The Little Dragon glow engine is a project any amateur machinist can tackle with full confidence of good results. It does not require any special tools, special talents, or extreme precision. A large part of the total time spent in developing the design was devoted to eliminating awkward machining jobs, delicate operations, and tricky assemblies. If the reader owns a small lathe and can center a piece of stock with $\frac{1}{64}''$, he need have no qualms about being able to turn out the job. On the other hand, the skilled builder who has a good "touch" for this sort of thing will discover he has an engine, which requires absolutely no apologies on the score of being homemade.

The motor is a basic design, as old-engine hands will recognize by the drawings. It has great amounts of leeway at every step of construction. This means there is plenty of room for the correction of errors, which should appeal to the amateur, and equally of importance, it allows the experienced motor builder to "soup-up" the design as he sees fit. For example, the weight of the original came out at 2 oz., complete with plug and prop. Skillful shaving-down by experienced machinists can reduce this figure greatly, but this has nothing to do with the operating characteristics. Port areas and valve timing are laid out with an eye to obtaining maximum start ability and a good rate of speed with average construction and internal fits, but the experienced worker who is capable of doing very good work will find it possible to increase the porting and degree of valve opening to obtain an extremely hot engine.

The original Little Dragon was turning the plastic prop shown in the photo at 8,000 rpm, 5 minutes after it was assembled. It did this on a break-in mix of 3 parts O & R No. 2 and 1 part castor oil. This is the performance the amateur can reasonably expect. For experts, and with one of the hot Francisco Lab fuels, 10,000 rpm is a reasonably conservative estimate.

The mounting of any engine uses up time and energy and in too many cases is fannicky and bothersome. We have tried to get around this and come up with something that is simple, quick, and practical. The two-stud mount is our answer. Simply press the studs against a piece of plywood to mark it in order to build engines, a glance through the list of tools required. The engine was turned in the lathe by a right-hand metal. By this rule, we see that the fins are machined first. If your lathe is a light one, use the back gears and feed the cutting metal. By this rule, we see that the fins are machined first. For example, if the piece is $\frac{1}{32}''$ shorter than it should be, the first fin would be $\frac{3}{32}''$ deep instead of $\frac{1}{8}''$.

The block is the easiest part to make, in terms of tolerances, and serves the amateur builder the purpose of getting his hand in as he goes along. Once the block is made the rest of the engine falls right into line. The first fin is extra heavy because this must carry the screwing in slowly, particularly at the start of each cut when it is chipping at the square corners of the stock.

An ordinary book of matches dwarfs our tiny engine.

Editors note: Cad drawing in thousandths.

Little Dragon all ready to roar! This engine is really "on the square".
The block is drilled out to an I.D. of a shy 9/16" and brought up to size with a boring tool, or reamer. Getting the correct depth is important, not because it will prevent the engine from running, but because you will have to go over the whole thing changing other dimensions to make it come out right. Note how a shoulder is left to support the liner. This liner must fit closely in order to prevent blow-by around the exhaust port and at the head. This does not mean a piston-type fit by any means, but it should be tight enough so that it is just about possible to pull the piece out with the fingers. A dummy sleeve cut from the steel tube stock is a great help here. If by some mischance the hole is oversize, don't scrap the job, just tin the sleeve and resize it to fit the hole. (But you won't be able to harden the sleeve if you do this, and then you will have to use an aluminum or cast iron piston.)

Remove the piece and re-chuck it in order to bore out the front of the case. Open this up part way with a drill and bring to final size with a boring tool. The inside rear must be faced off smoothly because the rotor valve will ride against it. The rotor pin hole is drilled out by holding a 3/32" drill in the tailstock. At this point lay the piece aside and make up the crankcase front section. Do a good job here and no gasket will be needed; in any case a short piece of thread wrapped around the plug portion of this part will serve very well as a gasket. If the inside end is turned first and fitted to the block, the job is easier, as this leaves something to chuck with. Next, reverse the piece and bore out to 3/16" I.D. and bring the outside down to size. No bearing is used other than the metal itself. If you want to be ritzy about it, the hole can be bored oversize and bronze, or Oilitbearing material pressed in. In practice, the writer has found aluminum to serve very well, but the coefficient of friction of Oilit material is undoubtedly more favorable if the end in view is extreme performance. For that matter, ball bearings small enough to be used in this engine can be obtained, and we are indebted to Malcolm D. Whitman, Jr., of Carmel, Calif., for that information. If you use ball bearings, the crankshaft diameter must be reduced or the outboard end of the bearing increased to accommodate the ball race, should double ball suspension be desired.

The crankshaft belongs to a breed of cats that seems able to scare a lot of people. Don't worry about it. Put the three-jaw chuck on your lathe and insert the piece of 9/16" drill rod. Bring this down to size with light cuts and power feed. Finish the journal with a fine file, crocus cloth and common sense. If you happen to have a tool post grinder, by all means use it. Custom fit the shaft to the crankcase front section, double checking to be certain the thrust washer clearance is adequate, then mark the spot and turn down to the size you have selected for the threaded portion. We call for an 8-32 thread, but this is a matter of choice and whatever die you have handy. The threads may be cut on the lathe, but some will find it less trouble to back off the tail stock and use an ordinary die. Be sure to start it straight; back the die off every half turn to break the chips and insure a good thread. A few drops of light oil makes the cut easier. Near the end of the cut it is a good idea to reverse the die in order to cut the threads up close to the journal. The thrust washer is simply a threaded disc. The writer has used threaded drive washers on a number of engines with good results and why no commercial engine uses them is something of a mystery since it is certainly easier than milling splines or grinding flats.

Now, remove the piece and put on the four-jaw. Chuck up the shaft by the journal and off-center the piece 3/16" by adjusting the jaws. It is possible to hold the piece adequately without marring the journal, but the cautious may wish to push the shaft into a length of brass tubing and squeeze the jaws down on this. If this is done, be sure to use only a gentle tapping to put it in place, because the journal must be knocked out again afterward. The whole secret of turning off-centers is setting the lathe tool on center, feeding in slowly, and using power feed to drag the tool along the work. In addition, be willing to take a little time to do the job. The pin should be brought to a good surface finish. The crank disc may be ground or filed away as indicated by the dotted lines on the plan for a sort of counterbalance effect, but this is not critical.

The rotor comes next. Most people seem to have the opinion that disc valves must be tricky since they come in the more expensive engines, so we'll give a little background on this. When the original Little Dragon was being laid out, a great deal of consideration was given to the induction method. It had to be very simple and very effective. Three-port induction seemed simple, but it meant tapping into the block and cutting another hole in the liner. Besides this it did not allow much leeway for error and would not produce the best power output. Shaft rotary looked good at first glance, but this would mean less than optimum strength for the crankshaft, chances for errors in both the port hole and the hollow shaft, and the added difficulty of setting the intake tube into the front case. So that was out. Next we toyed with the idea of flutter valve induction; these arrangements are simple, and since they work on crankcase pressure, very effective. However, a speck of dirt, or oil hardening in the valve makes them inoperable with a vengeance. Further difficulty was foreseen due to the great powers of fuel meniscus in these small sizes. Fuel meniscus? That did it! So we used a disc rotor and made it free-floating. Five minutes after assembly we knew we had it. Only two smooth faces are needed, and one of them is already inside the crankcase. Best of all the intake hole can be spotted easily, and if missed, it can be tried again with a new rotor. In addition to all these advantages, the thickness of the rotor is not critical and this gives the amateur machinist another place to pick up and correct accumulated error.

Chuck up the 5/8" aluminum rod and turn down the rotor shaft to fit the hole in the rear of the engine block. This should not be a tight fit, but smooth running and a bit loose if anything. Bring the O.D. of the rotor down to size and face it with a gentle cut, making certain there is no shoulder next to the shaft as this will prevent seating. Cutting loose from the stock should be halted about halfway through and all sharp edges broken, then complete the severance. Locate and drill the drive hole. This should be a bit oversize, but do not drill all the way through the disc, just enough for good clearance. Mark the outline of the port and file away the indicated area. The rotor may be held between two thin bits of wood or fibre in a vise for this operation. Break any edges that develop. Now, take up the block and put the rotor shaft into the hole from the outside rear of the case and scratch the outline of the round portion
as shown on the plan. Split the difference between this line and the edge of the shaft hole and drill a 1/8” hole along the diagonal. The intake tube is a length of 5/32” thin wall brass tube. Taper one end slightly (this taper is emphasized on the drawings) and press the tube firmly into the case. The needle valve assembly may be from a Baby *Spitfire* or other small engine.

The crankcase front section must now be drilled; set it in the engine block and spot the holes for drilling. These holes are drilled and tapped 2-56. The original engine used 3-48 screws throughout, but the larger size is not needed. However, it may be comforting to know that if you ruin the No. 2 hole you can always re-tap it for 3-48. Tapping is easier if the holes are first filled with kerosene and the tap backed off at frequent intervals. Tap in the mounting studs next.

At this point, clean up all the parts and make a trial assembly to be sure everything fits smoothly and turns freely. If the rotor valve shows a tendency to creep forward on the pin, don't worry about it—it won't when the engine is running. The important thing is that it seats well and does not bind at any point.

(Next month we'll bring you the concluding part of the Little *Dragon* construction article, giving instructions for con rod, cylinder head, and the amazingly simple sleeve and piston arrangement which eliminates the need of conventional milled or cast-in by-pass. Details of fuel, starting and running will also be covered.)

**BILL OF MATERIALS (for entire engine)**

- 8” of 3/4” sq. hard aluminum alloy rod
- 2” of 5/8” round hard aluminum alloy rod
- 3” of 1/2” round 17ST rod
- 3” of 9/16” seamless steel tubing
- 3” of 9/16” drill rod
- 1” of 1/8” O.D. heavy wall brass tube
- 1” of 5/32” O.D. thin wall brass tube
- Scrap of 1/8” thick dural sheet (hard) for con rod
- 2—3-48 studs 5/8” long
- 8—2-56 or 3-48 screws, fillister head, 3/8” long
- 2—No. 4 hole washers
- 2—3-48 nuts
- 1”-sq. thin gasket material
- 1 Baby *Spitfire* needle valve assembly
- 1 McCoy Hot Point Plug
THE Little Dragon shapes up rapidly once the block and lower assemblies are completed. The cylinder liner is made from a length of 9/16" seamless steel tubing which has a wall thickness of about 1/16". Use great care in cutting it to size. Hold it by means of a leather strap in a vise and use a fine hack saw blade (put in the frame backwards). Take light strokes. The final fitting is done in the lathe three-jaw chuck. Once again please note, here is an opportunity to adjust if you have already drilled the rod holes. The piston skirt must not hit on the front case plug at bottom stroke. If you require a longer rod due to small errors, make it longer—you can take the difference out of the head. The wrist pin is simply a short length of 1/8" heavy-wall brass tube. Assemble the engine, using light oil on all bearing surfaces, and turn it over by hand. The piston will (or should) have quite a bit of resistance, but no real "sticks" should develop anywhere. If they do, correct them. Check the position of the piston relative to the liner at top and bottom center. If these positions are within 1/64" of the positions shown on the plan, congratulate yourself on a job well done. If not, you will have to make allowances for the liner ports.

The exhaust port and intake by-pass are cut into the liner with a small, medium-fine file. Support the liner endwise between two thin pieces of wood in the jaws of a vise. The operation is very simple as can be seen by the plan, but care and accuracy can return big dividends here. Carefully remove any burrs that develop. The piston deflector is now filed on. Check this against both the plan and the liner. The exhaust port must open first, and leads the intake port by 1/32" of piston travel.

File through the barrel of the engine block below the last fin, put the liner in place and check the alignment. The block should be slightly larger than the liner slot, but not smaller. Take a scribe and mark the portion of the liner supporting rim below the by-pass slot, remove the liner and cut away this portion of the rim with a fine metal chisel or hand grinder. This ticks the by-pass problem.

The cylinder head is of the "plug" variety and also has a slight gasket-retaining groove. The combination makes it heat-proof even with very indifferent machining. Ideally, the plug should be a smooth push fit into the liner. The plug portion is extra long to facilitate final assembly. Tap a 1/4" x 32 hole into the head for the Glow Plug. The head is mounted the same way as the front case section, that is, drill the head holes first and use these as guides for drilling the holes in the engine block. These are tapped 2-56 all the way through the first fin.

Clean up everything, wipe castor oil on all contacting surfaces and assemble the engine except for the head. Put a prop on the shaft and turn it over a few times. There will probably be quite a bit of piston resistance, but this is all right. The thing to watch out for is jamming, though this is not likely to occur due to the general design of the engine. If it should happen, take the engine apart and look for surfaces that appear unnaturally bright, or scored-looking. Fix them up. The internal clearance between rotor, rod and crankshaft need be no more than 1/32". If the clearance is as much as 1/16 the meniscus effect will be lost on the rotor plate. This will not prevent running, but it will make starting a bit harder.
Set the head in place (without glow plug) and turn the piston up to top center, and see how much the head lifts off. Then rechuck the head and face off the plug portion enough to allow 1/32" clearance between it and the piston, at top dead center. Don't break the sharp edge of the cut—it's too handy to cut holes in gaskets with. Use it now to cut a gasket, and trim around the edges enough to allow the head screws to go through. Dip the gasket in castor oil and assemble the head to the engine. Pull the screws down "cross corner" fashion, a little at a time. They should be snug and fairly tight, but don't strip the threads out of the block.

Mount the engine on a piece of wood, which can be screwed down to something solid, and put on a four- or five-inch length of fuel line. Turn the engine over by hand for a few minutes and get used to its grunts and groans. Don't put the glow plug in yet. Get to know the various wheezes and pops and what they mean. Note the soft "tunk!" made by the intake port opening into the cylinder, the gurgle of the intake rotor. These sounds are usually masked by the louder pop of released compression when the motor is flipped over.

Turn the motor over slowly several times and the intake port noise may disappear. This means the rotor has ridden off its seat. A quick flip backward reseats it. Repeat this trick with the glow plug in place (McCoy Hot Point plug is recommended). When the rotor unseats there will seem to be a loss of compression. Again flip the prop backwards and the "compression" reappears. Unless you are familiar with this stunt, you may think the head gasket has blown, or there is dirt under the rotor, and tear the motor down to find the "trouble."

Mix up a break-in mix of three parts O & R No. 2 and one part castor oil. Fill the fuel line and squirt a couple of drops into the exhaust port. Hook up the wires and give it a flip. After a half dozen bursts, the parts will "find" and the motor will run out the fuel. Don't hook it up to a tank and lean it out until it has run off a few minutes of four-cycling.

The fuel you will use depends to a great extent upon the piston fit. If it is loose, more oil will be required, but if very good it can be run on straight O & R No. 2. Don't jump to conclusions about the compression ratio if it doesn't run correctly. Try altering the fuel mixture (oil ratio) because it may be a case of poor piston fit. If you're certain the piston fit is good, then increase the ratio by deepening the gasket groove. This engine has quite a wide range of glow C.R. because of good thermal characteristics and will operate well between 7- and 10-1, with 8 being about optimum. Once the engine is running properly don't take it apart unless absolutely necessary, as this disturbs the run-in. This is particularly true if the aluminum piston is used.

The Little Dragon is the result of about three months of design consideration by the writer, in an effort to obtain a layout in the ½A size, which could be, quite literally, all things to all men. A basically simple construction which could return good results to the beginner, yet give the old motor hand a design which would permit him full exercise of his skill and require no apologies for the fact of being homemade. If you like it, let's hear about it. If you run into difficulties, don't hesitate to write the author. Good luck.

GLOW PLUG DIAGNOSTICS

SYMPTOM: Starts readily, revs up well, rpm drops off when plug wire is removed. Indication: Compression ratio is too low.

Cure: Add oil and/or nitrate to fuel, deepen gasket groove to decrease head space.

SYMPTOM: Starts very hard with much flashback, but runs well once started.

Indication: Exhaust port not opening soon enough before intake transfer.

Cure: Check liner slots against plan, file more "lead" into exhaust.

SYMPTOM: Must be flooded to start and will run only on rich mixture.

Indication: Cylinder head, or glow plug gasket is leaking.

Cure: Replace gaskets, check surfaces for damage.

SYMPTOM: Kicks violently, runs in short high speed bursts, kicks off prop, stops suddenly. Indication: Compression ratio is too high.

Cure: Reduce compression ratio by shaving down inserted "plug" portion of cylinder head, or try high compression fuels with a cold glow plug.

SYMPTOM: Starts easily, holds up speed when wire is removed, leans out well, then gradually dies out. Indication: Motor is not yet broken-in, probably overheating.

Cure: Use heavy, low pitch prop and run motor as rich as it will take for ten to fifteen minutes, then try it again. General: Watch for the usual bugs, clogged fuel line or needle, tanks not vented correctly, loose prop, bad plug, loose wires, insecure mounting, evaporation weakened fuel. Use a port prime to start engine.