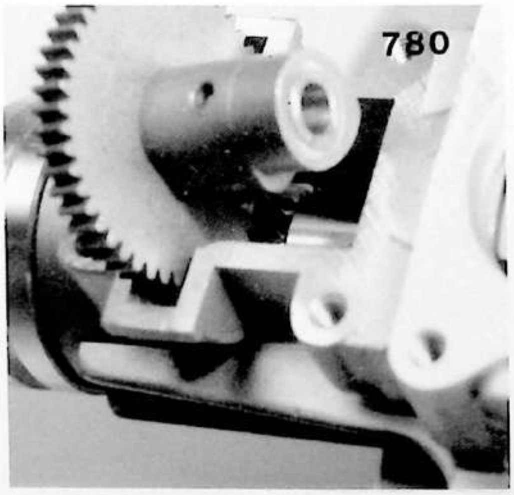
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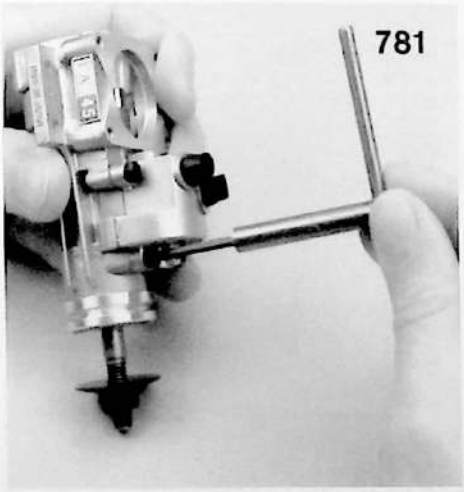
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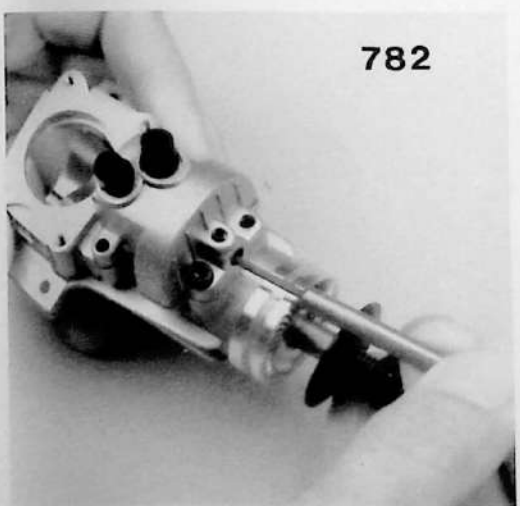
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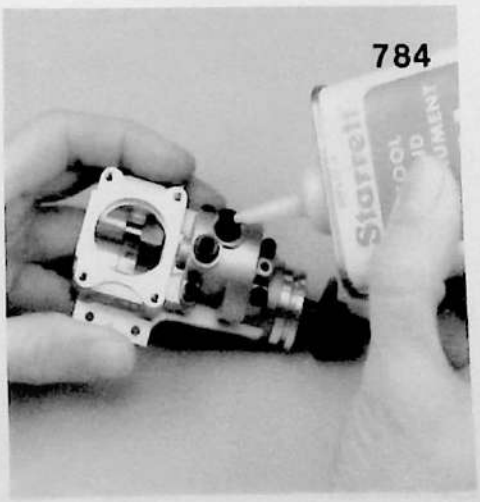
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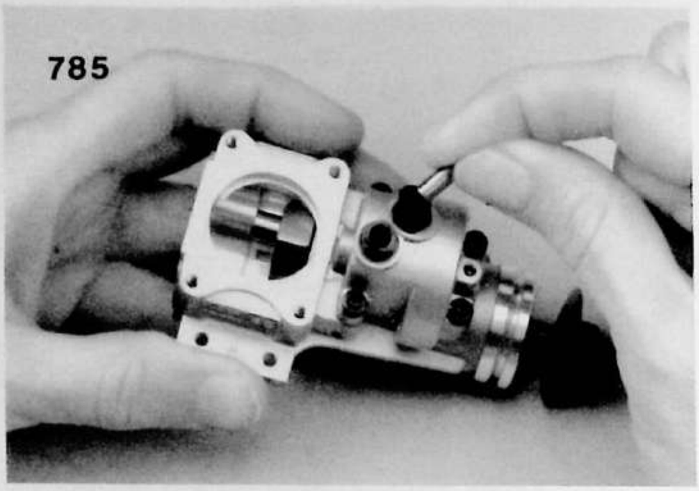
The remaining pieces shown in (786), go back on in the exact reverse order they came off. So, we just included a few sample photos (787-790) instead of repeating near duplicates of those for the disassembly. During reassembly, you will adjust the rocker arms as we explained in Chapter Seventeen.

SOME FINAL THOUGHTS

This completes our three chapter sequence on disassembling four-stroke engines, except for two suggestions. All four-stroke makers claim they adjust every engine. In spite of these manufacturers claims, you should test the valve play with feeler gages as shown in Chapter Seventeen. Some factories make these adjustments more consistently than others, but none do it perfectly every time. If the valves aren't set correctly, make the necessary adjustments. With only that exception, we recommend you do not needlessly disassemble a four-stroker until it needs service, unless you enjoy taking things apart as we do.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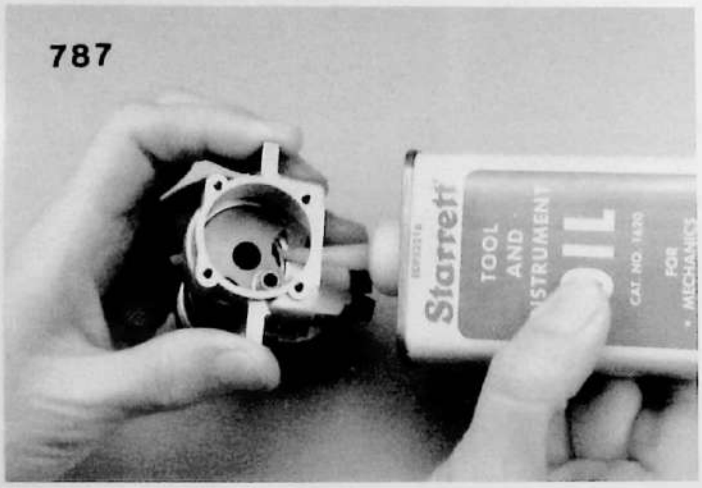

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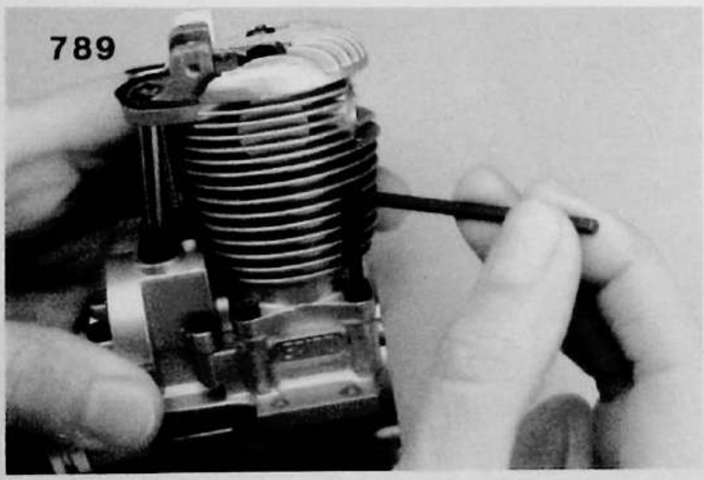
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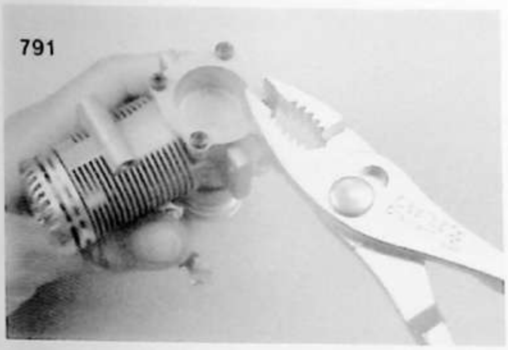
INTRODUCTION

Every mechanic develops procedures for nonstandard maintenance and modifications. People in the mechanic and gunsmithing trades call these kinks. Lets consider how the need for a kink arises with model engines. Heat, hardened varnish, crashes, and hard use take their toll in ways that do not allow repairs to go by the book. A varnished in screw may become stuck and break, or a threaded hole in the soft aluminum block strips. Incidentally, since this chapter involves screws, threads and taps, we included Appendices I through V that provide technical data about these things. Other kinks involve modifying parts from one engine so they fit on another.

STUCK SCREWS

Allen screws [their correct name is "socket head cap screws"] should be made from an alloy steel and heat treated so the hex socket doesn't strip, but Allen type screws supplied with model engines are a little soft. So, the screw head sometimes strips when a modeler overtightens the screw or it becomes varnished in the hole. Then, the hex wrench will no longer spin out the screw. Screws having an exposed head come out every time with pliers (791). A recessed screw, like those attaching most engine heads, presents a much greater problem. Measure a screw like the stuck one or use Appendix V to find the screw's diameter. Then, look at Appendix II and choose a drill just a little larger than the stuck screw. For example a number 28 or 9/64" drill is slightly larger than the 3.5 mm screw in this Enya. The stripped socket guides the drill through the screw head (792) until it separates from the threaded portion. After taking off the engine's head, the exposed troublesome screw (793) offers some area to grip. Removing the engine's head relieved all stress caused by overtightening, and often the screw spins out by hand. When that doesn't happen or varnish locks the screw in place, a pliers brings out the screw (794). The pieces appearing in (795) may help you to understand this useful process.

Unlike Allen type screws, which accurately guide a drill down the center of the screw head, stripped Phillips and slotted head screws allow the drill to wander and require a different method. Dremel makes a cutoff wheel that also slots screw heads beautifully (796) but with two serious drawbacks. The abrasive wheels break easily and can put out an eye. The breakage happens nearly every time you try this kink, not just once in a great while. You can reinforce the wheel somewhat by applying fast CA glue to it, but *do not slot a screw this way without wearing eye protection.* The second problem is abrasive dust from the wheel. Keep that dust off the engine by wrapping it tightly with a paper towel, except around the stuck screw. A screwdriver brings the newly slotted screw out (797). The close-up (798) shows that the slot, while adequate for the task, lacks the workmanship needed for repeated installations. Throw the screw away.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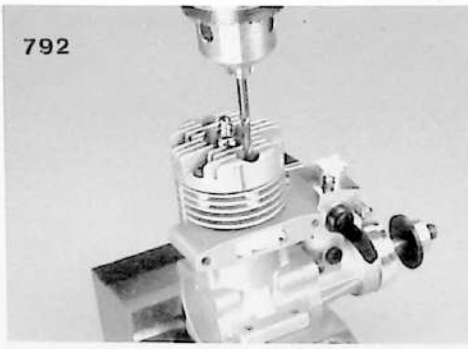
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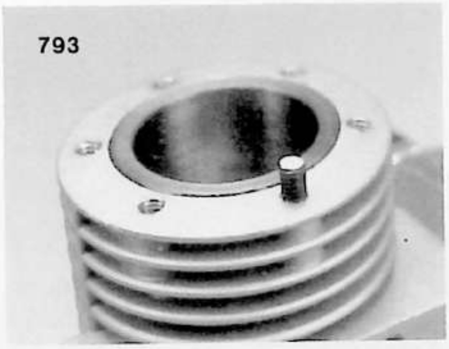
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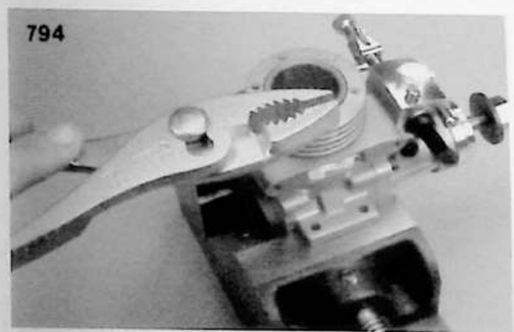
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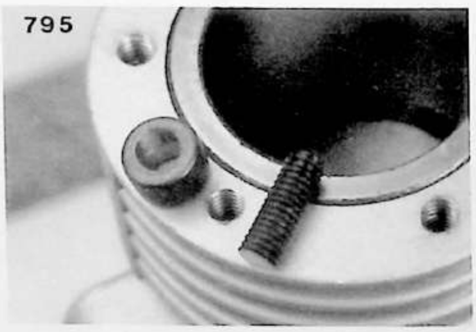
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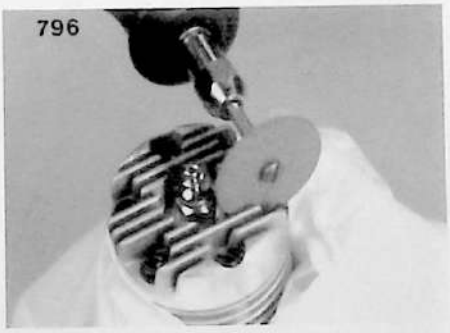
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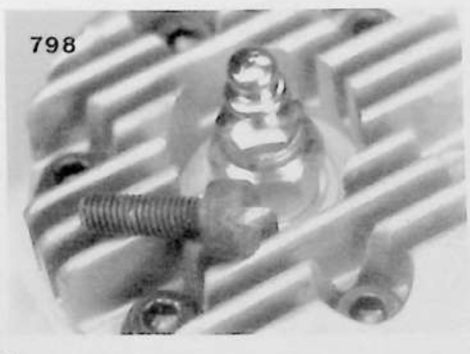
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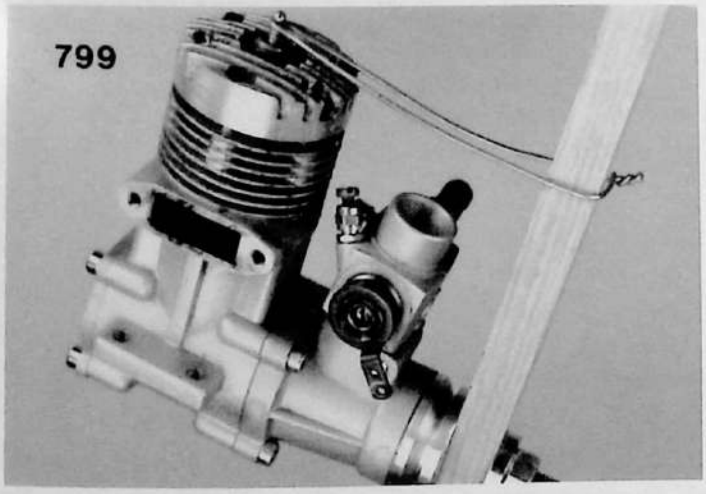
BENT RODS

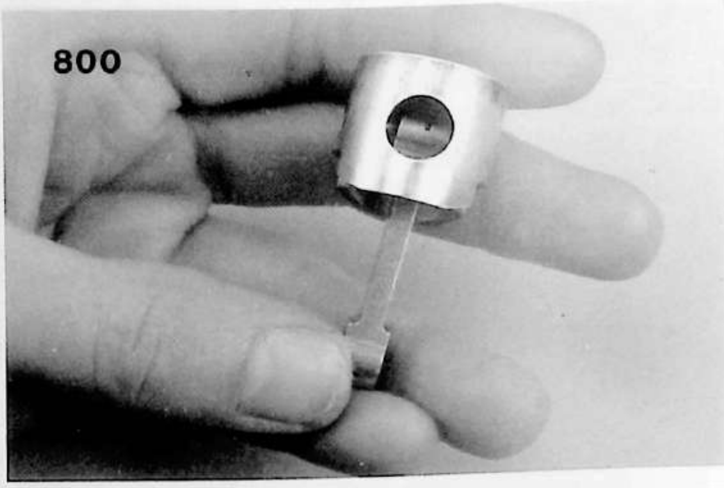
An engine can become flooded with raw fuel between flights in several ways. Fuel that siphons through the muffler pressure line enters the combustion chamber through the exhaust. Sometimes fuel siphons through the fuel line and accumulates in the crankcase, and a few turns of the propeller pumps that raw fuel into the cylinder. No matter how it gets there, raw fuel in the cylinder can bring your flying session to an abrupt stop. The rod bends the first time a starter touches the engine because the piston cannot compress the liquid fuel. Often, the fuel ignites and that bends the rod even more. Modelers call this connecting rod bending process, "hydrolock". An engine that backfires and then binds when you rotate the propeller probably hydrolocked and bent the rod.

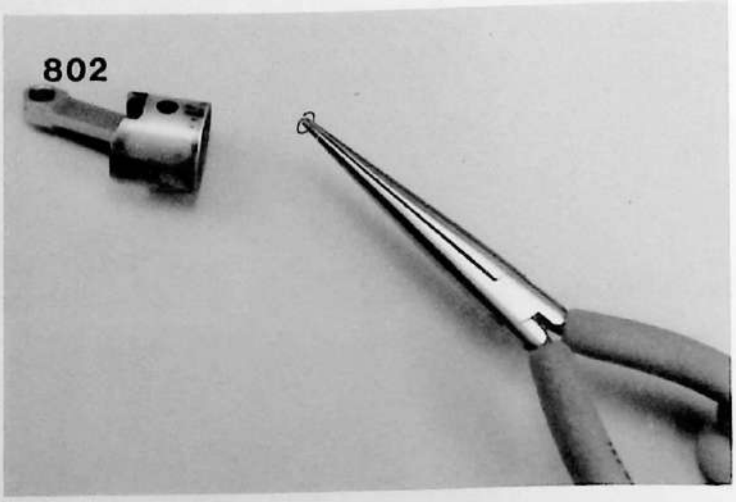
Surprisingly, the bent rod can be accurately straightened and made usable with simple tools. Clean the engine using methods you learned in earlier chapters. Photo (799) shows the engine after being treated with engine cleaner. By now you know how to take an engine apart so we won't repeat that, but we have not yet explained how to take "circlip" wristpin retainers out, so (800-802) are included to show that. Connecting rods usually bend at both ends into a serpentine or "S" shape. Toolmakers have expensive tools for determining straightness, but you will find the parallel vise jaws work well enough. The bend on the wristpin end of the rod is apparent in (803), and a few moderate blows from a light plastic hammer (804) straighten it (805). You can tell the rod straightened because it now lies parallel to the vise jaws. Photographs (806-807) show the process being repeated on the rod's crankpin end. *You must straighten both ends or this repair will not work.* Occasionally, a tremendous hydrolock force bends more than the rod. After reassembling the engine, turn the shaft slowly and check for any binding that may indicate more extensive damage (808). Chances are good the engine will turn freely and give many additional hours of service.

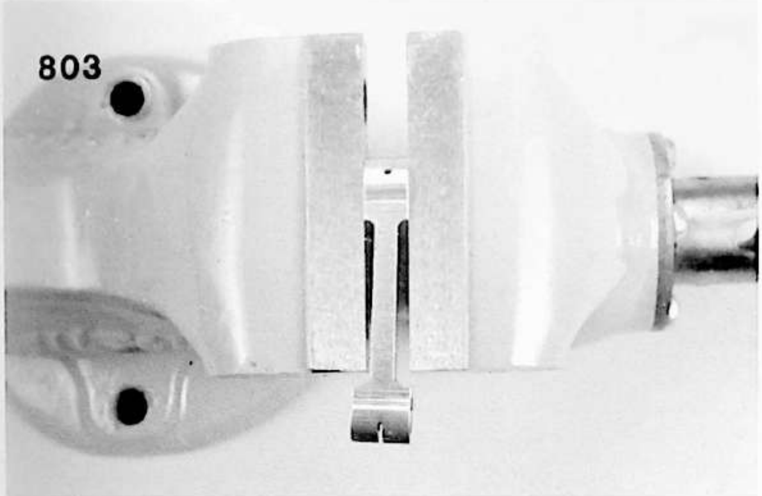
SOME CARBURETOR KINKS

Our first carburetor kink resulted from a crash that broke an inlet nipple off the carburetor and left the threaded portion in place (809). It comes out like a broken screw only much easier. An X-acto number 23 blade acts like an Easyout and never fails to spin the remaining piece of nipple out (810).





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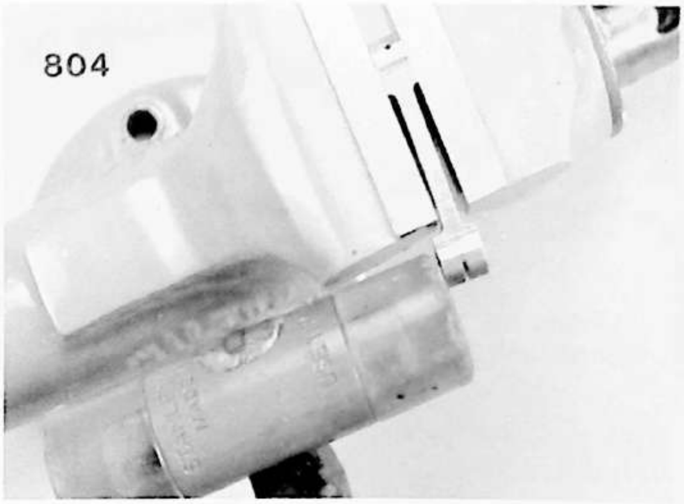
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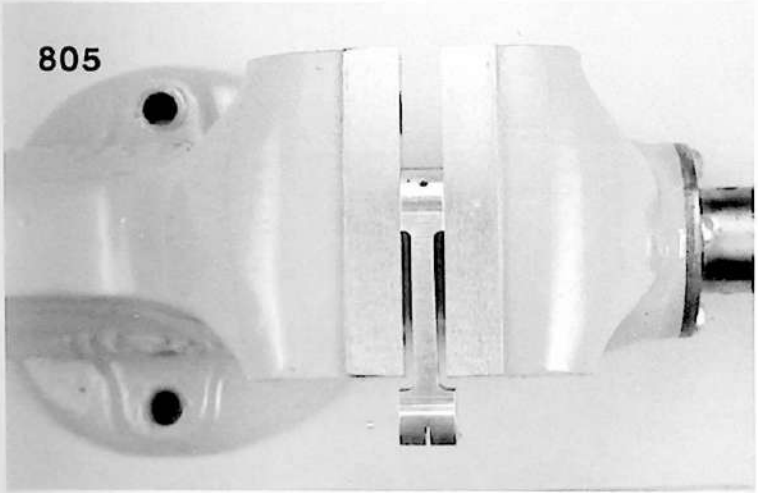
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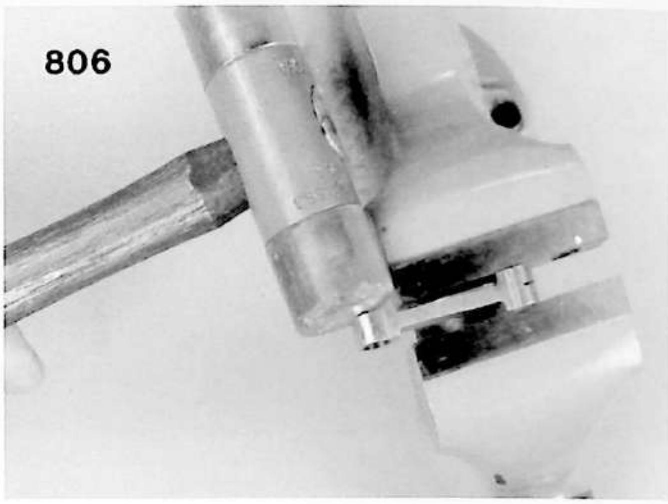
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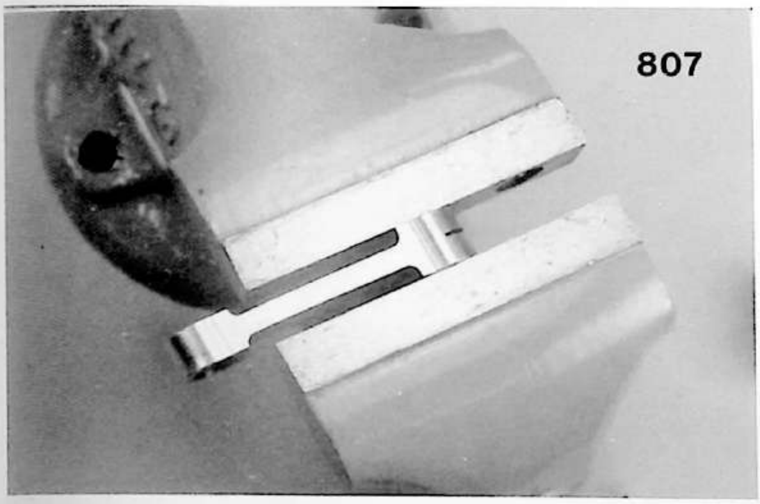
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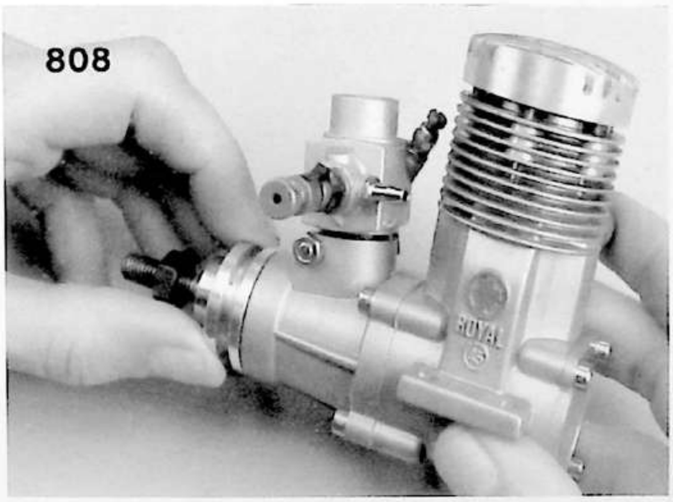

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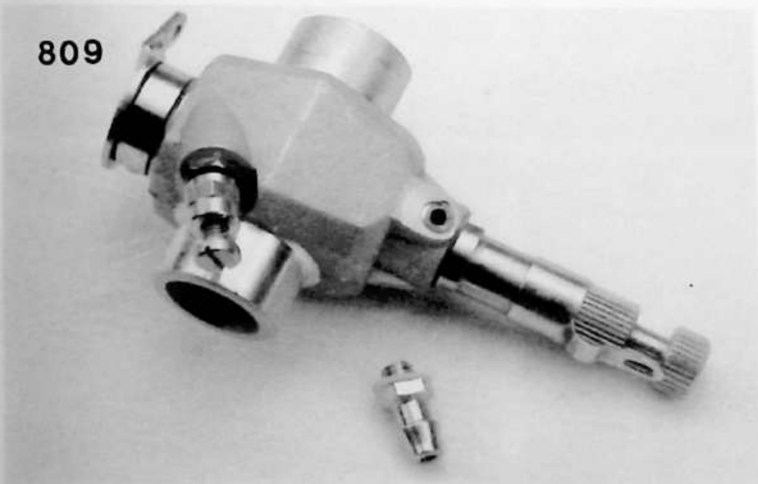
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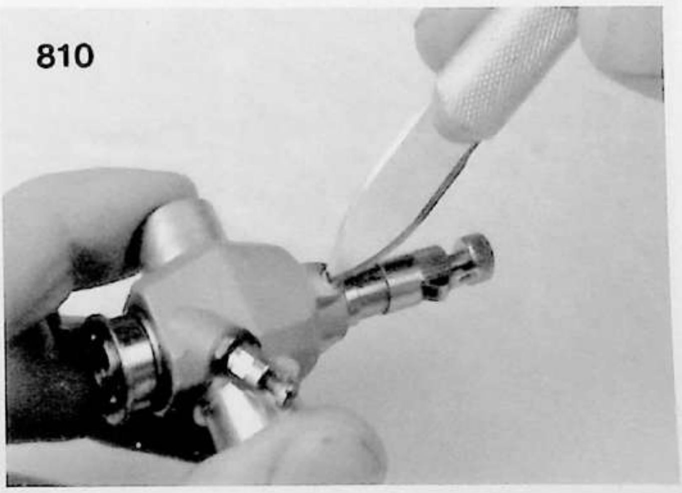
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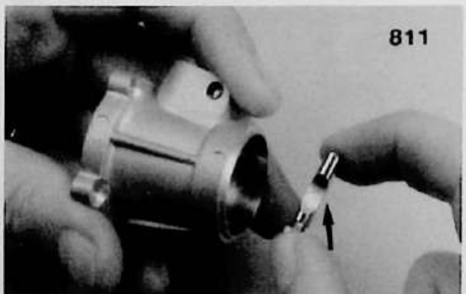
I had some leftover OS 4BK carburetors that were originally made for the magnificent but long discontinued OS FSR 40. A young flyer purchased a used Royal 40 without a carburetor, and he wanted a low cost replacement, so we installed a 4BK. There are differences between the OS and Royal carburetors. Royal locks theirs in place with a draw bolt (811), while OS uses two screws through the carburetor mount that look something like the one in (830). We decided to use the draw bolt and not drill the crankcase for the carburetor mounting screws. Photos (812-813) show a more important difference, the OS carburetor barrel is too small. Draw bolts don't give the most solid grip, and carburetors must fit tightly into the crankcase or vibration will shake them loose. Something solid needed to fill the space. K&S Engineering sells thin brass sheets and most hobby shops carry them. We cut a narrow strip of .001 inch thick brass so it fits as shown in (814), and the carburetor slid snugly in place (815). An "O" ring seals the carburetor and crankcase intersection and must be compressed between the two pieces. If you haven't read about the "O" ring yet, look back to (208). While pressing the "O" ring between the crankcase and carburetor, we tightened the draw bar (816). The OS carburetor (817) never vibrated loose and the engine responded beautifully to the throttle control.

Another 4BK carburetor was mounted in a K&B 40 though differently than the one in the Royal. OS supplies two 3.5 mm mounting screws with their carburetor, and since the K&B uses a similar mounting method, we decided to attach the carburetor with those screws. Besides, I think screws give a more vibration resistant mount than the draw bar. Photograph (818) shows that the holes in the K&B crankcase do not line up with those in the OS carburetor. The hole needs to be elongated, not drilled larger, because a drilled hole would be too big and the screw head would not have enough crankcase to grip. The round Swiss file, shown in (819) with the other items needed for this modification, elongates the hole (820) only enough to accept the screw. As with the Royal, the OS carburetor's mounting tube was too small. Teflon tape (819 and 821) that plumbers use for threaded pipe joints adds enough to the carburetor's tube to fill the excess space and provides a good seal. Notice the absence of an "O" ring in (822). Teflon tape works with an undersized carburetor held in by screws but not with a carburetor locked with draw bar. One of my proof readers, LeRoy Cordes, used Teflon tape and a screw mounted carburetor for several years without any vibration problems.

While our last carburetor kink involves Irvine's well-made Diesel 40 (823), this kink can be used on many other engines. The earlier example with the K&B crankcase and OS carburetor had screws that threaded into a carburetor body, but not all screw mounted carburetors work that way. The Irvine and some other engines rely on a headless set screw (824) that tightens against the carburetor body; the screw does not pass through it. A carburetor attached in this way often vibrates out. This kink shows how to drill and tap the carburetor body accurately for a longer mounting screw so that doesn't happen. I think the engine should be disassembled for any drilling so even the smallest metal chip can be cleaned out, and as you just saw, we disassembled the K&B and Royal. Some modelers don't think disassembly is necessary if you keep chips out of the engine by packing the exhaust with paper towel and rotating the crankshaft intake hole out of alignment with the hole in the crankcase. We have left the engine together for this modification, but we don't recommend it. You need both hands free for drilling and tapping so the engine should be clamped in a vise (823) for these operations. The close-ups and camera angles did not allow us to show that clearly in the other photographs. After positioning the carburetor so the "O" ring compresses, tighten one headless set screw (824) and remove the other. Then, drill through the empty hole with a number 21 drill (825) and tap the hole 10-32 (826). The new mounting screw (827) secures the carburetor while you repeat the sequence with the other hole (828-830). Now, remove the carburetor and carefully clean all the metal chips out from the crankcase and carburetor. If there is the slightest chance some chips remain, take the engine apart and clean it thoroughly, especially so nice an engine as this Irvine.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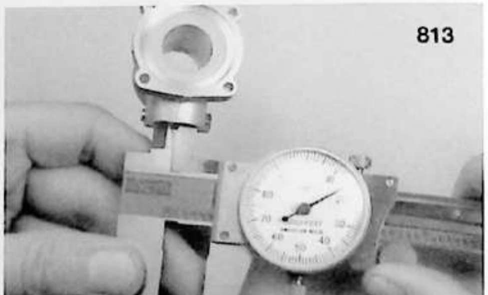
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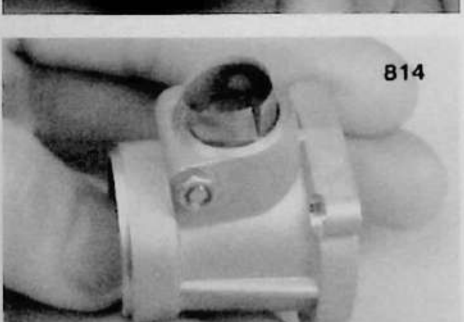
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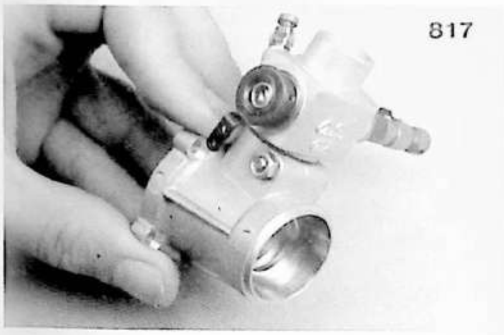
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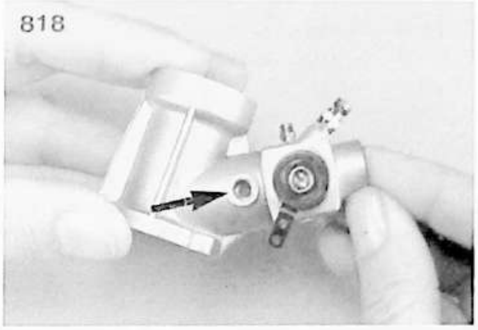
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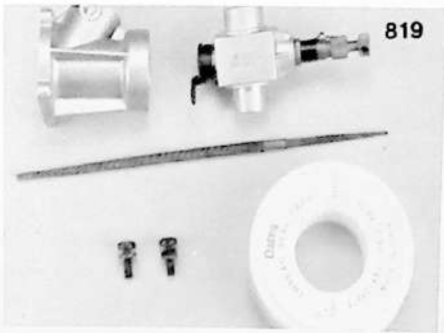
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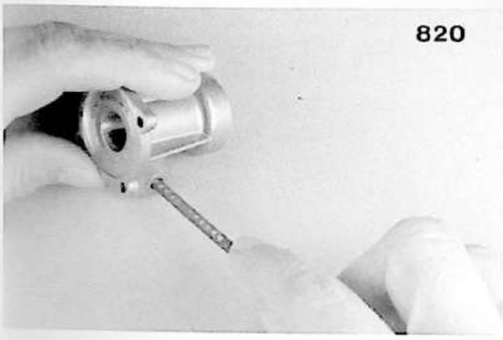
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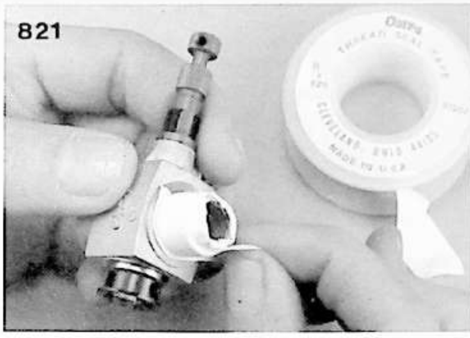
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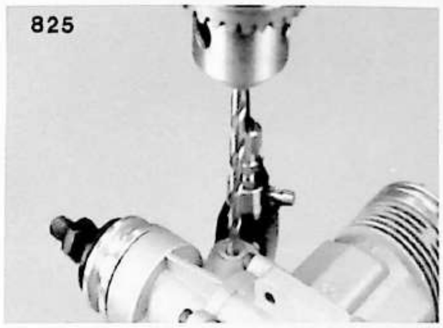
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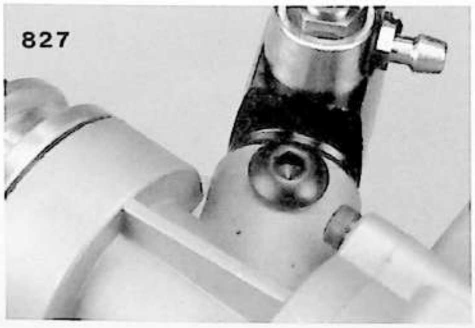
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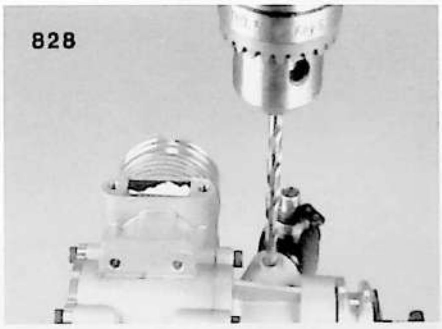
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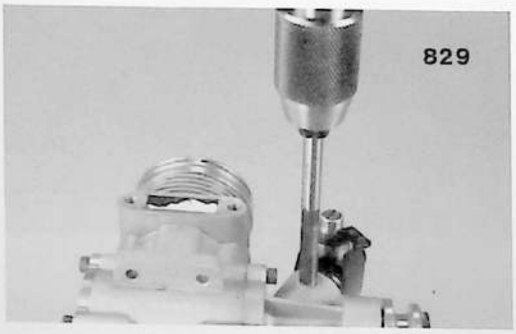
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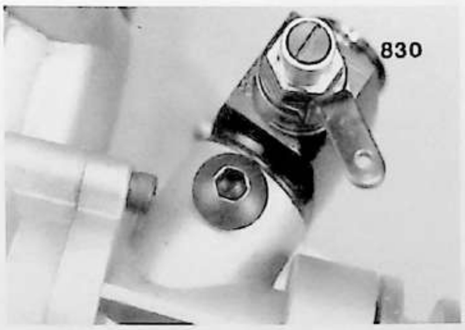
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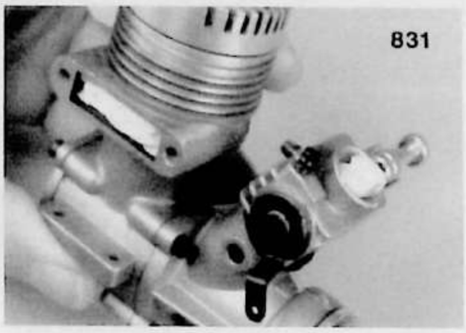
STRIPPED THREADED HOLES

Mufflers attach to many modern engines with long screws (832) that pass through the exhaust stack (831). Sometimes the threaded holes in the muffler strip, and then larger screws must be used. Let's show how to install them. For this repair you probably can get away with packing the carburetor and exhaust with paper towel (831). The next larger screw has a head too big for the hole countersunk in the block (832). We reduce the screw head diameter by chucking the screw in an electric hand drill (833) and filing the head (834) while the drill runs in low gear. The reduced-diameter screw head appears in (835). Next, holes through the exhaust stack are enlarged, also with drill in low gear (836). If you drill out too much, the bit may grab and break off in the block, so do this in small steps using progressively larger drills (837). Drill the muffler in the same way ending with the tap drill for the new size thread. Then tap the muffler (838). You would be well advised to use a Tap-N-Drill guide like the one in (841) for this operation though we didn't show it. Finally, remove the towel, clean out all the chips, and attach the muffler (839).

The final kinks show how our inexpensive Tap-N-Drill guide aligns the tap so it goes straight down the middle of the hole. My local dealer brought in a new engine with a stripped manifold screw hole that was originally 2mm. The stripped hole diameter almost measured number fifty, the correct tap drill for a 2-56 thread. The simple repair only required retapping the hole that size (840-841) and installing new screws. The last kink shows a mechanic using the Tap-N-Drill guide while repairing a stripped hole in a Super Tigre (842).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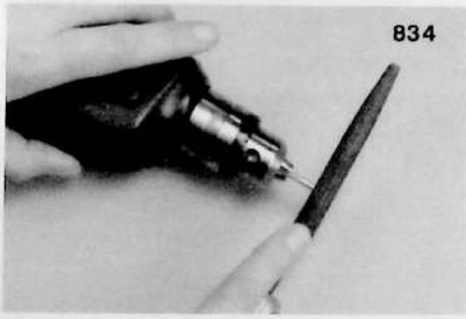
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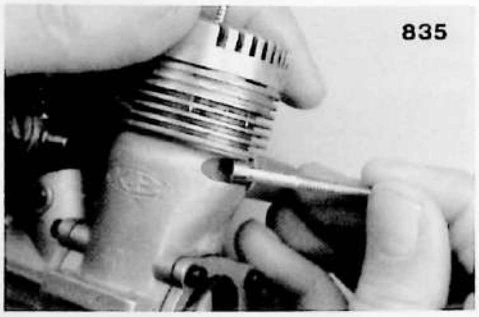
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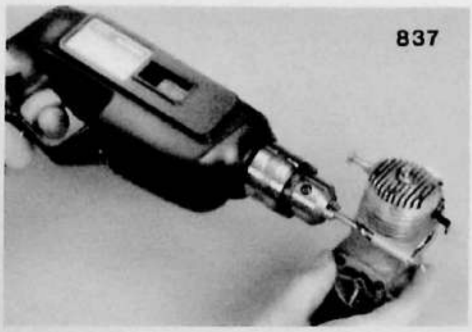
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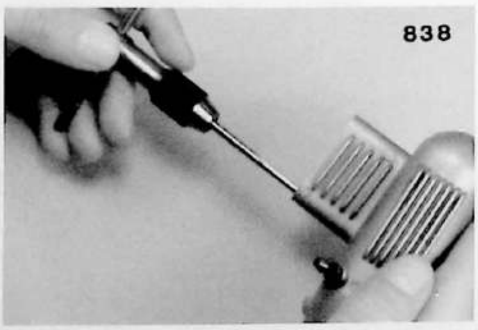
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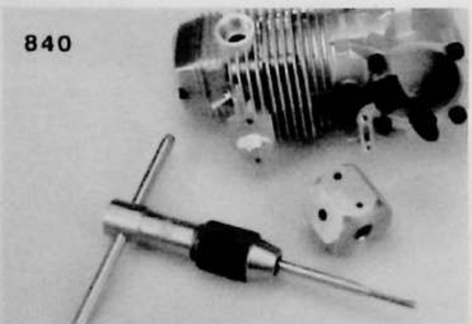
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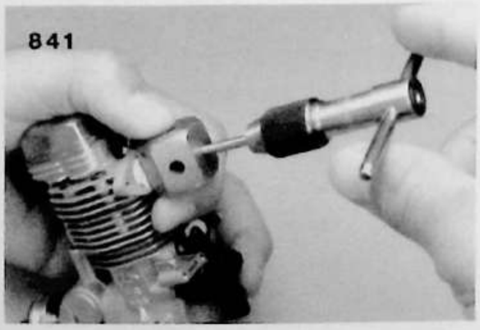
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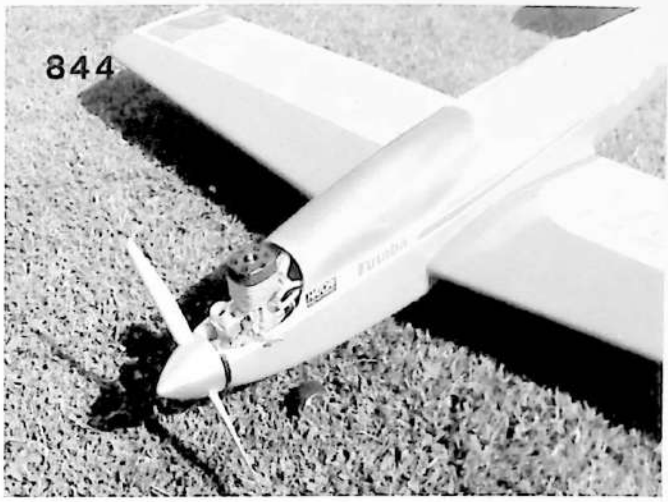
842

ABOUT THIS PAGE

Page 110 deviates from our customary chapter layout and I thought you might like to know why. You may have noticed that when a photograph is referenced it usually can be found without turning the page, and we work hard to accomplish that. This chapter presents an even more demanding page layout. The explanation of how a tuned exhaust pipe works necessitates having photographs (849-860) on two adjacent pages, which are both visible at the same time. As luck would have it, page 110 must be filled to have those photographs properly positioned on the adjacent pages 111 and 112. Since I though you might enjoy seeing some piped ships, and since this page needs to be occupied with something, those photographs appear next. The pattern ship in (845) belongs to Bill Bolz, and Randy Zorich built the Sportster 20 in (847-848). The other shots were taken at the annual Thorn Creek R/C Club's annual pattern contest.

843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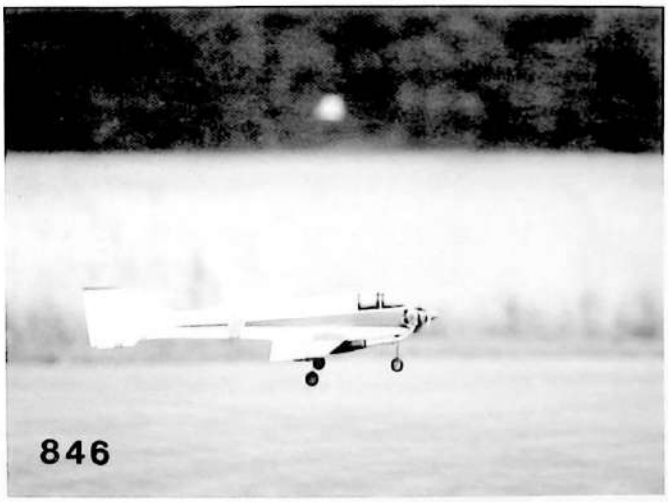
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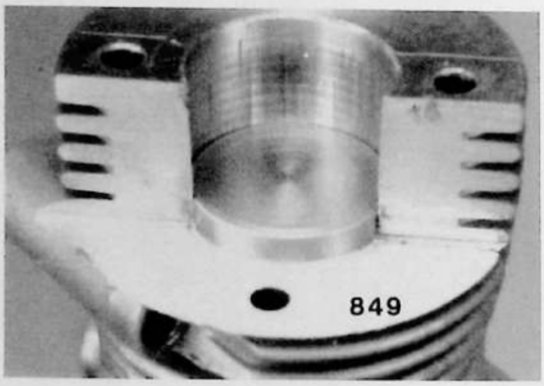
INTRODUCTION

In the engine essentials chapters you learned that all other factors being equal, the engine with the greatest amount of combustion mixture in each power stroke will have the most power. For example, OS's FP 35 and 60 are almost identical except for size, but their 60, operating with nearly twice the combustion mixture, produces a much greater horsepower. An elementary engine concept stresses this idea by stating: If you need more power, there is no substitute for additional cubic inches. However, rules for competition events restrict engine displacement so competitors must find other ways to get more mixture into the combustion chamber. Some of these power enhancements are practical for a sport flyer who wants more power for a ship he already flies without the expense and structural modifications a new, larger engine requires. Chapter Twenty-two covers two power increasers, tuned pipes and fuel pumps.

HOW TUNED EXHAUSTS WORK

While explaining this offers us a wonderful opportunity for a highly technical discussion, we will leave that for the physicists. Instead, only considerations needed to operate and adjust tuned exhaust pipes are stressed. Let's recall experiences nearly everyone has when they get away from it all, including modeling, by going fishing. A bobber bobs up and down on the waves. A wave has two halves, a peak pushes the bobber up and a valley sucks it down. The wave's peak half is called the high-pressure half wave. We call the valley half the low-pressure half wave. All waves including sound waves have high and low-pressure halves. Our bobber also moves horizontally with the wave just a little. That's because wave movement through the water does not move the water horizontally much. Let's discuss another wave characteristic. Do you remember what happens when a wave hits the boat? It forms a new wave moving away from the boat. Other waves types, including sound waves, also reflect off objects in their path. A tuned exhaust pipe uses sound wave pressure and reflections to increase the amount of combustion mixture.

To understand how sound waves do these things, you need to remember sound waves travel through exhaust gasses somewhat like the waves that raised and lowered the bobber moved along the water's surface. Photograph (850)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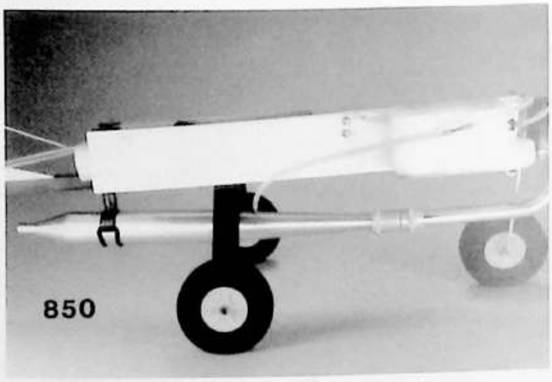
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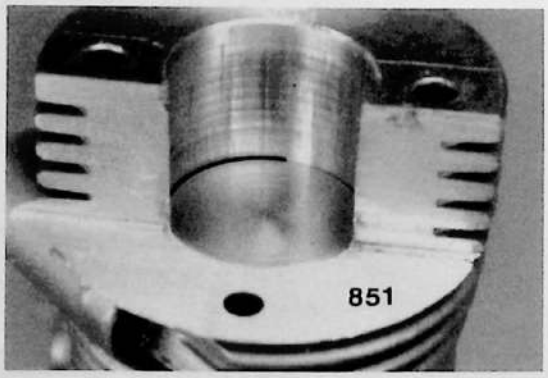
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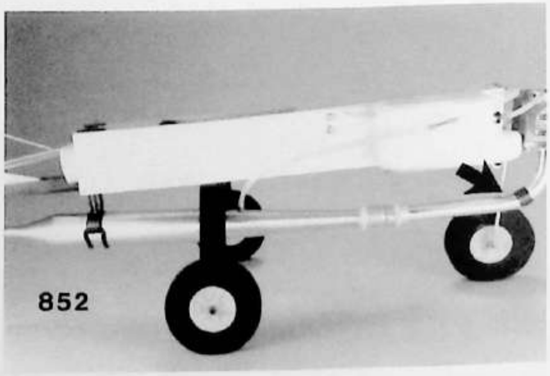
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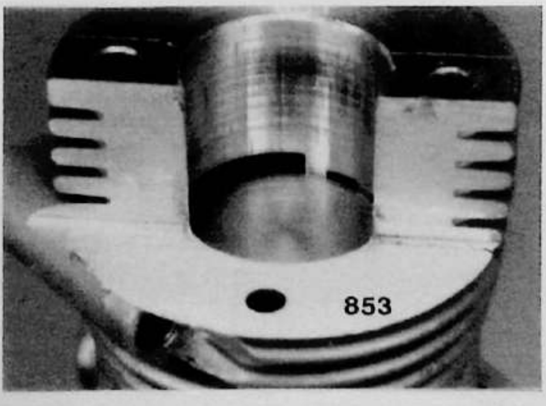
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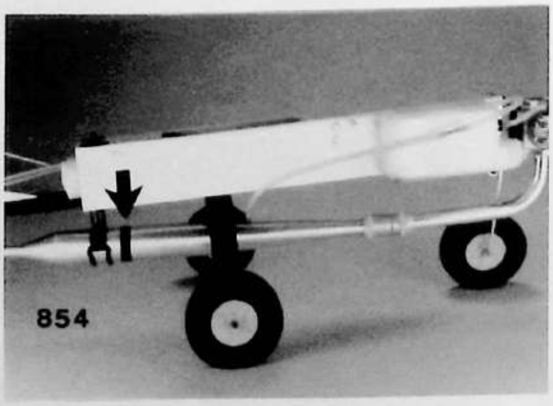
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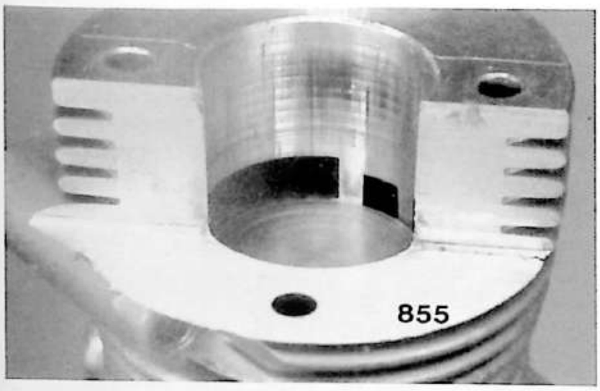
shows a **Futaba Hatori** tuned exhaust system on a DuraBat. Two different things travel down that pipe, exhaust gasses and sound waves. Sound waves move much faster and at a constant speed. It takes just a little imagination to realize that exhaust moves in pulses. When the exhaust port opens, burning, expanding gasses blast into the muffler. Shortly after that, the fire burns itself out and these gasses move much slower or may even stop. All this happens in a partial shaft revolution, but the average movement, the one we see, appears as a steady exhaust stream leaving the muffler. If the exhaust and sound wave moved together, the exhaust would leave the tuned pipe at the speed of sound, and you would have one hell of a jet engine on your hands.

The events in the combustion chamber and tuned exhaust are closely related, so the next twelve photographs appear in pairs, each pair consists of the combustion chamber and pipe. With this arrangement we can explain how events in these two locations affect each other. Solid arrows in the pipe photographs show about where the high-pressure wave half would be, and arrow outlines indicate the position of a low pressure half wave. The downward moving piston in (849) still seals the exhaust and intake ports, and only residual activity from earlier ignitions takes place in the pipe (850). When the exhaust port cracks open (851) a high-pressure half wave begins moving through the exhaust from earlier ignitions well ahead of the new rapidly-expanding exhaust gasses (852). As the intake ports open (853) the high-pressure half wave has moved well down the pipe (854) while the exhaust begins to burn out and expands much less rapidly than it did when the exhaust port just cracked open. With the piston near BDC (855) the high-pressure half wave hits the pipe's rear cone, and that starts a reflected high-pressure half wave back toward the engine (856). About now, the low-pressure half of the original sound wave begins its journey down the pipe and sucks additional exhaust from the combustion chamber. As the intake ports begin closing (857), the high-pressure reflected half wave continues moving toward the engine (858). Now, the engine has no exhaust left to expel so the low-pressure half wave, moving away from the engine, draws combustion mixture into the pipe. Just before the piston seals the exhaust port (859) the exhaust has finished burning and gasses in the pipe near the engine have little or no rearward movement. So, the reflected high-pressure sound wave, now at the arrow in (860), carries some fresh mixture back into the combustion chamber, just as the wave on the water moved the bobber a little. Since the intake ports have closed, the returning mixture compresses gasses in the combustion chamber, increasing the amount of useable combustion mixture.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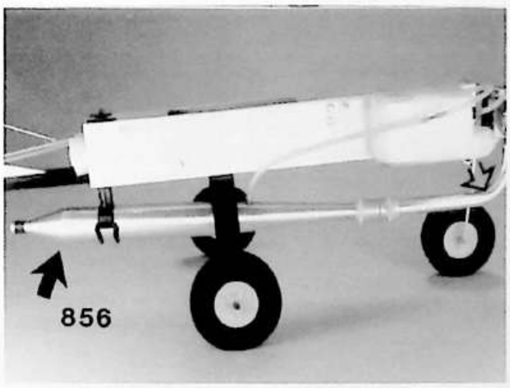
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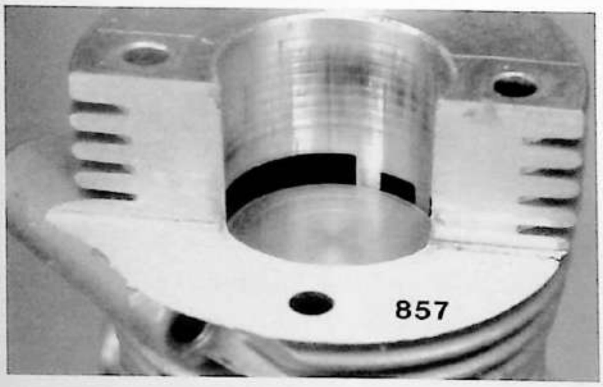
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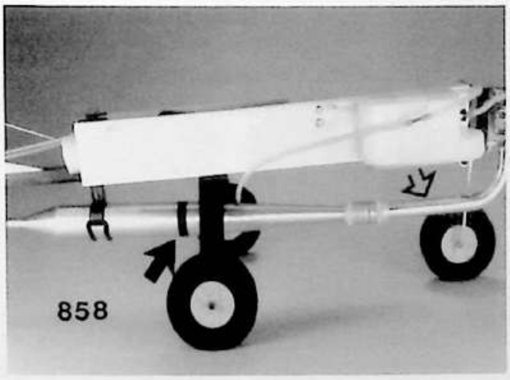
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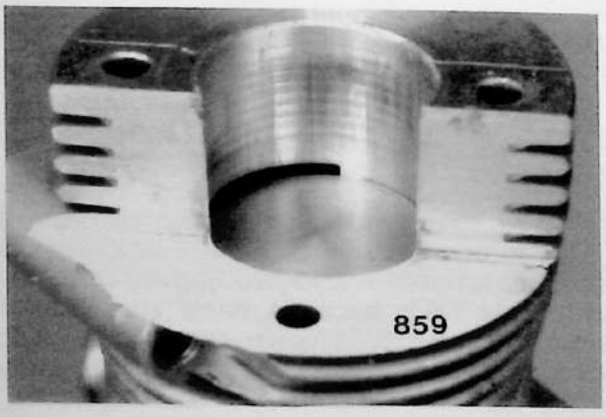
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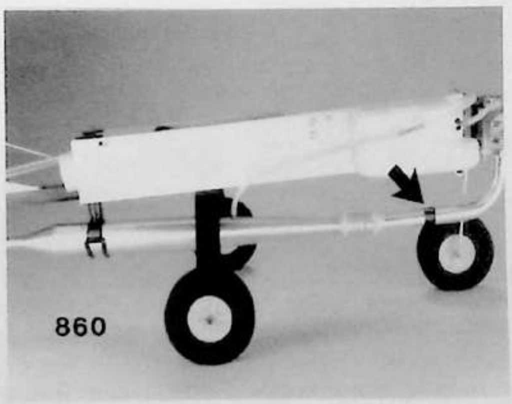
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PRACTICAL CONSIDERATIONS

This gives an idea of how a pipe works but says nothing about designing one. Measuring temperature and pressure within an airborne tuned pipe isn't practical, but these things must be known to theoretically calculate the speed of sound and the resulting pipe length. So, engine designers determine pipe length, volume, and cone dimensions experimentally, and that is no small job. K&B's designer, Bill Wisnewski, was first to do it successfully on a model engine. That took five or six years of research and testing, and won him the World Speed Championship in 1966. Bill's article on tuned pipes was published in the March 1967 issue of Model Airplane News and remains the definitive work on pipes to this day.

For those people wanting the results of hard work done by Bill and others without repeating it, pipes by manufacturers like Hatori, OS, Irvine, and Super Tigre give you the benefits of that research. Besides the tuned pipe, these modern tuned exhaust systems have a constant diameter "header" that bolts to the engine exhaust. An exhaust system operates at a high temperature, so a short piece of heat-resistant silicone tubing and two cable ties (862) connect the tuned pipe and header. Silicone is a poor conductor of heat and insulates the pipe from the engine. That helps maintain a constant temperature in the pipe by not letting the engine conduct heat away from the pipe. Then, the temperature-sensitive speed of sound through the pipe stays constant, and that contributes to keeping the pipe in tune.

Adding a tuned exhaust changes sound levels and fuel consumption in addition to increasing the power output. Tuned pipes are an exception to the rule that quiet operation costs power. While effective mufflers typically reduce noise at a cost of 300 RPM, a tuned exhaust system gives a similar or greater noise reduction, but the engine picks up 700 to 1500 RPM. Several factors about tuned exhaust systems contribute to increased fuel consumption. The added combustion mixture in each power stroke contains fuel so each power stroke uses more. The thousand extra power strokes per minute also burn additional fuel. Combustion mixture in the header that doesn't get pushed back into the engine increases fuel consumption too. Once the pipe is tuned, you can expect the power increase and noise reduction to be accompanied by a noticeably greater fuel consumption.

TUNING THE PIPE

Most tuned exhaust systems come a little long, and you cut them to length. That is what "tuning" means. The pipe's length must be chosen so the reflected sound wave pushes the combustion mixture in the pipe back into the cylinder before the exhaust port closes. If the pipe is too short, the wave will hit the exhaust port before the extra combustion mixture has entered the pipe. Then, the wave carries exhaust waste gasses back into the cylinder resulting in a power loss and perhaps some overheating. The reflected wave from a long pipe reaches the extra combustion mixture after the exhaust closes and won't supercharge the engine. While that wastes the extra combustion mixture, the engine runs cool and the pipe acts as an effective silencer. *It is better to have a pipe too long than too short.*

Anything that changes RPM also affects the correct tuned pipe length because higher RPMs generate a higher pitched sound with a shorter sound wave. A lower pitch sound from reduced RPMs has a long sound wave. So, small fast-turning propellers need a shorter pipe while large slow-turning propellers take a longer pipe. Engines run on high nitromethane fuels, which make the engine run faster, take shorter pipes. As any engine accumulates running time its speed also increases. Modelers who do not account for these RPM related factors correctly, make the easy job of tuning a pipe unnecessarily difficult. You, should not change anything that affects RPM while tuning a pipe, because we use RPM to decide when the pipe length is correct. A new engine can use the untuned long pipe as a muffler during its break-in and early flights. Once the engine breaks in, decide what fuel and prop you will use, and *fly the airplane with this combination until every thing works well together. Then, tune the pipe.*

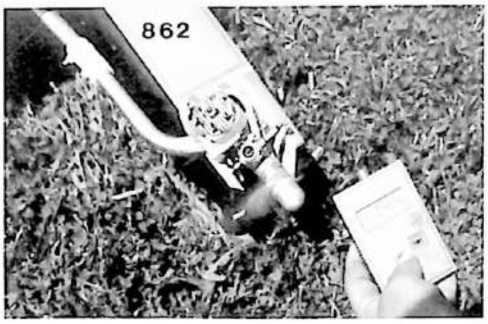
You'll need a tachometer to tune a pipe. Install the stock and probably too long tuned system - we'll explain how in just a minute. Start the engine and adjust the needle valve until the tachometer will go no higher. Our OS 32 FSR tacked at 14,100 RPM (861). Then, cut a 1/4 inch piece off the header (864), readajust the needle valve and check the engine again (862). This time we picked up 300 RPM, and our next cutoff (863) produced a 400 RPM pickup. The third cut (865) made the engine run at 15,000 RPM. Most engines pick up about 1000 RPM with a tuned exhaust system. Since we got almost that much improvement, the pipe was not shortened any more. You can continue until the engine looses some speed, which means the pipe is too short. Then a new header should be cut just a little less, or the pipe can be attached to the header with a gap in the silicone tubing. Either approach lengthens the pipe slightly. Photograph (866) shows the Aero Star 20, originally intended for a 20, zipping along at a healthy clip with a piped 32.

PRETUNED SYSTEMS

Pipes, like those shown so far, come a little long and you find their correct length as we just explained. At speeds most sport engines run, that length can be off a little and still allow the sound wave to do its job. Irvine and Super Tigre took advantage of this latitude and designed easier to use pipes, tuned for moderately high performance engines. The sound path through their pipes folds back on itself and that allows a much shorter unit (867). Irvine's Super Silencer, originally designed for an OS 21, gave our OS 32 an immediate 700 RPM increase with no other changes (868-869). We didn't check sound levels, but neither the stock muffler nor Super Silencer seemed objectionable. You can fine tune a pipe like this without cutting it by reducing the propeller diameter 1/4" at a time. Check the engine RPM before and after any change. Do not expect miracles because experimenting may give only 200 - 400 RPM before the reduced propeller diameter hurts the airplane's performance. Photo (870) features our pipe test bed, an Aero Star, flying with a Super Silencer. For a modeler wanting to try tuned exhausts, we recommend starting with Irvine's or Super Tigre's units.

You may have noticed we stressed "moderate" RPM in the preceding paragraph. As the RPM increases, pipe length becomes more critical. Bill Wisnewski may have set a World Speed Record, but less talented speed flyers had fits trying to get the sound wave to do its job on their high performance engines. For every successful flight, a speed flyer would have a dozen or more where the pipe only acted as a power reducing muffler. Out of their frustration came a compromise "mini" pipe (871), which attaches to the engine with a silicone "O" ring (872). It doesn't give the same power increase but offers much greater reliability. I was covering the 1979 Nationals for Model Airplane News and had lunch with Tom Lauerman, a die hard speed flyer. He had been frustrated for years with tuned pipes and had nothing good to say about them. The next day he switched to a mini pipe and flew his sixty-one speed ship near 200 MPH. This shows the power penalty isn't much. However, mini pipes do nothing to suppress noise, and they are loud. If your flying field has a muffler requirement, mini pipes will most likely not be permitted. Mini pipes work a little differently than other tuned exhausts. As the sound leaves the end of a pipe, something like a reflected wave starts back toward the engine. Organ pipes work in same way. These reflected waves, though generated in a different way, still supercharge the engine.


861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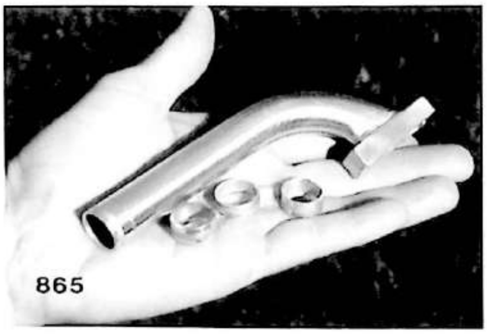
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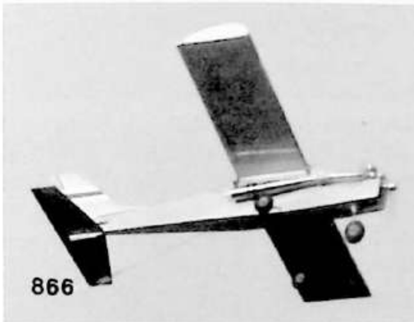
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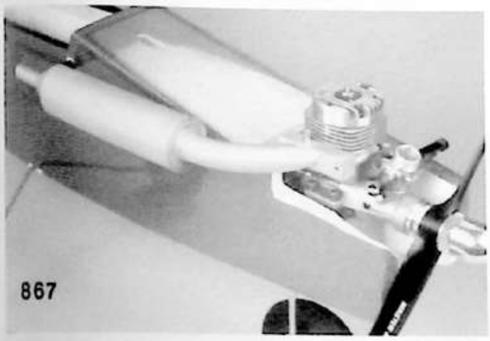
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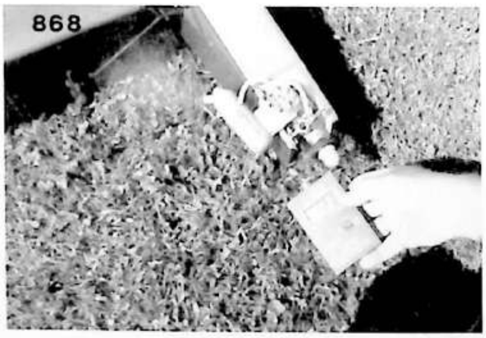
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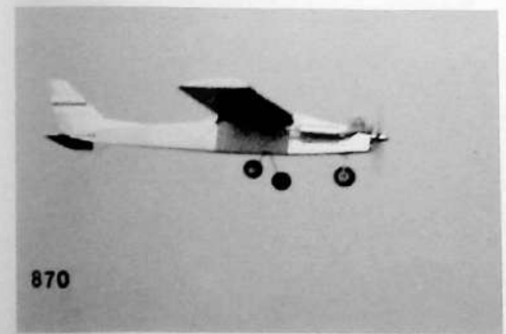
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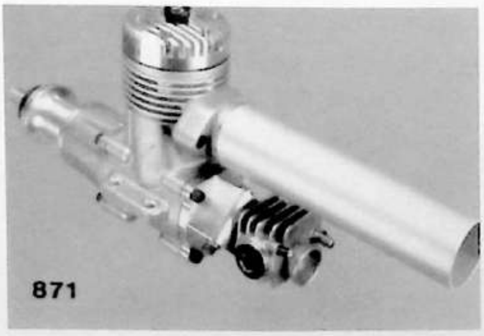
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872

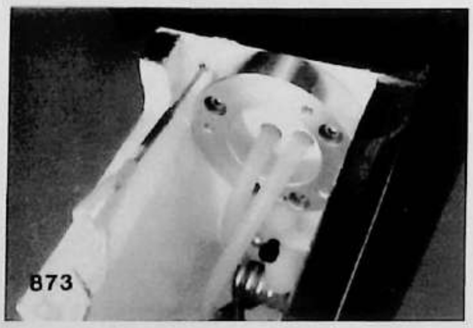
MOUNTING PIPES

Very few sport models have provisions for mounting tuned exhaust systems, because the need for one comes about after the model has accumulated some flying time. Then, the modeler finds he would like more power. A new larger engine is expensive and usually requires time consuming modifications to his model's nose. A tuned exhaust system will get the desired power increase for less money and with only some simple modifications to the ship.

The earlier photograph of the Irvine Super Silencer in the Aero Star (867) showed a serious problem. The pipe interferes with the dowel rod for the wing rubber bands, so the engine position had to be changed. We made an adapter (873) that bolts to the original motor mount firewall holes. A new motor mount screws to the adapter with the engine rotated thirty or forty degrees (874). That rotation also moves the pipe away from the wing mounting dowel. For practical reasons like this and sometimes for appearance, engines are rotated away from the vertical. Most modelers do not have a metal lathe to make an adapter like the aluminum one shown; that should not prevent anyone from making an adapter from plywood on a scroll saw. An easier alternative, if you know you are going to mount a pipe, would be to install the mount at an angle during construction. Let's consider the tail pipe support next. Some simple, inexpensive plastic fittings that come with most units attach the pipe and fuselage (875-876). A piece of 1/4" plywood, fitted with a blind nut (877) and glued to the inside of the fuselage, securely holds the tail pipe. When necessary, that plywood piece can be glued in place through the radio compartment after the model is completed.

The simple tail pipe mounting we'll show next can be done with a completed model, but we'll show it on an Ultra Sport under construction. That model has a balsa wood block under the wing that accommodates a 1/4" plywood mount (879), but the pipe doesn't pass over the wing there. A plastic right-angle bracket that comes with most pipe mounts locates the post next to the pipe instead of directly underneath it (880). This places the post over the balsa block in the wing. Nylon screws and plywood nuts make a good combination so we tapped the 1/4" plywood mount (878). For those preferring metal threads, a steel blind nut, like the one in (877), could also be used. With the engine mounted and the pipe attached, mark where the plywood mount goes (879). The plywood, countersunk and glued in the balsa block, contributes to a durable installation (880).

We also used the Ultra Sport to show a shock absorbing or flexible pipe mount. The plywood base installs easily on a completed model so only a small area needs recovering or refinishing, but we show this while the model is being built. Performance Products Unlimited markets the hardware [or flexware] featured in the following photograph sequence. Begin by marking the post location on the wing planking (881) and remove a nickel size piece (882). Next, cut the plywood pieces shown in (883). The circular part, called the "spacer", must be as thick as the planking. A blind nut needs a 1/8" plywood "nut plate" to bite into, and the remaining "cover" piece can be any thickness. We made it from 1/16" plywood. Drive in the blind nut (884), file any surplus tines flush (885), and file the nut barrel flush with the spacer (886-887). Photo (888) shows the completed nut plate prior to installation (889). After slipping the nut plate through the hole, thread in a screw, apply some thick CA glue and draw the plywood and planking together (890) while the glue dries. Drill the cover plate for the mounting screw. Next, glue in the circular spacer (891-892), glue the cover piece over the assembly, and finally thread in the post (893). The next three shots, (894-896) show how this product works, while the completed installation appears in (897).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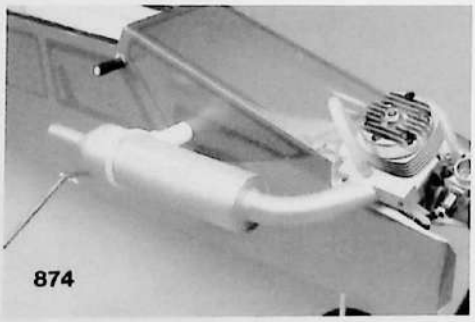
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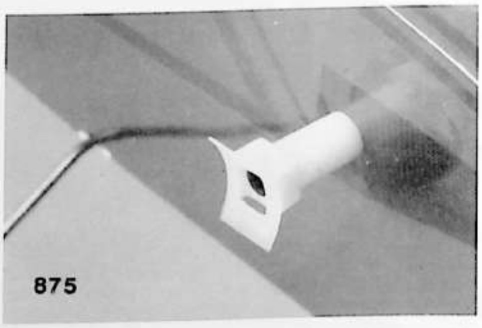
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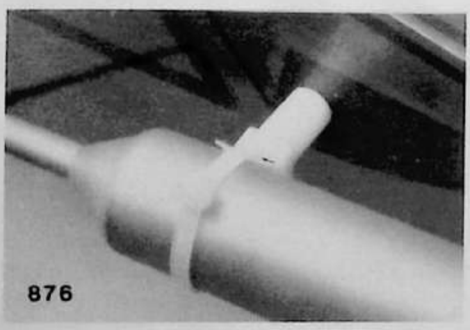
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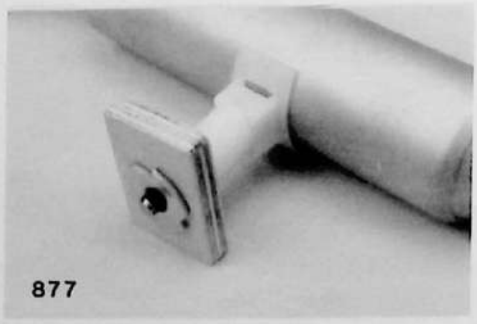
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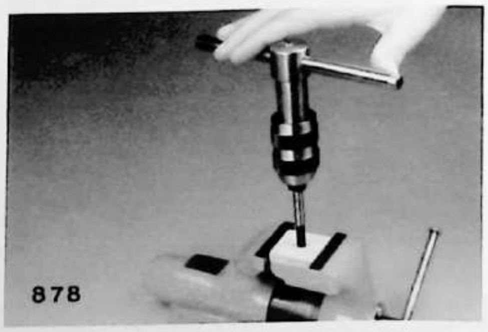
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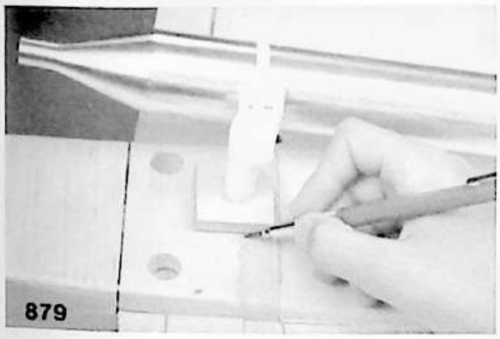
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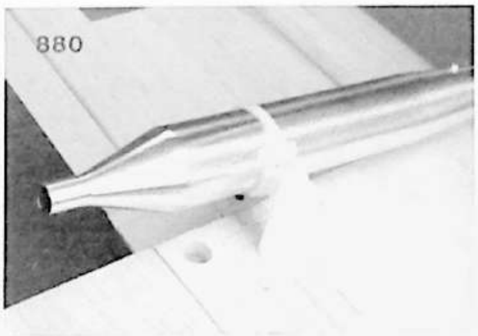
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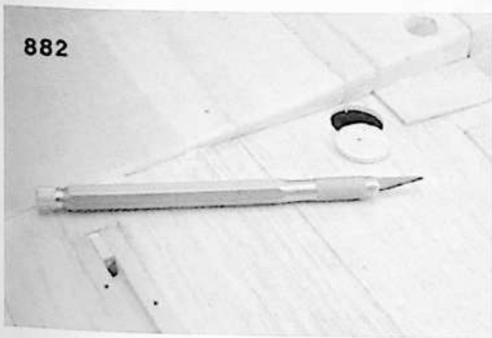
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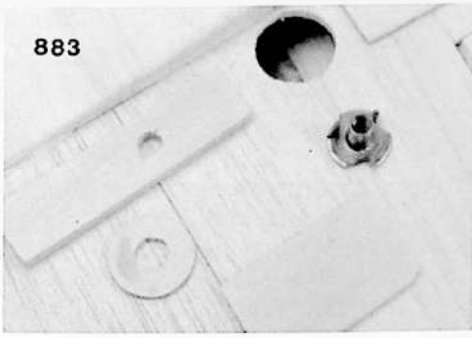
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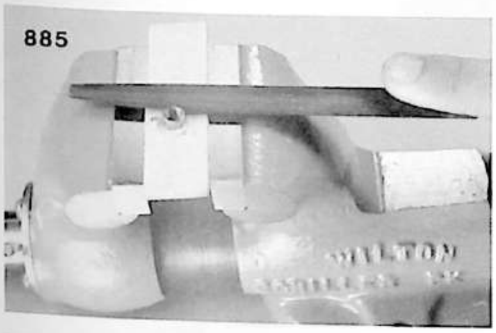

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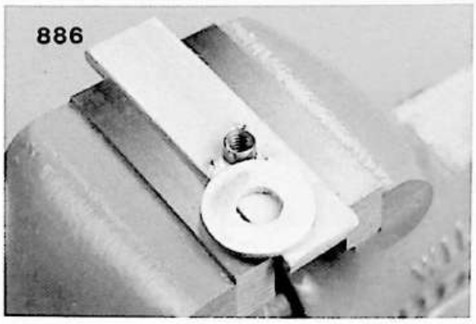
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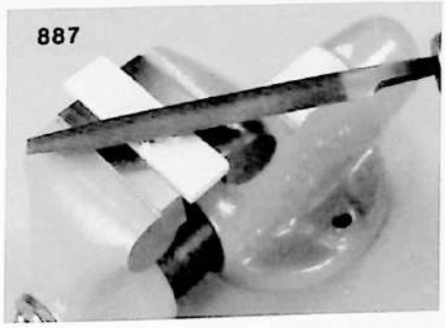
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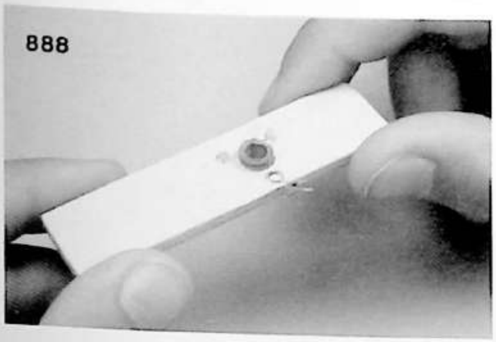
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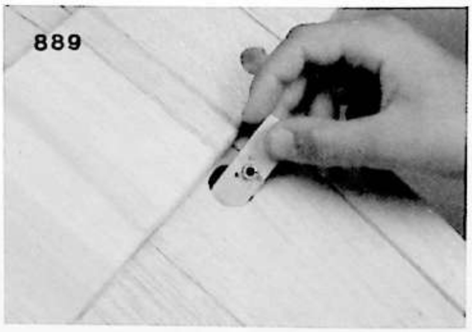
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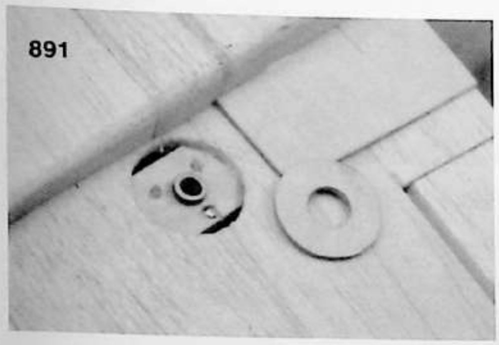
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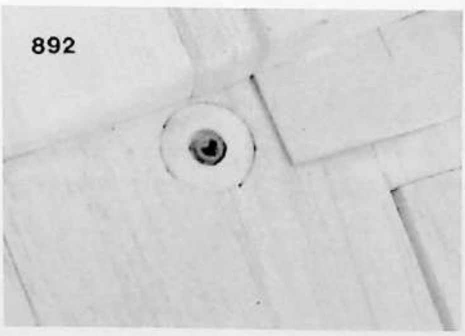
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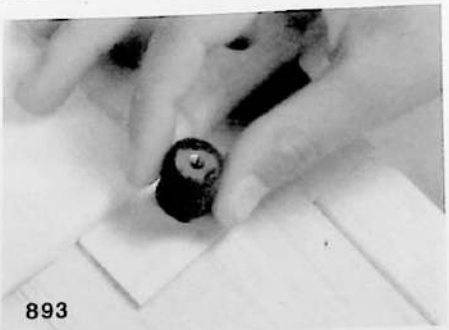
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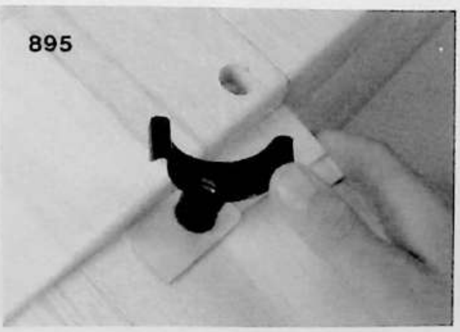
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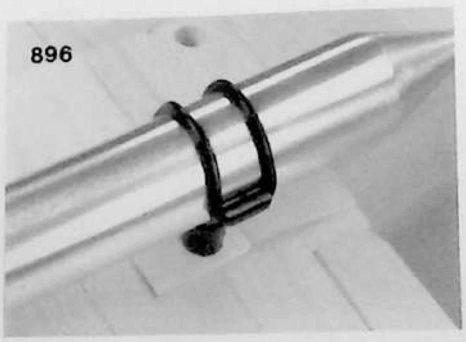
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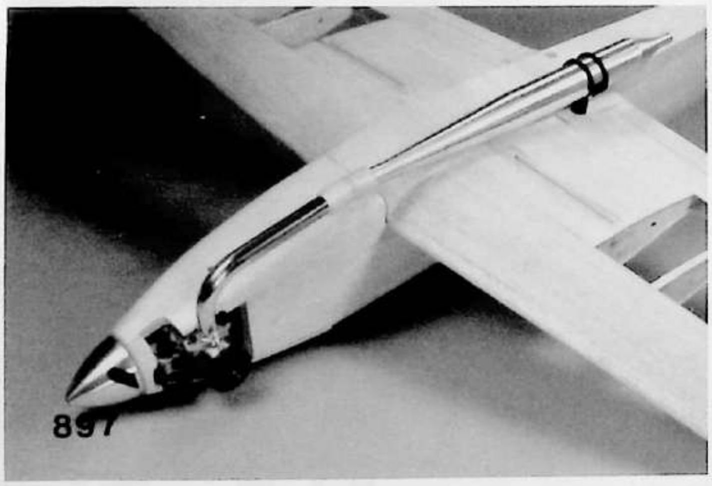
FUEL PUMPS

Fuel pumps get extra combustion mixture into the engine in the following way. As the piston rises and makes a vacuum in the crankcase, air and fuel are drawn through the carburetor. Suction fuel feed and the low muffler pressure fuel system need a high velocity airflow through the carburetor barrel to draw and atomize the fuel. To provide a high speed flow, the carburetor bore must be small, and it can't draw in enough combustion mixture to completely fill the crankcase vacuum. A greater air volume moving through a large carburetor bore fills the vacuum more completely, but then the fuel draw suffers. A fuel pump delivers fuel no matter how fast air moves through the carburetor bore. The upper carburetor in (898) was designed for OS's SF 46 pump engine and has a larger open bore area then the lower carb, which comes with the same engine but for a muffler pressure system.

A pump does another important thing. A good one draws fuel from any tank location and regulates fuel pressure. That gives the builder flexible tank placement. In contrast, a muffler pressure system only works if the tank lies close to the engine and level with the carburetor's atomizing jet. Pattern flyers routinely locate the tank over the center of gravity so the airplane's trim doesn't change while the fuel tank empties and becomes lighter. We did not photograph a pattern ship with a tank mounted like that, but the DuraBat in (899) gives some idea of what we are talking about. Mounting a tank there requires a fuel pump of some kind. The Bat, powered by an OS pumped 46, flew very well that way. Photo (900) shows a typical pumped fuel system. Most pumps have a diaphragm actuated by the crankcase pressure change that takes place every revolution. A piece of fuel line between the crankcase chamber and pump transmits these impulses. The pump unit draws fuel in through a second line, regulates the fuel flow, and then pumps the fuel to the carburetor through a third line. The tank must have a vent so air can replace the fuel as the engine uses it. Photographs (901-903) show fuel lines as they are installed in an airplane. The fuel line that transmits the crankcase pressure required some bends in a piece of brass tubing (904-905). Our Biso Bender (906) does that better than anything else we've found. Randy Zorich flies our pumped, piped DuraBat (907). It cooked right along. After a flying session the fuel path through the pump should be rinsed with alcohol (908) in the same direction the fuel normally flows. Pressure applied in the other direction will blow out the tiny, fragile valves in the pump and ruin it.

A FINAL THOUGHT

This completes the final chapter of our most extensive work to date. Originally, we only intended to update our earlier and still very popular book, Harry's Handbook For Miniature Engines, but we scrapped that plan to give you a completely new book. The first photographs were clicked off over a year ago and All About Engines has occupied our efforts nearly full time since then. Nothing pleases us more than knowing you appreciate these efforts and enjoy our books. So, if you happen to be at a trade show, come by and say hello.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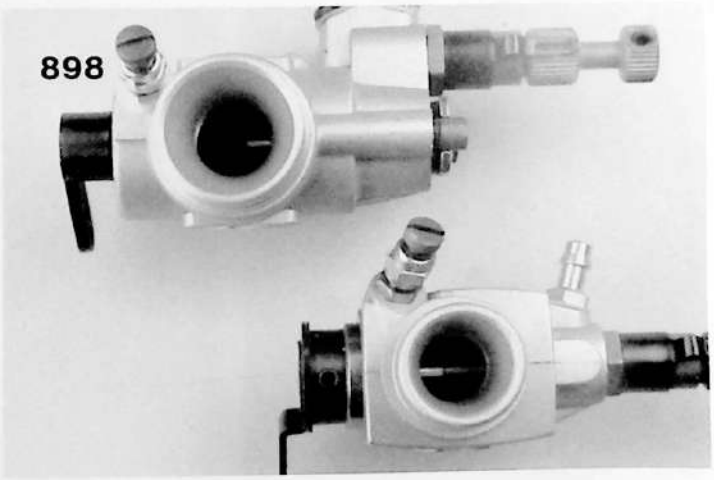
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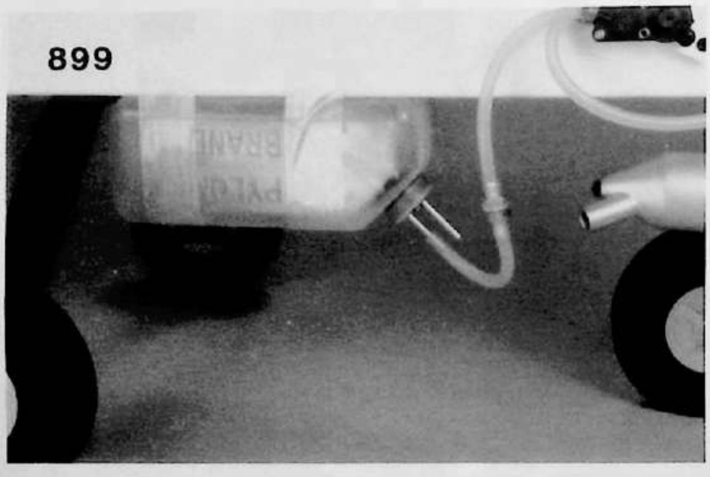
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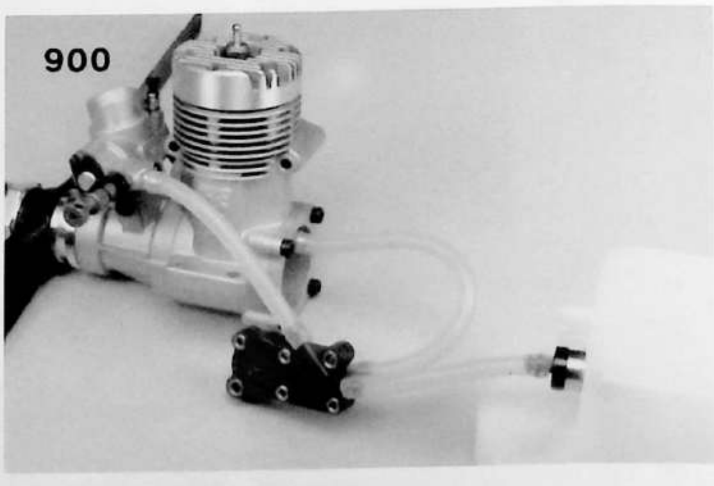
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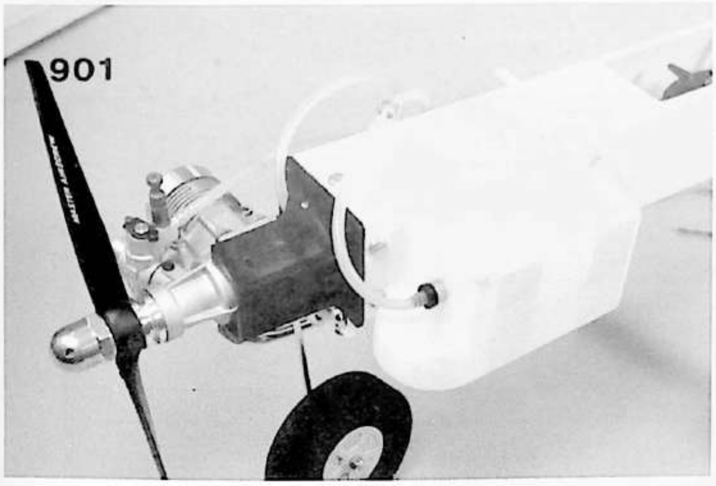
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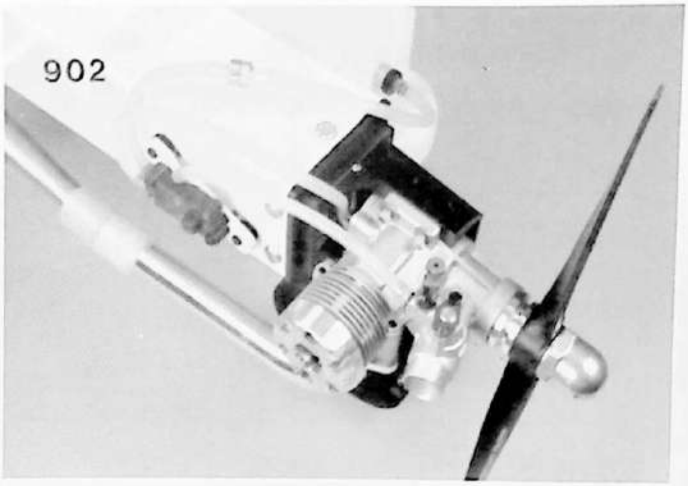
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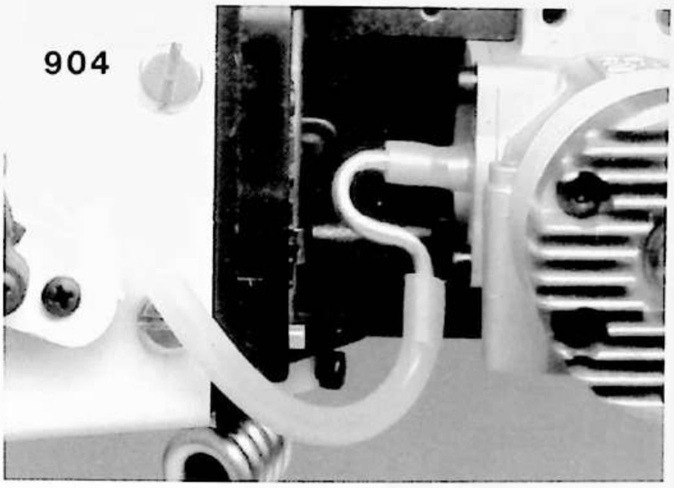
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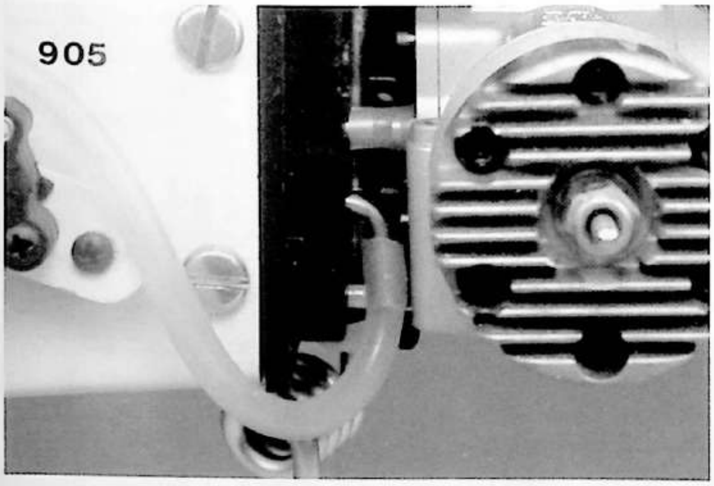
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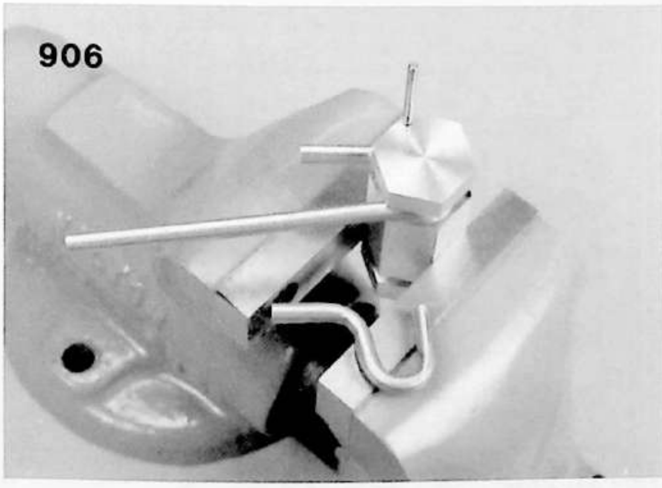
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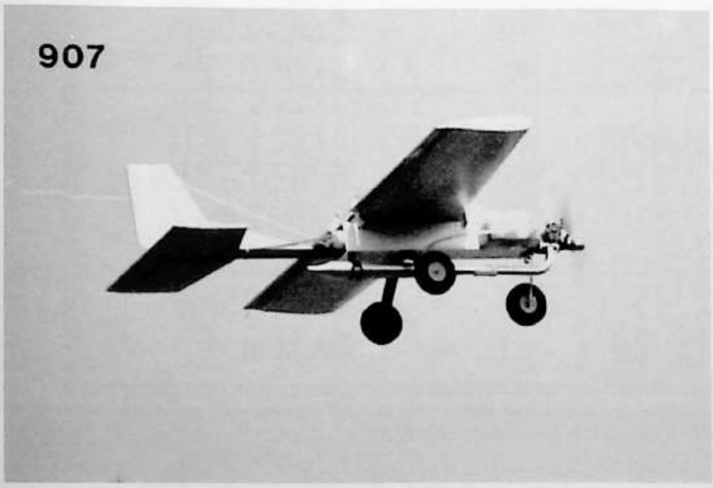
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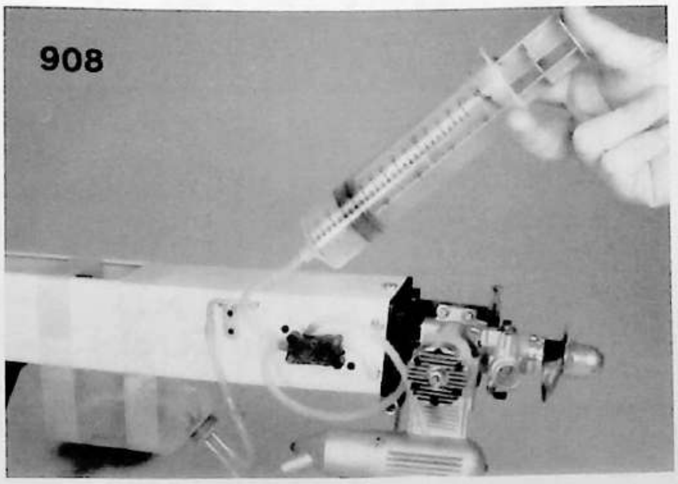
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APPENDIX I
CRANKSHAFT SIZES

MAKE	MODEL	SIZE	SHAFT SIZE
ASP	All Models	.46 & Smaller	1/4-28
ASP	All Models	.60	5/16-24
ASP	All Models	1.08	3/8-24
Enya	Four Stroke	.46, .53	1/4-28
Enya	Four Stroke	.60, - 120	7x1mm
Enya	Four Stroke	R120	8x1mm
Enya	SS 2 Stroke	.25 - .50	1/4-28
Enya	NonSS 2 Stroke	.15 - .25	6x1mm
Enya	NonSS 2 Stroke	.35 - .60	7x1mm
Fox	All Models	.19 - .50	1/4-28
Fox	All Models	.60 - 1.20	5/16 - 24
HB	All Models	All Sizes	1/4-28
HP	All Models	.21 - .61	1/4-28
Irvine	All Models	All Sizes	1/4-28
K&B	All Models	All Sizes	1/4-28
Magnum	All Models	.21 - .45	1/4-28
Merco	All Models	.33 .35 & .40	1/4-28
Merco	All Models	.50 & .61	5/16-24
OS	Four Cycle	.20 - .48	1/4-28
OS	Four Cycle	.60 - 120	5/16 -24
OS	Max	.20 - .50	1/4-28
OS	Max	.61 - .90	5/16-24
Picco	All Models	.21 - .45	1/4-28
Picco	All Models	.60	8x1.25mm
Rossi	All Models	.40 - .90	8x1.25mm
Royal	All Models	.21 - .46	1/4-28
Saito	FA	.40 - .45	6x1mm
Saito	FA	.50 - .90T	7x1mm
Saito	FA	1.2	8x1.25mm
Super Tiger	All Models	.19 - .56	1/4 - 28
Super Tiger	G and ST	.60	1/4 - 28
Super Tiger	S and X	.61 - .90	5/16 - 24
Webra	All	.21 - .60	1/4-28
Webra	All	.80 - .90	8x1.25mm
Y S Futaba	All Models	.45 - .61	8x1.25mm
Y S Futaba	Four Stroke	1.20	8x1mm

APPENDIX II
DECIMAL EQUIVALENTS FOR ENGLISH AND METRIC DRILLS

DRILL	INCHES	MM	DRILL	INCHES	MM	DRILL	INCHES	MM
80	.0135	.343	2.9 mm	.1142	2.900	E	.2500	6.350
79	.0145	.368	32	.1160	2.946	6.4 mm	.2520	6.400
1/64	.0156	.397	3.0 mm	.1181	3.000	6.5 mm	.2559	6.500
.4 mm	.0157	.400	31	.1200	3.048	F	.2570	6.528
78	.0160	.406	3.1 mm	.1220	3.100	6.6 mm	.2598	6.600
77	.0180	.457	1/8	.1250	3.175	G	.2610	6.629
.5 mm	.0197	.500	3.2 mm	.1260	3.200	6.7 mm	.2638	6.700
76	.0200	.508	30	.1285	3.264	17/64	.2656	6.747
75	.0210	.533	3.3 mm	.1299	3.300	H	.2660	6.756
74	.0225	.572	3.4 mm	.1339	3.400	6.8 mm	.2677	6.800
.6 mm	.0236	.600	29	.1360	3.454	6.9 mm	.2717	6.900
73	.0240	.610	3.5 mm	.1378	3.500	I	.2720	6.909
72	.0250	.635	28	.1405	3.569	7.0 mm	.2756	7.000
71	.0260	.660	9/64	.1406	3.572	J	.2770	7.036
.7 mm	.0276	.700	3.6 mm	.1417	3.600	7.1 mm	.2795	7.100
70	.0280	.711	27	.1440	3.658	K	.2810	7.137
69	.0292	.742	3.7 mm	.1457	3.700	9/32	.2813	7.144
68	.0310	.787	26	.1470	3.734	7.2 mm	.2835	7.200
1/32	.0313	.794	25	.1495	3.797	7.3 mm	.2874	7.300
.8 mm	.0315	.800	3.8 mm	.1496	3.800	L	.2900	7.366
67	.0320	.813	24	.1520	3.861	7.4 mm	.2913	7.400
66	.0330	.838	3.9 mm	.1535	3.900	M	.2950	7.493
65	.0350	.889	23	.1540	3.912	7.5 mm	.2953	7.500
.9 mm	.0354	.900	5/32	.1563	3.969	19/64	.2969	7.541
64	.0360	.914	22	.1570	3.988	7.6 mm	.2992	7.600
63	.0370	.940	4.0 mm	.1575	4.000	N	.3020	7.671
62	.0380	.965	21	.1590	4.039	7.7 mm	.3031	7.700
61	.0390	.991	20	.1610	4.089	7.8 mm	.3071	7.800
1.0 mm	.0394	1.000	4.1 mm	.1614	4.100	7.9 mm	.3110	7.900
60	.0400	1.016	4.2 mm	.1654	4.200	5/16	.3125	7.938
59	.0410	1.041	19	.1660	4.216	8.0 mm	.3150	8.000
58	.0420	1.067	4.3 mm	.1693	4.300	O	.3160	8.026
57	.0430	1.092	18	.1695	4.305	8.1 mm	.3189	8.100
1.1 mm	.0433	1.100	11/64	.1719	4.366	8.2 mm	.3228	8.200
56	.0465	1.181	17	.1730	4.394	P	.3230	8.204
3/64	.0469	1.191	4.4 mm	.1732	4.400	8.3 mm	.3268	8.300
1.2 mm	.0472	1.200	16	.1770	4.496	21/64	.3281	8.334
1.3 mm	.0512	1.300	4.5 mm	.1772	4.500	8.4 mm	.3307	8.400
55	.0520	1.321	15	.1800	4.572	Q	.3320	8.433
54	.0550	1.397	4.6 mm	.1811	4.600	8.5 mm	.3346	8.500
1.4 mm	.0551	1.400	14	.1820	4.623	8.6 mm	.3386	8.600
1.5 mm	.0591	1.500	4.7 mm	.1850	4.700	R	.3390	8.611
53	.0595	1.511	13	.1850	4.699	8.7 mm	.3425	8.700
1/16	.0625	1.588	3/16	.1875	4.763	11/32	.3438	8.731
1.6 mm	.0630	1.600	4.8 mm	.1890	4.800	8.8 mm	.3465	8.800
52	.0635	1.613	12	.1890	4.801	S	.3480	8.839
1.7 mm	.0669	1.700	11	.1910	4.851	8.9 mm	.3504	8.900
51	.0670	1.702	4.9 mm	.1929	4.900	9.0 mm	.3543	9.000
50	.0700	1.778	10	.1935	4.915	T	.3580	9.093
1.8 mm	.0709	1.800	9	.1960	4.978	9.1 mm	.3583	9.100
49	.0730	1.854	5.0 mm	.1968	5.000	23/64	.3594	9.128
1.9 mm	.0748	1.900	8	.1990	5.055	9.2 mm	.3622	9.200
48	.0760	1.930	5.1 mm	.2008	5.100	9.3 mm	.3661	9.300
5/64	.0781	1.984	7	.2010	5.105	U	.3680	9.347
47	.0785	1.994	13/64	.2031	5.159	9.4 mm	.3701	9.400
2.0 mm	.0787	2.000	6	.2040	5.182	9.5 mm	.3740	9.500
46	.0810	2.057	5.2 mm	.2047	5.200	3/8	.3750	9.525
45	.0820	2.083	5	.2055	5.220	V	.3770	9.576
2.1 mm	.0827	2.100	5.3 mm	.2087	5.300	9.6 mm	.3780	9.600
44	.0860	2.184	4	.2090	5.309	9.7 mm	.3819	9.700
2.2 mm	.0866	2.200	5.4 mm	.2126	5.400	9.8 mm	.3858	9.800
43	.0890	2.261	3	.2130	5.410	W	.3860	9.804
2.3 mm	.0906	2.300	5.5 mm	.2165	5.500	9.9 mm	.3898	9.900
42	.0935	2.375	7/32	.2188	5.556	25/64	.3906	9.922
3/32	.0938	2.381	5.6 mm	.2205	5.600	10.0 mm	.3937	10.000
2.4 mm	.0945	2.400	2	.2210	5.613	X	.3970	10.084
41	.0960	2.438	5.7 mm	.2244	5.700	Y	.4040	10.262
40	.0980	2.489	1	.2280	5.791	13/32	.4063	10.319
2.5 mm	.0984	2.500	5.8 mm	.2283	5.800	Z	.4130	10.490
39	.0995	2.527	5.9 mm	.2323	5.900	10.5 mm	.4134	10.500
38	.1015	2.578	A	.2340	5.944	27/64	.4219	10.716
2.6 mm	.1024	2.600	15/64	.2344	5.953	11.0 mm	.4331	11.000
37	.1040	2.642	6.0 mm	.2362	6.000	7/16	.4375	11.113
2.7 mm	.1063	2.700	B	.2380	6.045	11.5 mm	.4528	11.500
36	.1065	2.705	6.1 mm	.2402	6.100	29/64	.4531	11.509
7/64	.1094	2.778	C	.2420	6.147	15/32	.4688	11.906
35	.1100	2.794	6.2 mm	.2441	6.200	12.0 mm	.4724	12.000
2.8 mm	.1102	2.800	D	.2460	6.248	31/64	.4844	12.303
34	.1110	2.819	6.3 mm	.2480	6.300	12.5 mm	.4921	12.500
33	.1130	2.870	1/4	.2500	6.350	1/2	.5000	12.700
						13.0 mm	.5118	13.000

APPENDIX III
TAP AND BODY DRILL SIZES

TAP	DRILL TYPE	TAP DRILL	BODY DRILL
0 - 80	num	56	52
	mm	1.2	1.6
	in	3/64	1/16
1 - 72	num	53	48
	mm	1.5	2.0
	in	1/16	5/64
2 - 64	num	50	44
	mm	1.8	2.2
	in	none	3/32
2 - 56	num	50	44
	mm	1.8	2.2
	in	none	3/32
3 - 56	num	45	39
	mm	2.1	2.6
	in	none	7/64
3 - 48	num	47	39
	mm	2.0	2.6
	in	5/64	7/64
4 - 40	num	43	33
	mm	2.3	3.0
	in	3/32	1/8
5 - 40	num	38	30
	mm	2.6	3.2
	in	none	1/8
6 - 32	num	36	28
	mm	2.7	3.6
	in	7/64	9/64
6 - 40	num	33	28
	mm	2.9	3.6
	in	none	9/64
8 - 32	num	29	19
	mm	3.5	4.3
	in	9/64	11/64
10 - 32	num	21	11
	mm	4.0	5.0
	in	5/32	3/16
1/4 - 20	num	7	let E
	mm	5.1	6.4
	in	13/64	1/4
1/4 - 28	num	3	let E
	mm	5.5	6.4
	in	7/32	1/4
1/4 - 32	num	2	let E
	mm	5.6	6.4
	in	7/32	1/4
5/16 - 24	let	I	let O
	mm	7.0	8.0
	in	none	5/16
3/8 - 24	let	Q	let V
	mm	8.5	9.6
	in	21/64	3/8
METRICS 2.0 x .4	num	52	46
	mm	1.6	2.0
	in	1/16	3/32
2.5 x .45	num	46	39
	mm	2.1	2.5
	in	none	7/64
3.0 x .5	num	40	31
	mm	2.5	3.0
	in	none	1/8
3.5 x .6	num	33	28
	mm	2.9	3.5
	in	none	9/64
4.0 x .7	num	30	21
	mm	3.3	4.0
	in	none	11/64
5.0 x .8	num	19	8
	mm	4.2	5.0
	in	none	13/64
6.0 x 1.	num	5	let B
	mm	5.0	6.0
	in	13/64	1/4
7.0 x 1.	let	none	J
	mm	6.0	7.0
	in	15/64	9/32
8 x 1.25	let	H	O
	mm	6.7	8.0
	in	17/64	21/64
10 x1.25	let	R	X
	mm	8.7	10.0
	in	11/32	13/32

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APPENDIX IV
APPROXIMATE THREAD DIAMETERS

SCREW	INCH DIA.
#0	.058
#1	.071
2 mm	.076
#2	.084
2.5mm	.096 *
#3	.097 *
#4	.110
3 mm	.116
#5	.125
#6	.135 *
3.5mm	.135 *
4 mm	.153
#8	.163
#10	.187
5 mm	.193
6 mm	.230
1/4	.245
7 mm	.267
5/15	.305
8 mm	.314
* Use Pitch Gage For These	

INSTRUCTIONS

Find the screw diameter with a micrometer or dial caliper and locate the closest entry in the table. The entries having an * are too close to tell apart so use a pitch gage for the final determination.

APPENDIX V
COMMON ENGINE METRIC SCREWS

Manu.	Model	Size	Head	Back-plate	Crank-case	Muffler	Carb
ASP		32	3.0x10	3.0x6		3.0x30	
ASP		46	3.0x10	3.0x8		3.0x30	
ASP		61	4.0x14	4.0x8		4.0x14	
ASP		108	4.0x14	4.0x8		4.0x14	
Webra	Silv	40	3.0x10	3.0x10	3.0x10		
Webra	Q500	40	3.5x14	3.5x8	3.0x10		
Webra		32	3.5x12	3.0x8			
Webra		61	3.5x15				
Enya	CX	40	3.5x10	3.5x10		3.0x30	4.0x6
Enya	SS	40	3.0x10		3.5x12	3.0x30	4.0x6
SuperT	S	40	3.5x14	3.0x5			
SuperT	G	51	3.5x14	3.0x5			
OS	FP	35,40	3.0x10	3.0x8		3.0x35	3.5x5
OS	SF	40,46	3.5x10	3.5x8		3.0x35	3.5x5
OS	SF	61	3.5x15	4.0x10			3.5x5
OS	Surp	48	3.0x18	3.0x8			
OS	Surp	70	3.5x20	3.5x8			
YS		61	3.5x15	3.5x10		3.0x35	3.5x5
Royal		21,28	2.5x10	2.5x7		2.5x7	3.5x5
Royal		40,45	3.0x12	3.0x8		3.0x8	
Magnum		40	3.0x12	3.0x8		3.0x30	

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