No castings are needed for this speedy ball-bearing gas engine. Reliable and easy to start, it will power a model plane, car, or boat in flashy style.

By J. C. Magee

PART I

**HIGH-SPEED GASOLINE ENGINE**

<table>
<thead>
<tr>
<th>BORE</th>
<th>1&quot;</th>
<th>R.P.M.</th>
<th>13,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>STROKE</td>
<td>1&quot;</td>
<td>WEIGHT (less flywheel)</td>
<td>15 oz.</td>
</tr>
<tr>
<td>DISPLACEMENT</td>
<td>12.7 cc.</td>
<td>HP.</td>
<td>1/4</td>
</tr>
<tr>
<td>OVERALL HEIGHT</td>
<td>4&quot;</td>
<td>COMPRESSION RATIO</td>
<td>15 to 1</td>
</tr>
</tbody>
</table>

An angle plate mounted on the faceplate holds the crankcase. The indicator checks for squareness. Then the crankcase is bolted to the angle plate, and the fit for the cylinder is carefully bored.

Two views of the crankcase with the machining completed. At left, the crankcase from the front at the angle shown in the assembly at top.

And at right, a view of the crankcase from the rear. The groove that can be seen inside the bore can be cut with a homemade tool.
ENGINE hits 13,000 r.p.m.

THIS is just the model gas engine you have been waiting for. And after you've built it, you can, if you wish, put it up on the mantelpiece for all to admire: But you won't do that, for it will rev up to 13,000 without a murmur and supply plenty of power and speed for a model car or model boat. With a propeller adapter, it can be used as a power plant for an iceboat or a large model airplane. It requires no castings, is sturdily designed, and starts easily, but remember that performance can only be proportional to the care and workmanship you put into its construction.

The solid crankshaft is mounted on two ball bearings, one on either side of the crankpin, an arrangement that provides perfect support for the crankshaft while it travels at high speed. A rotary valve is an integral part of the crankshaft. This allows a greater charge of gas mixture to be drawn into the crankcase at each revolution than the cylinder port common in two-cycle engines, so the engine will develop more speed and power. The connecting rod is solid phosphor bronze with a separate bearing cap at the big end to provide for adjustment in case of wear.

Three work sheets are given on this and the following pages. They contain a de-

---

**WORK SHEET NUMBER ONE**

1. Rough-turn, allowing 1/32" stock on all surfaces. Do not drill or bore the cylinder hole.

2. Allow the piece to stand for a few days to equalize strains.

3. Chuck lightly in the four-jaw chuck, finish-bore inside the crankcase complete, using the grooving tool shown on page 148, and face the end. Fit the ball bearing (part 10) to a push fit in the .875" diameter bore. The depth of the bearing bore should be .003" less than the width of the ball bearing. Boring and facing must be carefully done in one setting (chucking) to obtain perfect concentricity of all fits.

4. Chuck and turn the arbor on page 151 to a push fit in the 1.500" diameter of the crankcase. Mount the crankcase on the arbor and face to 1 9/16" over-all length. Assemble with a bolt and washer to prevent slipping. Turn the 1.125" diameter shoulder. Turn the outside diameter of the crankcase and two chamfers.

5. Lay out the cylinder hole. Mount the crankcase dead square on the angle plate in its proper location. Bore and face the cylinder hole complete and face to 1 15/16" over-all length.

6. Lay out, drill, and file the by-pass slot adjacent to the cylinder hole.

7. Lay out, drill, and tap all holes except the four 2-56 holes. Tap the two holes on the boss side 6-32, 5/32" deep.

8. Assemble the completed retainer (part 6) and mark the retainer and crankcase so they will always be assembled in the same position. Spot-drill the four 2-56 holes lightly with a No. 43 drill, remove the retainer, drill and tap the 2-56 holes.
Here is the setup for boring the .502" diameter in the cover held in a nest. Stub arbors and nests assure concentricity of fits when machining can’t be done in one chucking.

Tapping of the needle-valve hole in the crankcase cover is best done by hand in the drill press, as above. Just at the right, a rear view of the cover showing the ball bearing, and at the far right, a front view of the completed cover.

tailed, step-by-step explanation of the operations required for making the crankcase assembly. Don’t be fooled by the fact that some of the dimensions are given to three decimal places. Unlike the work done in a large shop where one mechanic makes only one part, you will be making the entire engine and will have some leeway. What you really want is to be sure that mating parts fit each other without play.

Thus when a crankcase bore of 1.500" is called for and a 1.499" diameter is specified for the crankcase cover, the important thing is to keep within the .001" allowance. If you should make the bore 1.501" by mistake, a 1.500" diameter for the cover will correct the error, and the engine will run as perfectly. Generally, the machinist finds it easier to bore to size first and then turn down the mating piece to fit the bore.

Rough-turning provides an opportunity for you to become acquainted with the part to be machined and the tools that have been ground for the job. Since 1/32" stock is left on for the finish cut, all bores will, of course, be 1/16" undersize and all outside diameters 1/16" oversize.

In roughing out the crankcase, face down both ends first to 1 1/2", thereby leaving 1/32" on each end for finish turning. A 1/2"

**TOOL FOR GROOVING CRANKCASE**

Forge the gooseneck on 3/8" drill rod with sufficient stock on the end for the cutting edges. Let the tool cool slowly, and then file to the shape shown. Reheat to a cherry red, quench in water, and draw to a light straw color. Touch up the cutting edges on a grinding wheel and round the sharp corners slightly with a fine hand stone.

The tool is fed into the work gradually as the carriage is run back and forth slowly between stops. Its fishtail cutting edges prevent chatter, permit feeding in freely while the work is being traversed, and produce a fine finish.
PART 2, INTAKE TUBE
1. Face to 1 3/16" long and remove burrs.

PART 3, CRANKCASE COVER
1. Rough-turn, leaving 1/32" on surfaces.
2. Let stand a few days to equalize strains.
3. Chuck on the back end, finish-bore inside, turn and face the 1.499" diameter and shoulder. Fit the ball bearing (part 11) to a push fit in the 1.125" diameter bore. The depth of the bearing bore should be .003" less than the width of the ball bearing. Be sure the 1.125", 1.437", and 1.499" fits and shoulders are concentric and square with each other.
4. Chuck lightly on the 1.499" diameter, finish-turn the outside, and face to length.
5. Mill or file the intake and needle-valve boss and remove burrs.

6. Lay out, drill, and ream the intake-tube hole to a press fit (.0005" interference) with the intake tube (part 2).

PART 4, CRANKCASE-COVER ASSEMBLY
1. Oil parts 2 and 3 lightly and assemble.
2. To facilitate boring, file out the portion of the intake tube that extends into the hole.
3. Chuck and bore the nest, shown in the drawing on page 151, to fit the 1.499" diameter. Mount the cover in the nest and bore the .502" diameter concentric with fits on the opposite side.
4. Lay out, drill, and tap all holes except the four 2-56 holes around the 1.125" diameter-bearing bore. This operation is the same as in part 1, step 8, using the part 5 retainer. The 10-32 tapped hole for the needle valve is drilled and tapped straight through from one side so the holes will be in alignment.

diameter hole is then drilled straight through while the piece is still chucked. More stock can be removed by drilling if a 1" or 1 1/8" drill is available, but be careful not to drill too deep. Next, bore the 1.500" diameter hole to 1 7/16" by 1 3/32" deep, the 1.375" bore to 1 5/16" by 1 11/64" deep, the .875" bore to 13/16" by 1 25/64" deep, and the .625" bore to 9/16". The 1/32" left on the face from which you work automatically leaves 1/32" at the bottom of each bore for finish-boring.

Some care will be required in making the 1 13/16" diameter groove, or it may end up in the wrong place. Work from the same face, which is already 1/32" oversize, and add 1/16" to the 31/64" dimension, thus locating the near edge of the groove 35/64" from the working face and the far side 57/64". If this sounds involved, study it out with pencil and paper.

Use the grooving tool shown in one of the drawings with a spacer block the width of the groove minus the width of the tool (11/32"— 1/8") or 7/32". Place the spacer between the lathe stop and the carriage and put another stop against the right-hand end of the carriage. This will restrict the carriage to the proper travel for the width of the groove. A piece of brass carefully clamped to the lathe bed will serve for the right-hand stop. You can use a scale for the measurements, but spacers are more reliable and are as easy to use as a scale.

The crankcase is next turned end for end in the chuck and trued up, and its 1.125" diameter is then turned to 1 3/16" by 3/16" deep. Because of the 1/32" extra stock on
WORK SHEET NUMBER THREE

PART 5, RETAINER

1. Clamp the duraluminum sheet on the faceplate, drill and bore the hole to size.
2. Face to correct thickness and chamfer.
3. Part the piece out 1/32" oversize.
4. Mount on a stub arbor and turn the outside diameter to size and concentric with the bore.
5. Lay out, drill, and countersink.
6. Remove all burrs and sharp edges.

PART 6, RETAINER

1. Follow the same procedure as in part 5. Be sure to make this part last so the stub arbor can be rechucked and turned down each time.

PART 7, COVER

1. Clamp the duraluminum sheet on the faceplate, take a light facing cut, and part out to size.
2. Lay out, drill, and remove all burrs.

PART 8, FLYWHEEL

1. Chuck the piece in the lathe, allowing 3/4" of the stock to extend beyond the jaws. Rough-turn the outside diameter, part in the starting-cord groove, finish-face, turn the shoulder, and bore to size.
2. Rechuck and rough out the opposite end complete, allowing 1/32" for finish turning.
3. Turn and polish a stub arbor to fit the bore snugly and mount the flywheel on the arbor.
4. Finish-turn complete, including the outside diameter, and polish. All surfaces must run true.
5. Cut a keyway, or drill and tap for a setscrew, and remove burrs.
6. Lay out, drill, tap, and remove burrs, including the two 5/32" holes at the bottom of the slots.
7. File out two slots for the starting cord.

PART 9, TIMER CAM

1. Drill, countersink, and part off.

the face, the shoulder must be turned the full 3/16" length shown in the drawing. It is not necessary to rough out the maximum outside diameter or the chamfers, but it will do no harm.

Stub arbors and nests provide a sure method of obtaining concentricity between parts when they cannot be bored in one chucking. Such pieces are made of scrap stock chucked in the lathe and turned and polished to fit snugly the

Below are completed retainers, a cover, and ball bearings. At right are views of the flywheel from the front and back. The starting-cord groove and slots can be seen in the front view at top, and the assembled timer cam in the lower photo.
part that will be mounted on or in it for turning. An arbor or nest cannot be used again after it has been removed from the chuck unless it is turned down smaller or bored out larger for the next job. Be sure to oil mating surfaces before using.

The importance of concentricity between fits cannot be overemphasized. Wherever possible, all diameters should be turned or bored at one chucking. However, the .502" diameter on the crankcase cover must be concentric with the fits on the opposite side, so concentricity is obtained by mounting the cover in a nest and locating from the 1.499" diameter and shoulder for boring. Concentricity is necessary here so the rotary-valve end of the crankshaft will float free in the .502" bore and the latter will not act as a bearing or cause interference when the motor is running.

By a push fit for the ball bearings is meant one that will allow a ball bearing to be pushed into its housing with the fingers—a snug fit. The best way to obtain this fit is to use the ball bearing for a gauge. Mount it on a makeshift handle between two washers that will keep it clean.

Hold the ball bearing square when attempting to fit it, for if it is cocked it may cause you to misjudge the size of the bore and lead to taking off too much stock. The depth of the bores is .003" less than the width of the bearing so the retainer will hold the bearing in its proper position. A ball bearing is a precision unit and must be handled carefully and kept meticulously clean both during the fitting and the final installation.

Directions for making the model gas engine are being presented in three installments to provide plenty of space for a full discussion of each part. The parts to be taken up next month include the cylinder, piston, and connecting rod.

The ball bearings, bar, rod, and sheet stock called for in the list of materials can probably be obtained by most readers from the larger hardware stores, jobbers, salvage or war-surplus stocks, or mail-order supply houses. However, as an accommodation for those who cannot obtain the materials elsewhere, a kit containing the ball bearings, timer points, timer-cam stock, and alloy-steel screws and wrenches is available. Some of the bar and rod items needed can also be supplied.
Cylinder, Piston, and Connecting Rod
FOR YOUR HIGH-SPEED GAS ENGINE

PART II

By J. C. MAGEE

DESIGNED for assembly without gaskets, this little engine has few intrinsically critical dimensions, though it does call for painstaking work to produce gas tight fits between mating parts. But if the cylinder is bored a thousandth or so oversize, it is only necessary to make corrections in the piston and ring so clearance and fit are not changed (see P.S.M., June '46, p. 146).

Care must be taken, however, to get a good radius of not less than 1/16" at the base of the spark-plug boss to avoid weakening the cylinder head. Also, since the outside diameter affects the cylinder-wall thickness, this should not be less than 1 3/32" at any point, nor should any fin groove be deeper than 4" for the same reason.

Parting in of the fins is done with a well-sharpened parting tool .071" wide. In spacing the fins, the lathe compound is set exactly parallel to the ways. The parting tool is next set so it just touches the cylinder face, the lathe carriage locked, and the compound-rest collar set at zero. Then the tool is backed off with the cross feed and advanced .101" with the compound feed for cutting the first groove. This leaves the fin .030" wide. Repeat for each groove.

For proper depth, the tool is set just touching the 1 5/8" diameter of the work, the cross-feed collar set at zero, the tool advanced .250", and a stop clamped to the cross-feed slide. Plenty of cutting fluid should always be used when parting.

Note that the depth of the cylinder bore is measured from the lower face of the flange. Set the tool so it just touches the flange and lock the carriage stop with a 2.000" spacer intervening to get proper depth.

Use a good layout fluid and mark off the exhaust and by-pass ports and the by-pass

ROAD TEST in an experimental racing-car chassis. The engine shown, an earlier one built by Mr. Magee, only turned up to a free speed of 8,000 r.p.m. but pushed the car at 65 m.p.h. The engine described in the accompanying article has run free at 13,500 r.p.m., and Mr. Magee believes it will drive a racing car at better than 85 m.p.h. The new engine has a 20 percent greater piston area.
PART 12, CYLINDER

1. Face the stock to 2 21/64" in length and rough-turn it to 1 21/32" in diameter.

2. Drill a 3/4" hole straight through in the lathe, and drill a 3/8" hole 2 3/8" deep, measured from the point of the drill.

3. Turn the work around and chuck with 1 3/4" extending from the jaws. Bore the 3/4" hole to .330" and tap with a 3/8"-24 tap for the spark plug. Turn a 3/8" diameter spark-plug boss 3/8" long, using a tool with a 1/16" radius.

4. Turn the fin section to 1 3/4" diameter, and part in the fins to a depth of 3/4".

5. Rechuck carefully on the fins so the piece will run true, and turn the 1 1/16" length between the last fin and the flange down to 1 3/32" diameter. Turn the flange to 1 5/8" diameter and turn the 1 3/8" diameter shoulder 3/8" long. The flange should be 5/64" thick after turning at this stage of the work.

6. Bore the cylinder to 31/32" in diameter for a depth of 2" from the flange.

7. Lay out the exhaust and by-pass ports and the 3/8" slot in the flange. Drill and file to size.

8. Remove all burrs and sharp edges.

PART 13, BY-PASS CHAMBER

1. Form sheet stock over a forming block and file or machine to fit the cylinder snugly. The outer radius should be 1/16" less than that of the flange when fitted. Use only steel for the chamber.

PART 14, BRAZING ASSEMBLY

1. Assemble part 13 on part 12 so it will cover the three by-pass ports and the flange slot. Silver-solder carefully around the edges, using just enough solder to make the chamber airtight.

Slot. An index plate or a 180-tooth gear mounted behind the chuck will determine the degrees (see P.S.M., Oct. '44, p. 185). The center of the by-pass slot is on a line with that of the middle by-pass port. Use a height gauge if available or a surface gauge to determine the port heights. Scribe the slot arc as a radius from the center of a plug put temporarily in the cylinder, or else scribe with a pointed tool while the cylinder is still chucked in the lathe.

So long as each group of ports is properly located in respect to the other, the width of the ports is not critical. The total of the three by-pass ports should not exceed, however, the 3/8" width of the by-pass chamber.

Locate the ports from the cylinder flange so they will be in proper position when assembled. This can be done by supporting the flange on two blocks of known height, say 3/4", set up on a surface plate and adding 3/8" to the desired dimensions. A surface gauge may be used if no other more accurate lay-out device is available.

The 1.093" diameter of the cylinder fits the 1.094" bore of the crankcase (part 1), and clearance up to .001" may be allowed. A snug fit is insurance against leakage. The .004" clearance in the fit of the flange in the crankcase is not critical.

In boring the cylinder, it is well to examine the first few cuts to see that the tool
PART 21, CONNECTING ROD

1. Cut two pieces of stock, one 2 1/16" long and the other 5/16" long. Machine the ends square, tin them, and sweat the two pieces together.

2. Lay out, as shown in the drawing.

3. Drill two No. 44 holes 5/6" deep in the end.

4. Saw and file the outside contour to size. Holes for the radiiuses may be drilled if similar stock is clamped on the side where needed.

5. Prick-punch both parts so they will always be assembled in the same position.

6. Unsolder the parts and clean the tinned surfaces off with fine emery.

7. Tap the bearing-cap holes with a 4-40 tap.

8. Drill and counterbore the No. 32 holes in the connecting rod, as shown.

9. Assemble the cap and rod with two 4-40 socket-head cap screws 7/32" long, mount on the faceplate, and bore the .375" and .250" diameter holes.

10. Mount the crank end on a short arbor, face the boss to .370" thickness, and chamfer the .55" shoulder. Then face carefully with light cuts to the 7/32" thickness halfway up the rod.

11. Mount the piston end on a stub arbor, face and chamfer both sides also to a 7/32" thickness, and face the remainder of the rod.

12. Lay out and drill six holes to lighten.


14. Lay out and drill the three oil holes in the connecting rod and the oil hole in the cap.

15. Cut oil grooves in the rod and cap.

16. Remove all burrs and sharp edges.

Remove it and apply a film of solder to the turned portion while rotating it slowly over a gas flame, using just enough heat to make the solder stick without running to one side. When an even film of solder is obtained, rechuck the bar, turn the soldered portion down to .999", and face off the end so the lap will reach to the far end of the cylinder. Then on the lapping surface apply a fine, even coat of No. 400 flour emery and light oil. Lap by running the lathe at slow speed and sliding the cylinder back and forth.
It is not necessary to bring the bore to exactly 1.000", for the piston and ring can be turned to correspond, but a true, smooth surface is important. If the lap wears down before the job has been completed, it can be resoldered and re-turned. All the compound must be removed by repeated washings when the work is finished.

Cut the piston-ring groove in the piston with a sharp parting tool .094" wide. Feed the cross slide in .0485" after touching the outside diameter with the tool and setting the graduated collar at zero. The corners must be sharp, sides straight and smooth.

Bore the piston-pin hole with the piston clamped to an accurately square angle plate, which in turn is clamped to the lathe faceplate with its inside face .025" from the center of the spindle. Check the setting with scrap stock, boring a .250" hole and setting the cross-feed collar at zero after the last sizing cut. A .250" dowel pin is a good gauge.

Extend a .250" dowel pin through the piston-pin hole and locate from it to lay out the exhaust chamfer and by-pass radius on the piston head. Then stand the piston on its head and mark off the ¼" depth. In end-milling inside the piston to lighten it, be careful not to cut closer than 1/32" from the piston-pin holes, leaving the bosses there to support the pin. Locate the slots from the holes so they will be centered.

The stub arbor on which the piston is finish-turned must be a snug fit for the 15/16" diameter, and must have a shoulder to hold the piston square. Turn the piston to a smooth finish that fits the cylinder with a clearance of .003".

If a grinder is not available, the piston rings can be parted off close to size and polished down to .094" with fine emery cloth laid on a flat surface.

Sweating the two parts of the connecting rod together helps in aligning the two screw holes, which must be laid out accurately and drilled square with each other and with the sides of the block. Keep matching surfaces flat and square when polishing off the tin after unsoldering. Counterboring requires care and a very fine feed because the cut starts on a sloping surface. The counterbore shown below should be tried first on scrap stock.

A flat auxiliary plate may be needed under the rod for support over the faceplate when the holes are bored in the crank and piston ends. If toolmaker's blocks are available, they help in obtaining the 1.875" dimension between centers. However, an error up to .005" should not cause trouble.

Bore the crank-end hole accurately; the other a free but not loose fit on the piston pin. A little oil in the bores when they are mounted on the arbor will prevent scoring.

When the piston and rod are assembled with the piston pin, the distance from the center of the crank-end hole to the extreme top of the piston should be 2.309" to 2.312". If it is less, hope for the best or make a new part. Should it be greater, take a cut off the top of the piston and correct the exhaust chamfer and by-pass depths to maintain proper port action.

**LIST OF MATERIALS**

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Description</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Machine steel</td>
<td>1¼&quot; dia. by 3½&quot;</td>
</tr>
<tr>
<td>13</td>
<td>Sheet steel</td>
<td>.030&quot; by 1½&quot; sq.</td>
</tr>
<tr>
<td>16</td>
<td>Dural</td>
<td>1¼&quot; dia. by 3&quot;</td>
</tr>
<tr>
<td>17</td>
<td>Gray cast iron</td>
<td>1¼&quot; dia. by 3&quot;</td>
</tr>
<tr>
<td>18</td>
<td>Drill rod</td>
<td>5/16&quot; dia. by 1½&quot;</td>
</tr>
<tr>
<td>19</td>
<td>Dural</td>
<td>¼&quot; dia. by 1½&quot;</td>
</tr>
<tr>
<td>21</td>
<td>Phosphor bronze</td>
<td>½&quot; by ¾&quot; by 2¾&quot;</td>
</tr>
</tbody>
</table>

**PISTON-RING ARBOR**

*NOTE: PLACE PISTON RING ON 080'SHOUMLDER, HOLD SHUT WITH CLOSING RING, CLAMP WITH WASHER AND NUT. REMOVE CLOSING RING AND TURN PISTON RING TO SIZE*

**PISTON-RING ARBOR**

*NOTE: HARDEN AND DRAW CUTTING END ONLY. TRY CUTTER IN SCRAP STOCK TO CHECK SIZE AND ACTION. THE 080 LONG UNDERCUT IS 10 CLEAR 080 DIA. TOP BOSS OF CONNECTING ROD*
PART 15, CYLINDER (FINISH TURN)

1. Chuck the assembled cylinder carefully and lightly on the fins so it runs true.

2. Turn the 1.093" diameter and face the flange to 1.062" from the top of the exhaust ports. Turn the flange to 1.590" diameter and face the cylinder end to leave the 7/64" shoulder.

3. Bore the cylinder to a fine, smooth finish, allowing .0003" to .0005" for lapping. Locate the 2,000" depth from the lower face of the flange. Use a 1/32" radius boring tool. Turn the 30-deg. chamfer.

4. Lay out and drill the four flange holes.

5. Mill or file the two flats to the 1 3/4" dimension.

6. File out the flange slot nearly flush with the 1.093" diameter, taking care not to mark or score this diameter or the cylinder seat.

7. Remove all burrs and sharp edges, including properly sharpened and set to produce a fine, smooth finish. The easiest way to get the correct bore is to turn down a piece of scrap stock to .9995", which allows for lapping to 1,000", and use it as a plug gauge to check when boring. Be sure to use the 2,000" spacer with the carriage stop so the bore won't go too deep. Take care after finish-boring so as not to distort the cylinder in clamping or other operations.

Use a lead lap or one made of brass and solder. Chuck a length of 1" diameter brass in the lathe and turn it down to 31/32" for about 2 1/2" from the end. [Turn the page.]
**PART 16, PISTON**

1. Chuck the stock with 1 3/8" extending from the jaws. Rough-turn to 1 1/32" diameter.

2. Face the end, rough-drill and bore the 11/16" diameter 15/16" deep. Bore the 15/16" diameter to a depth of 15/32".

3. Part in the .094" ring groove, and part off the piece 1 3/32" long.

4. Rechuck lightly. Face to a length of 1.062".

5. Set up on an angle plate, and drill and bore the .250" piston-pin hole.

6. Lay out the exhaust chamfer and the by-pass radius, and machine and file them.

7. End-mill inside the piston.

8. Lay out two 3/16" by 1/2" slots. Drill and file.

9. Mount the piston on a stub arbor that is a snug fit for the 11/16" and 15/16" diameters, and turn the .997" diameter to size.

10. Remove all burrs and sharp edges.

**PART 17, PISTON RING**

1. Chuck, bore to .935", turn to 1.055", and part off. Make several extra rings.

2. Grind to a width of .094".

3. Mill or saw the .040" slot.

4. Mount on the piston-ring arbor shown on page 181 and turn the outside to 1.000" diameter.

5. Polish the sides to fit the ring groove in part 16, remove burrs, and check for .005" clearance with the ring in the cylinder. File if the clearance is insufficient.

**PART 18, PISTON PIN**

1. Chuck the stock, drill the No. 24 hole, and turn and polish to a diameter of .250".

2. Bore a .187" diameter 3/32" deep in each end.

**PART 19, PISTON-PIN CAPS**

1. Turn and part off.

**PART 20, PISTON-PIN ASSEMBLY**

1. Press the caps into the ends of the piston pin and file or turn 1/2" radiiuses on the ends. The overall length must not exceed 31/32".

---

A 5/16" end mill ground into a radius cutter is used for end-milling the by-pass radius (left).

Finish-turning is done with the piston pressed on a stub arbor turned to fit its two bores.

Rings may be parted off close to size (left) and polished on fine emery.

At right, using a feeler gauge to check the ring for .005" end clearance in the cylinder.
Your High-Speed Gas Engine

PART III
By J. C. MAGEE

NOW approaches the big moment for you to cash in on your work in building the 13,000-r.p.m. model gas engine. Those who couldn't wait for the complete story have already finished the crankcase (P.S.M., June '46, p. 146) and the cylinder, piston, and connecting rod (P.S.M., July '46, p. 176). There remain only the crankshaft, timer, and needle valve. Then you will be ready to assemble the engine for its first tryout.

Use only a good grade of machine steel for the crankshaft. Face it to finished length so you can work from either end. Hold the shaft and flange diameters close to size for a snug fit in the crankshaft fixture shown on page 179.

To mount the fixture off center, first chuck a piece of scrap and turn it to a 2.500" diameter. Then clamp an indicator in the tool post touching the 2.500" diameter and set it at zero. The fixture and crankshaft are next clamped to the faceplate with the indicator reading zero when it touches the 1.500" flange. Thin brass in the setscrew holes prevents marring. When the crankpin has been turned to .500", it should be flush with the 1.500" diameter. A few thousandths error is not serious.

The depth of the 1.500" bore of the fixture is .202" so the flange thickness can be located from the face. If the center hole in the lathe faceplate is smaller than 1 7/16" in diameter and ½" in depth, make the fixture 2½" long instead of 1½". Clamp a stop on both sides of the lathe carriage to restrict the tool travel to .375".

Make the crankpin slightly oversize and polish down with fine emery and crocus cloth for a good bearing surface. File the flange cutouts carefully to get balance, but do not form the chamfers yet. To insure an absolutely true center for finish-turning (step 9), chuck a piece of rod, turn a 60-deg. point, and use this as a live center. Then the work can be turned end for end without worry. Make the .375" and

WATER COOLS the engine used in this model boat. The water intake is directly behind the propeller in the shaft strut, assuring an adequate supply when the engine is running with the boat stationary. Either an air- or water-cooled cylinder can be used on the model described on these pages.
1. Rough-turn, as at A, to the 3 7/16" finished length.

2. Mill out the flange with a 5/16" cutter to a depth of 1 1/32", leaving a 3/16" width for the crankpin.

3. Chuck the short end true and center the other end.

4. Rechuck on the long end, bore the short end 3/16", as at B, and bore a 60-deg. chamfer to serve as a center.

5. Mount between centers, turn the shaft, as shown at B, and face the flanges to the finished .780" dimension.

6. Mount in the fixture shown on page 179, finish-face .375" between flanges, as in the photo at top left, turn and polish the crankpin, and drill the pin 3/16".

7. Lay out the counterbalances as in the end view.

8. Drill two 3/4" holes, saw out the remaining material, and finish-file to shape.

9. Mount a small .375" block with rubber cement between flanges opposite the crankpin to support the shaft while it is being turned between centers, as shown in the middle photo.

10. Finish-turn on centers to the dimensions at C.

11. Mill the keyway on the side opposite the crankpin.

12. Lay out the rotary-valve hole (section A-A at C), and drill and file to size.

13. Remove all burrs.

Note: Do not machine or file the two 45-deg. chamfers now; they are for balancing later. The completed crankshaft is shown in the lower photo.
(1) a light film of oil is required on mating surfaces before they are fitted together; (2) screws in dural parts must have a light film of oil on their threads before being put in; (3) all screws must be tight.

Seat the two ball bearings squarely against the inner ends of each of the bearing bores, oiling liberally with high-grade light bearing oil. Lock the retainers in with screws. Assemble the crankshaft in the crankcase bearing, using a .375" block between flanges and tapping lightly if necessary, and place the crankcase cover on the opposite end, again supporting and tapping for proper seating. Four screws hold the case. Check to see that the crankshaft rotates freely; then screw on the small cover.

Attach the connecting rod to the crankshaft with two cap screws chamfered 45 deg. for clearance in the crankcase. Match the marks on the rod and bearing cap. To be sure the bearing cap is aligned right, use two .005" shims between the rod and one crankshaft flange during assembly.

Carefully expand the piston ring with the fingers and slide it down over the top of the piston into the groove. Then attach the piston to the connecting rod with the piston pin, which should be a running fit in the rod bearing and a snug fit in the piston. It may be necessary to polish down the center of the pin.

Use a half-and-half mixture of colloidal graphite and SAE No. 30 machine oil to "run in" the engine in the lathe. Apply a few drops around the two connecting-rod bearings and in the oil holes. Hold the piston ring in closed position with the fingers and slide the cylinder down over the piston, seating it on the crankcase, and tighten the four cap screws. The exhaust ports should face you when the rotary valve is on your right.

Apply a few drops of the running-in mixture to the piston through the spark-plug hole, exhaust ports, and rotary-valve intake. Clean the lathe chuck and plate of all chips, and chuck the .375" shaft extension. Move or swing the engine a few times by hand to make sure all runs free, set the lathe for about 900 r.p.m., grip the fins firmly, and start the lathe. A one-hour running in, broken into 10- or 15-minute periods, is sufficient. Apply the running-in mixture during each pause—never while the engine is running—and touch nothing but the fins. Keep the lathe carriage away. After running in, remove the cylinder and drain the crankcase, apply a few more drops of the mixture, check the connecting-rod screws, and replace the cylinder.

Assemble the timer on the crankcase with the two shoulder screws, part 30. The shoulders are .001" longer than the thickness of the bracket flange to prevent turning while the motor is running and yet permit adjustment without unscrewing. Attach the timer cam to the flywheel, slide the flywheel against the ball bearing, put in the key, and tighten the setscrew. Remove the contact arm and bend it slightly so about 2-oz. pressure will be needed to pull the points apart. Set the timer cam to hold the points at maximum opening and adjust the contact screw to make the opening .010". Put in the spark plug and its gasket, checking for piston clearance. The needle valve—its locking arm goes on either side of the boss and the needle-valve seat on the opposite side.

Mount the engine on a steel test block and clamp this block, not the engine, in the vise. Attach the gas tank, and wire as shown in the diagram above. Check for proper spark by laying the spark plug on the cylinder while the flywheel is rotated counterclockwise by hand. Use fresh batteries. Connections must be tight (soldered after final installation). Set the timer so the points break when the piston is at top dead center or a little beyond.

Fill the gas tank with a mixture of 1 part high-grade SAE No. 40 oil and 4 parts white aviation gasoline (90 octane is best), adding a few drops of colloidal graphite. Do not use leaded gas.

Now, open the needle valve two complete turns, wind a starting cord on the flywheel, and choke the engine by holding a finger over the air-intake tube and turning the flywheel two or three times with the cord. Turn on the switch and choke again, this
time only partially closing the air intake. Remove your finger when the engine fires, advance the spark a bit by moving the timer arm, and slowly close the needle valve until firing is smooth and speed picks up. The engine turns in a counterclockwise direction, viewed from the flywheel end.

An air-cooled engine should be run for only short periods while stationary to avoid overheating, and never at high speed until well broken in. After an hour or two of short runs, apply a few drops of the running-in mixture through the exhaust ports. Run it out of doors, if possible, because of fumes; if not, have the windows open. Don't stand in line with the flywheel. When the engine is mounted in a model boat, car, or plane, be sure the cylinder is exposed to the air stream.

After breaking in, it is safe to rev up on the test block by advancing the spark for short periods. The engine can be run for long periods on the block if a water-cooled cylinder is used. One can be made by turning off all but the two outer fins and brazing to them a 15/16" long and 1/8" I.D. brass tube having a 1/32" wall. The tube should have an inlet and outlet for siphoning a continuous stream of water.

Keep the engine in good condition and use only a fresh mixture of gas. If it fails to start, check wiring connections, clean the breaker points and check clearance, clean the spark plug and check the gap and spark, and check the batteries. Check also the valve-seat jet opening. If the motor becomes flooded, shut the needle valve and turn the engine a few times to remove excess gas.

Should an accumulation of small errors on the timer make idling or revving up impossible, the timer cam on the flywheel can be moved either way by drilling another 2-56 hole in the flywheel on the same radius. Here the engine is assembled complete except for the flywheel. This view shows how the timer fits on the front of the crankcase.

Assemble the piston on the connecting rod in this relative position, with the by-pass radius forward when the rotary valve is to the left.
.500" shaft diameters push fits in the ball bearings and do not try to force them on. A .002" clearance is necessary on the .500" and .625" shoulders for the retainers. The .085" length of the shoulders can vary a few thousandths, but the over-all distance between their outside faces must not exceed .950". Lay out the rotary-valve hole by the same method followed for the cylinder ports in Part I.

Don’t make the 45-deg. chamfers shown at C in Worksheet No. 8 until after a trial run. Then, if the engine vibrates badly, the crankshaft can be taken out for filing these chamfers to balance.

The 1.126" bore of the timer bracket fits the 1.125" shoulder on the front of the crankcase. Points can be silver or platinum, if available, or standard auto or telephone-relay points. They need not be more than 1/16" in diameter.

If the threads for the needle valve and valve seat are cut in the lathe, the parts will be in alignment when assembled. Hold the .015" diameter as close as possible. The arm, part 34, locks the needle valve adjustment. Since its travel is restricted to a semicircle, its 3/4" thickness may require filing to assure locking.

Because of the high compression ratio of the engine, it is advisable to use a VR-1 spark plug. A type V and other types can be used, but the ground electrode will have to be shortened and bent down to within .020" of the center electrode to decrease over-all height. To make sure the spark plug will not interfere with the piston, cut in the top of the piston a chamfered recess not exceeding 3/8" in diameter or 3/64" in depth.

The stock and hardware required are available in large cities, but for those who experience difficulty, kits can be supplied. These include hardware and ignition kits, along with the VR-1 spark plug, and also some material such as a duralumin block for the crankcase.

Check each part before assembly, remove burrs and sharp edges, and clean it. Then, as you proceed, remember three points: