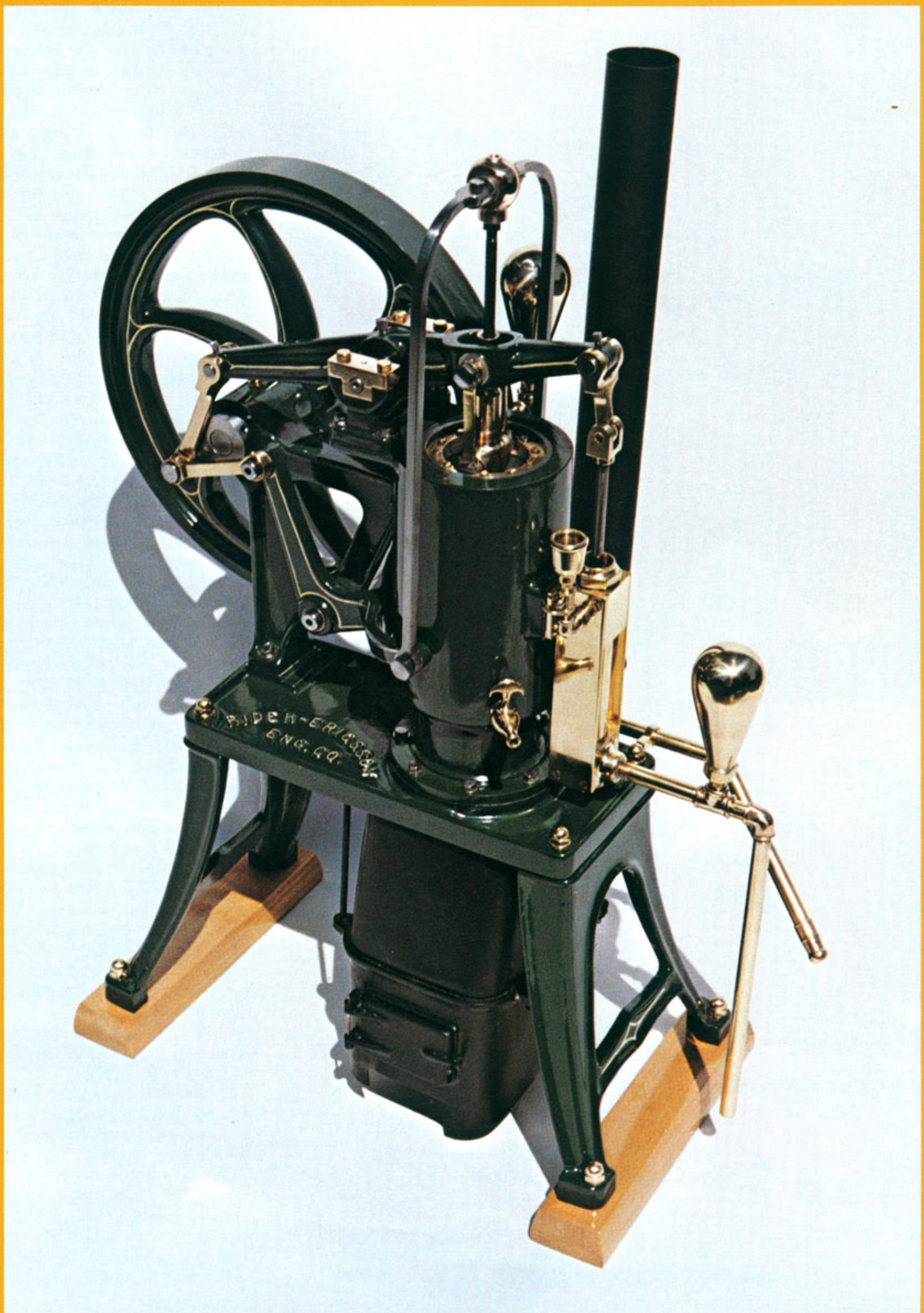
A quarter-size Rider-Ericsson

Hot Air Pumping Engine

by Larry Kazyak

Photos by the Author



The hot-air or Stirling Cycle Engine was invented in 1817 by a Scot named Robert Stirling. Although such engines were quite low in power output in proportion to their large size, they became popular due to their simple operation. Steam was the only other practical choice, since internal combustion engines were not invented until the 1880's. Steam engines, with their boilers operating at high pressures and the trained engineers require to watch over them, were often impractical for small or isolated installations.

The Ericsson Hot Air Pumping Engine was first patented in 1880. It was the creation of John Ericsson, who was born in Sweden in 1803 and emigrated to America in 1839. Many inventions are attributed to this prolific inventor. Perhaps one of the most noteworthy was the ironclad ship *Monitor*, built for the United States (Union) Navy during the Civil War. Another monumental—but only semi-successful—venture was the building of a 250′ ship named *The Ericsson*. This vessel was powered by a hot-air engine having four cylinders operating at nine RPM. The pistons measured 14′ in diameter and the stroke was six feet in length. The ship was launched on the east coast in 1853. Even though the ship had an engine of such heroic dimensions, it could travel at only seven knots, about half the speed of a comparable steam-powered ship.

The fact that Stirling Cycle engines use an external heat source and that John Ericsson designed a solar-powered engine in 1872, point out that in one sense, there's really "nothing new under the sun."

So much for background on the inventor. Let's get down to facts on the engine being modeled. The original is in the Henry Ford Museum, in Dearborn, Michigan. It is classified as an eight-inch engine, referring to the bore. The stroke is 3⅞″. Operating at 100 to 120 RPM, it was capable of pumping 500 gallons per hour. The indicated horsepower was approximately ⅛.

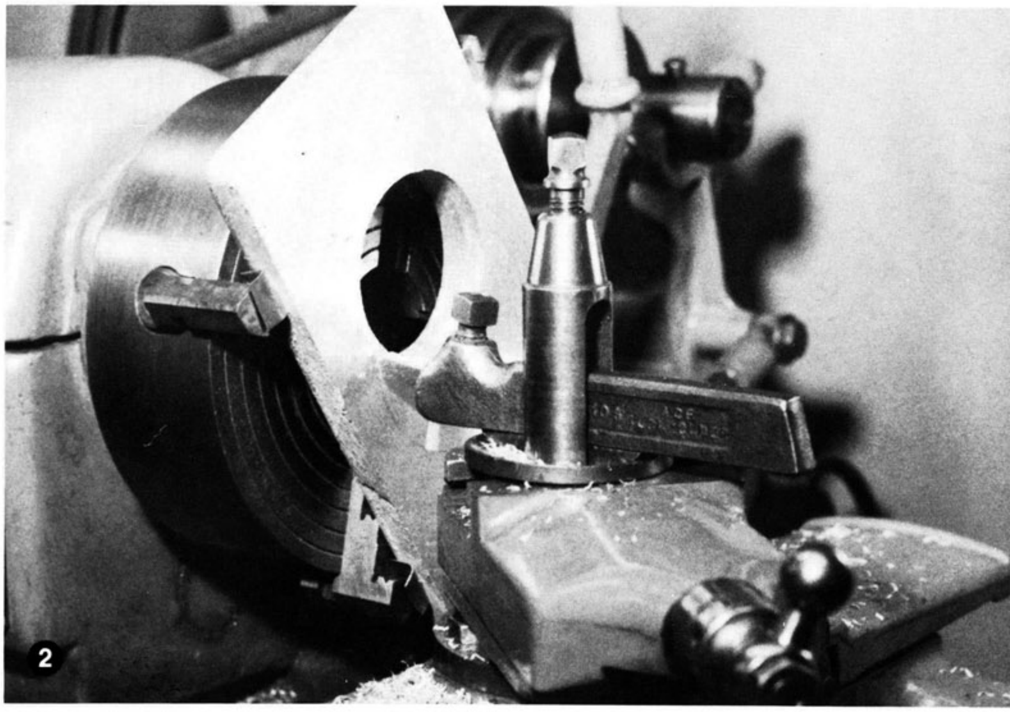
Although the first Ericsson Pumping Engines were put into production in 1880, this particular engine was produced at the turn of the century. The main difference is in the legs and crankshaft bracket. Legs on earlier models were forged round bar stock instead of the cast type.

The Rider-Ericsson Engine Company (the successor to the DeLamater Iron Works, which was established in 1842) was established in 1870, with offices in New York, Philadelphia, Boston, Chicago and Sydney, Australia.

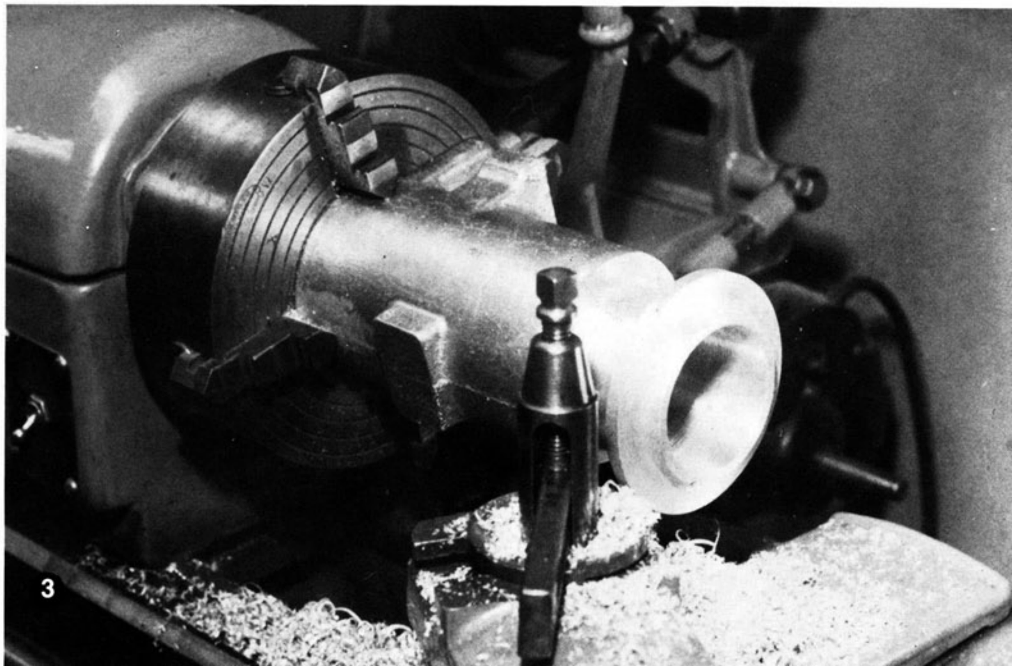
In operation, the engine was fired with wood, coal, producer gas or kerosene, depending on the type of firebox ordered. When the displacer cylinder reached operating temperature—usually in about fifteen minutes—the flywheel would be rotated by

This quarter-sized model (opposite page) follows the prototype of an 8″ Rider-Ericsson Hot-Air Pumping Engine, which is in the Henry Ford Museum at Greenfield Village, Dearborn, Michigan.

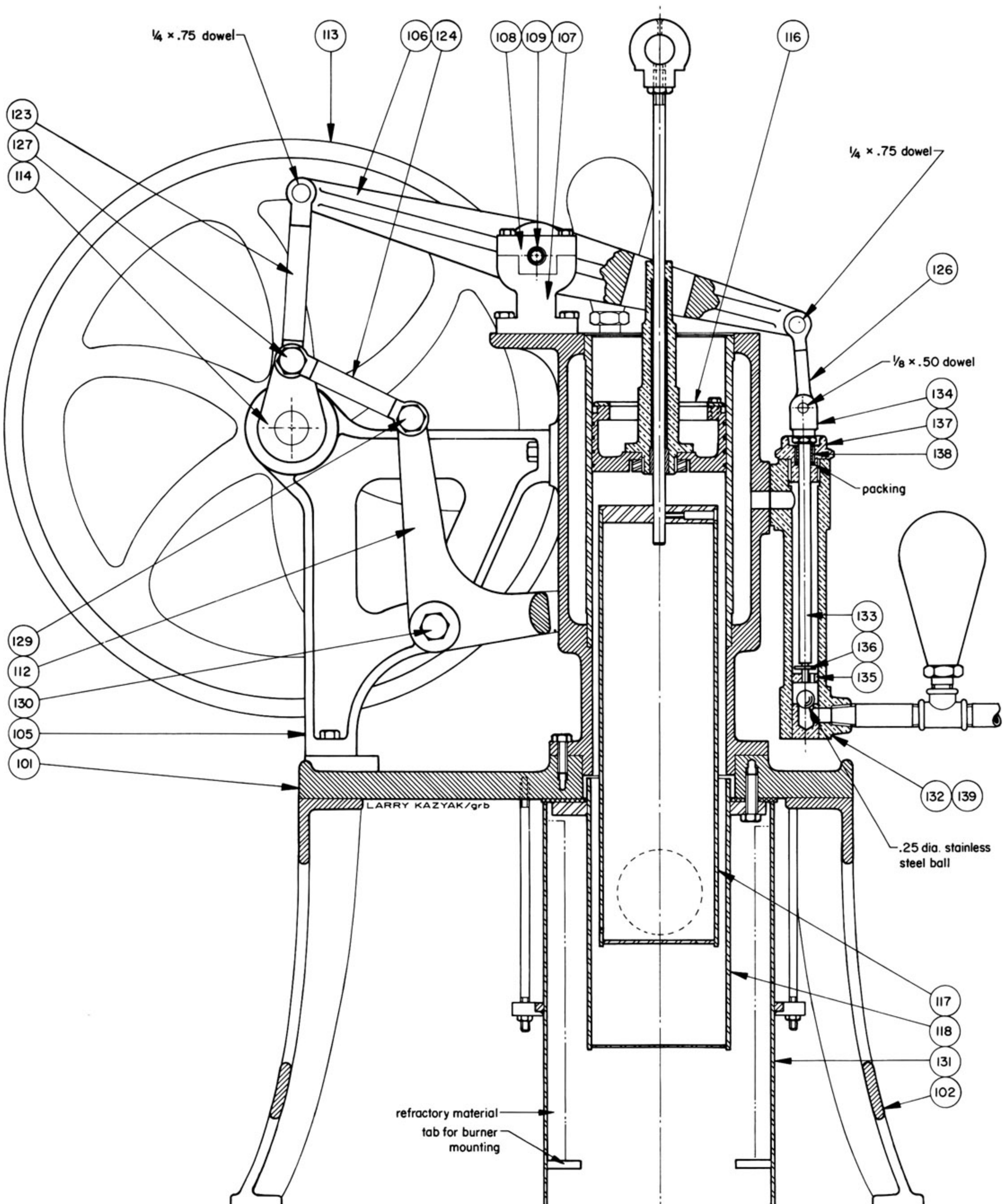
1 Facing the top side of the cast aluminum Base (101) in the lathe.



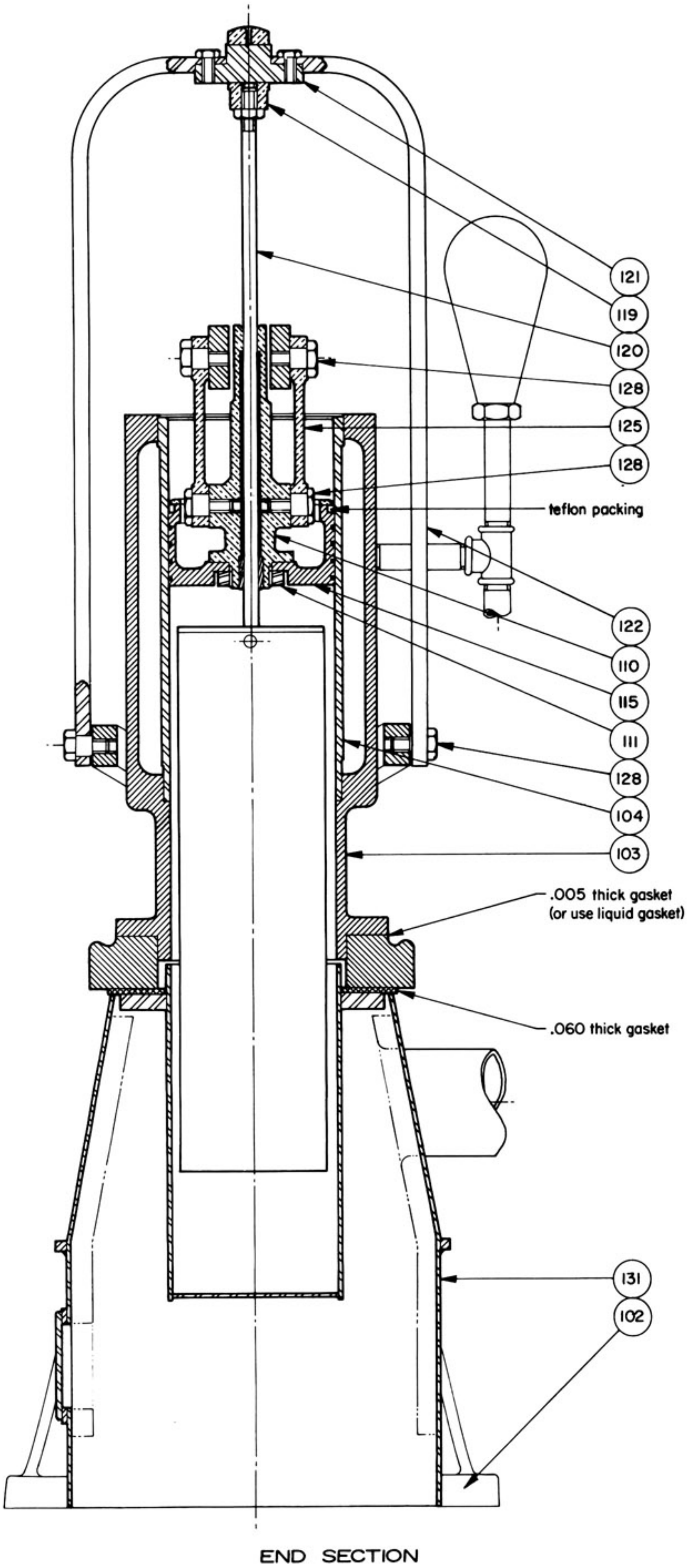
2 Facing the bottom of the Base.



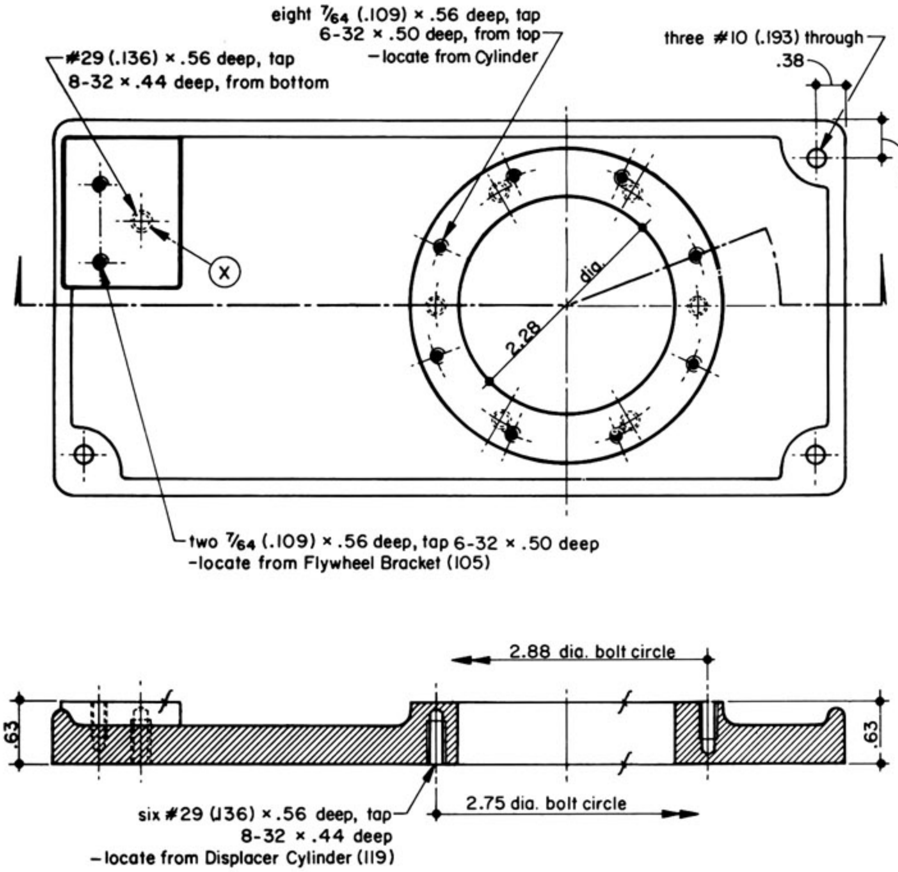
3 Turning the bottom end and mounting flange of the Cylinder (103).



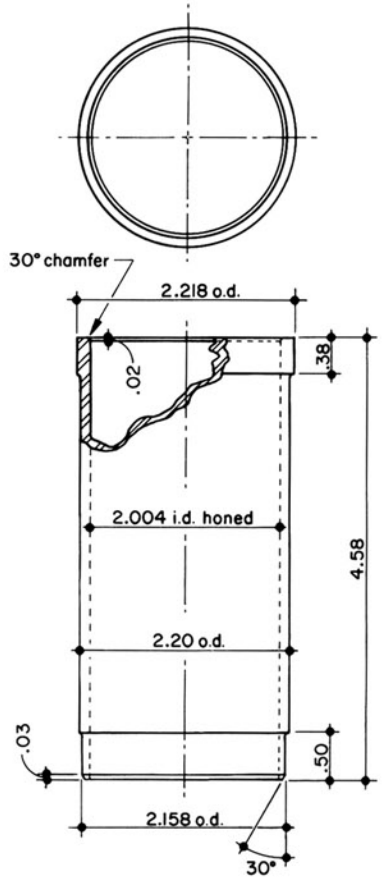
SIDE SECTION



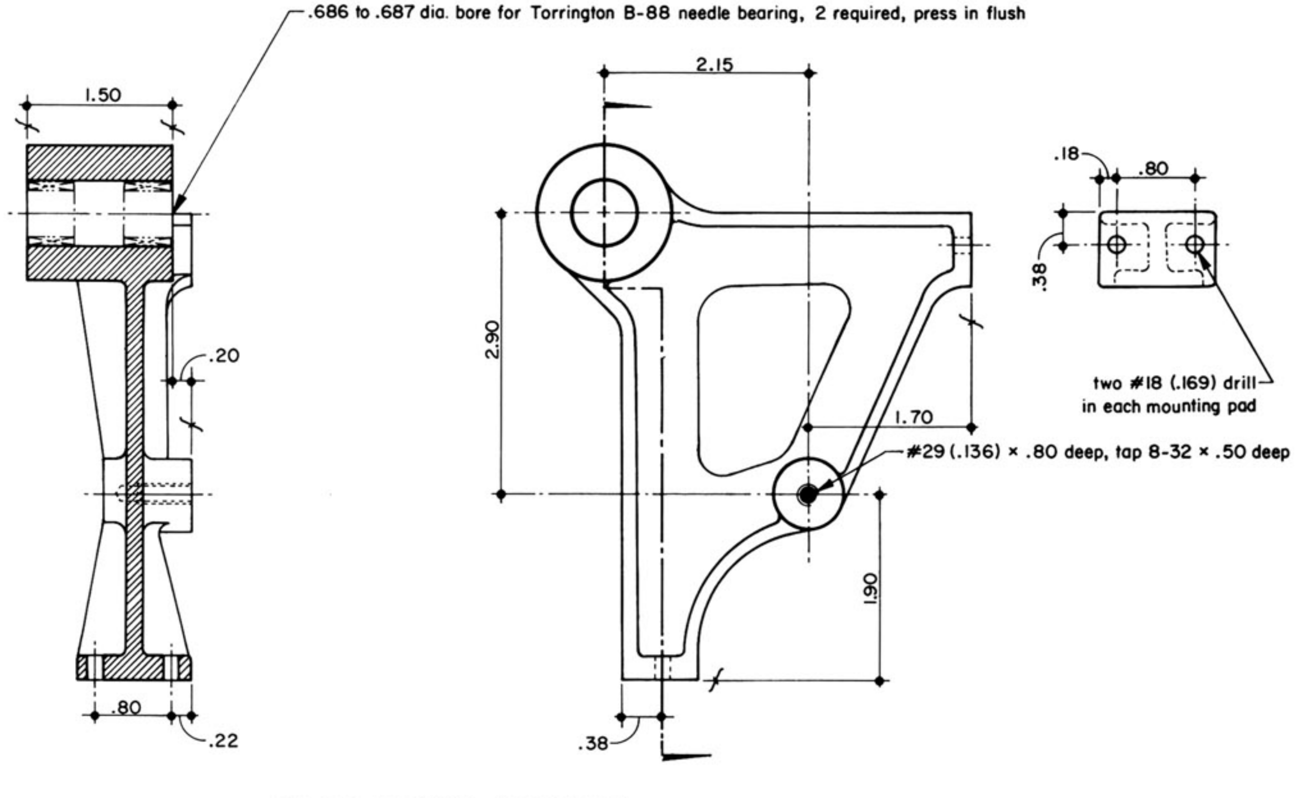
Ink Tracings by George R. Broad, Jr.,
from originals by Larry Kazyak



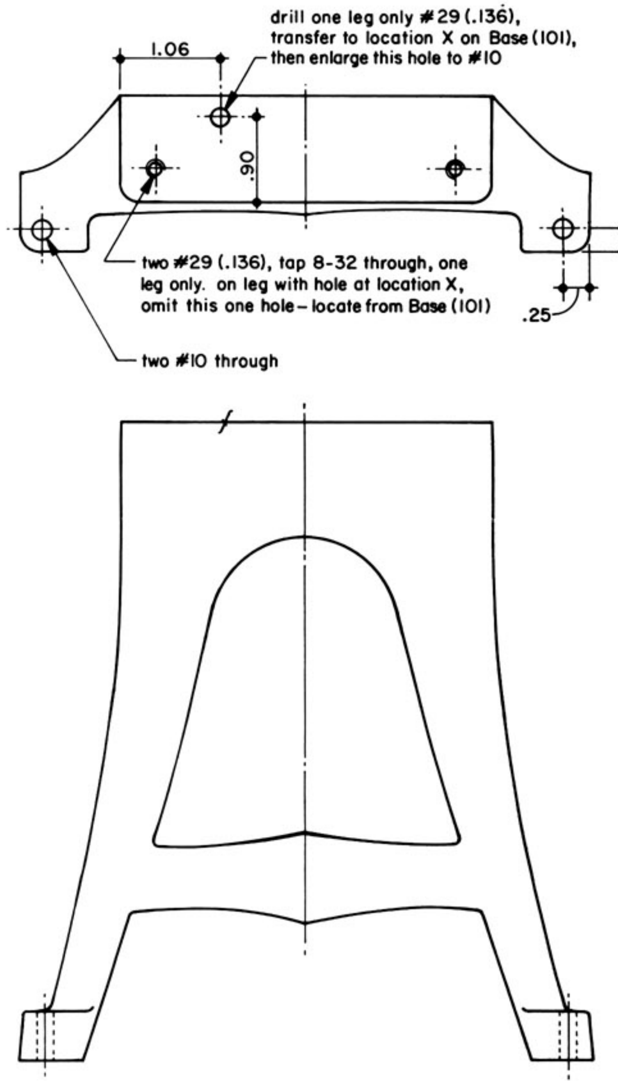
101 BASE
Cast Aluminum, 1 required



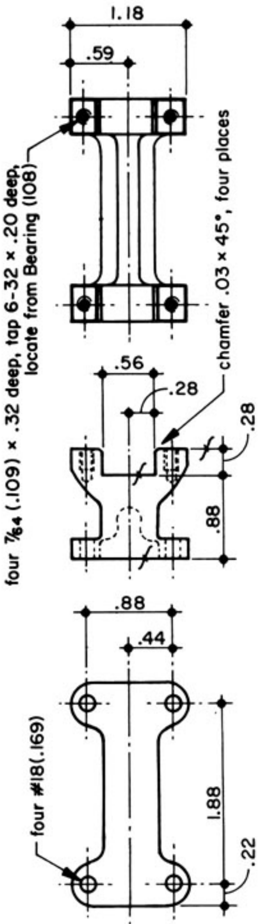
104 SLEEVE
Seamless Steel Tube, 1 required



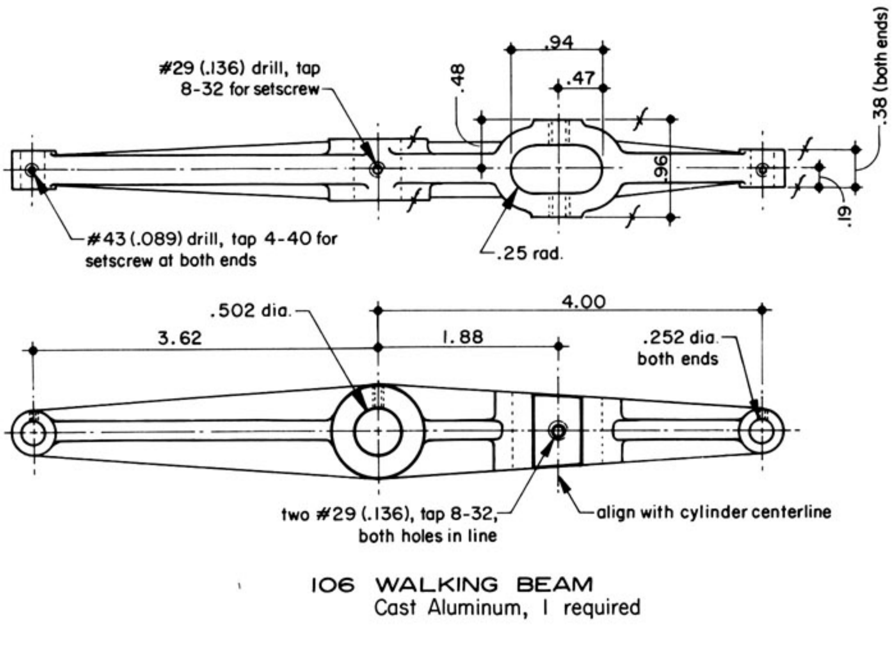
105 FLYWHEEL BRACKET
Cast Aluminum, 1 required



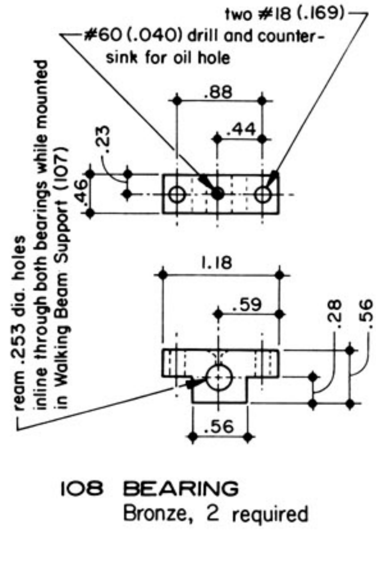
102 LEG
Cast Aluminum, 2 required



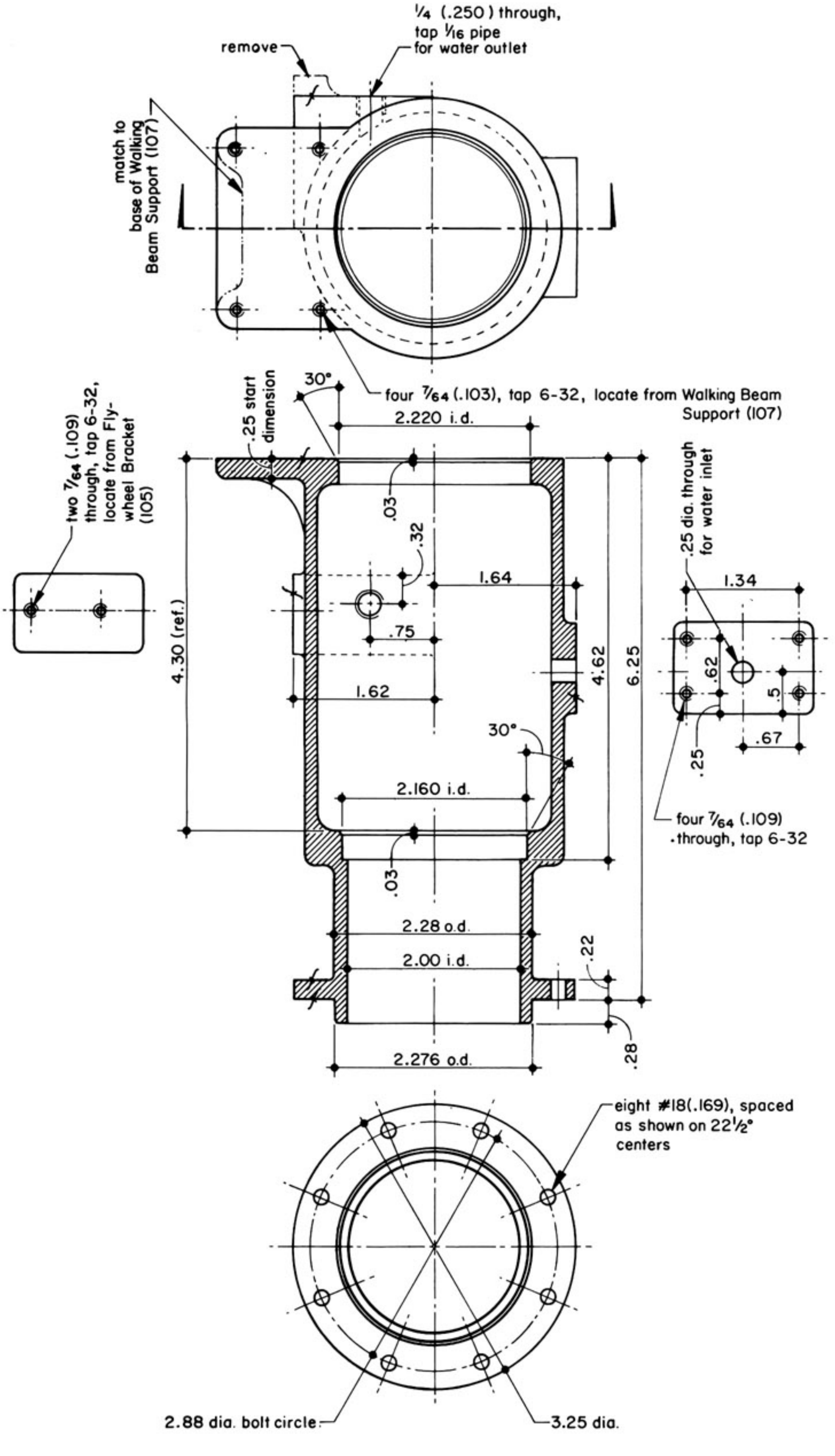
107 WALKING BEAM SUPPORT
Cast Aluminum, 1 required



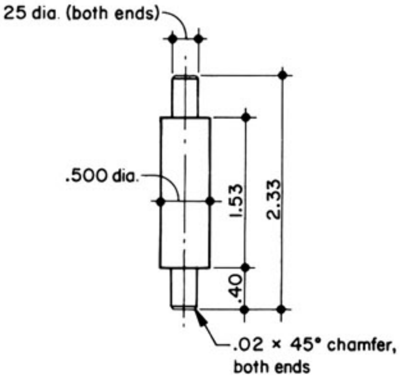
106 WALKING BEAM
Cast Aluminum, 1 required



108 BEARING
Bronze, 2 required



103 CYLINDER
Cast Aluminum, 1 required



109 PIVOT
Steel, 1 required

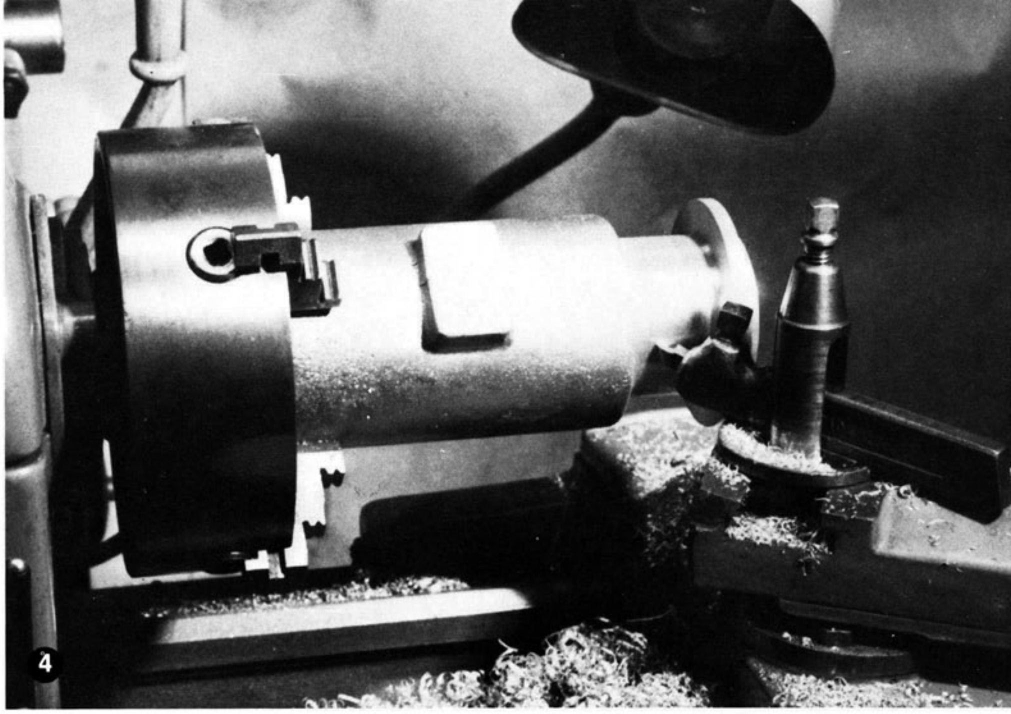
hand and the engine would run. The water pump was connected to the far end of the walking beam via a link. Water was drawn up through the lower inlet of the pump and into the main engine cylinder water jacket through a port in the pump mounting flange. The water was first used to cool the power piston portion of the cylinder, then it was expelled out the flywheel side of the cylinder to the storage tank or reservoir. The dome-shaped air chambers located at the inlet and outlet were used to cushion the pulsation created by the single-acting pump.

Construction is best started with the **BASE (101)**. Face the bottom and top to the .63″ dimension, averaging out the stock on either side. **Photos 1 and 2** show this operation being carried out in the lathe. Having no mill, I have no other choice, but those of you blessed with one might find it easier to flycut both surfaces. Bore the 2.28″ diameter opening next. Then, the corner holes for mounting the legs are done by drilling them with a #29 tap drill.

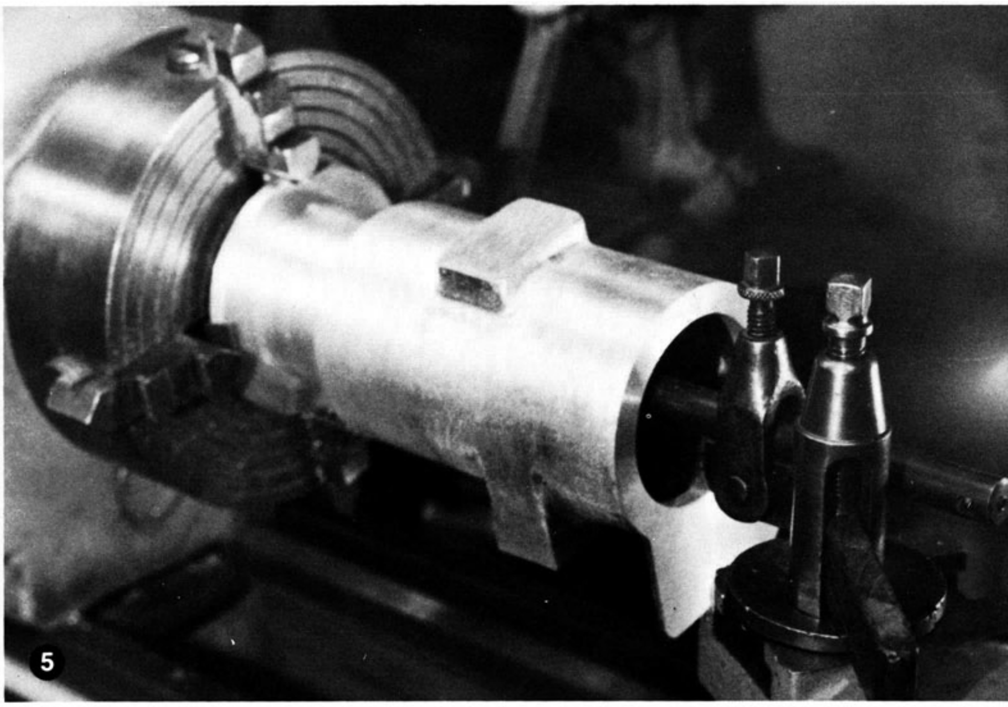
Take the **LEGS (102)** and dress the top surfaces by filing. Clamp them in proper position on the base and then drill through the #29 holes we just drilled in the base and into the leg mounting surfaces. This will assure proper alignment. Redrill the holes in the base with a #10 drill (with one exception) and tap the legs 8-32, inserting a stud into the leg and attaching it with a nut on top. The leg attachment hole under the corner pad is the exception. It uses a screw inserted from the bottom, through the leg, and threaded into the base. Tap the base 8-32 and use the #10 clearance drill in the corresponding hole in the leg.

The **CYLINDER (103)** is machined next, as shown in **photos 3, 4 and 5**. The top is faced off to the .25″ start dimension, then turned around and rechucked so the bottom flange can be machined to 2.00″ inside diameter and 2.28″ outside diameter. Blend it into the cast portion of the cylinder. The casting is turned around again and the 2.220″ upper bore and the 2.160″ lower bore for the steel cylinder sleeve are machined. Mill the two vertical mounting pads. The eight 7/64″ cylinder mounting flange holes are added next. The same technique described for the legs — using a tap drill first, transferring hole locations to the base for drilling and tapping, then enlarging the cylinder holes with a #18 drill — is an easy way to locate the bolt circle without need for an index head or rotary table. The other holes will be machined later.

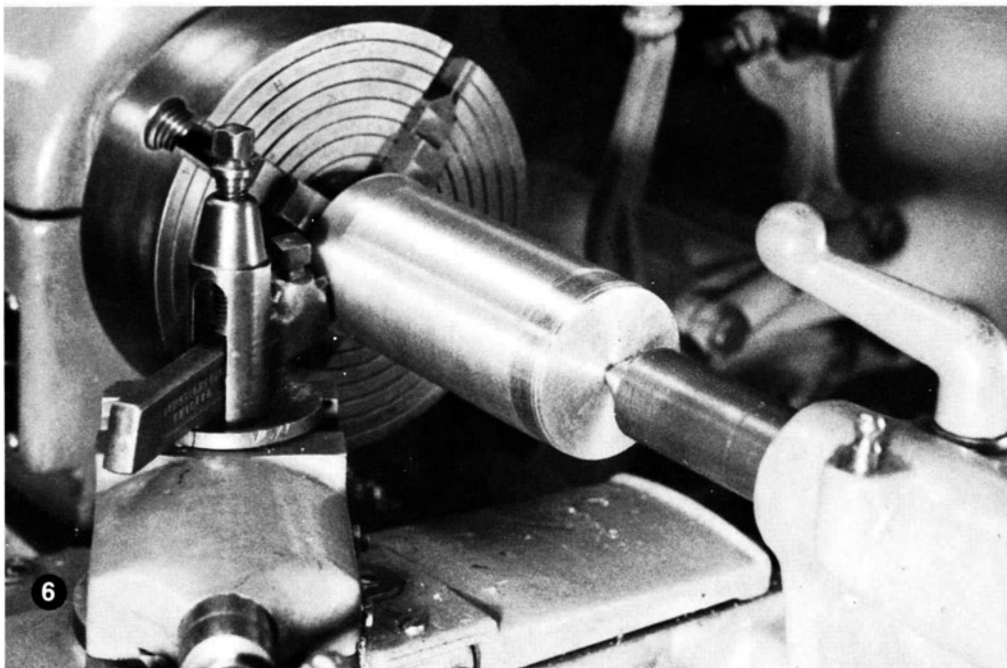
The steel **CYLINDER SLEEVE (104)** is the next item we will machine (see **photo 6**). The tubing used is 2.25″ o.d. x 2.00″ i.d. seamless, cold-drawn mechanical tubing. The inside diameter is not machined. The manufacturer's tolerance for roundness and size is adequate and it requires only honing.



4



5

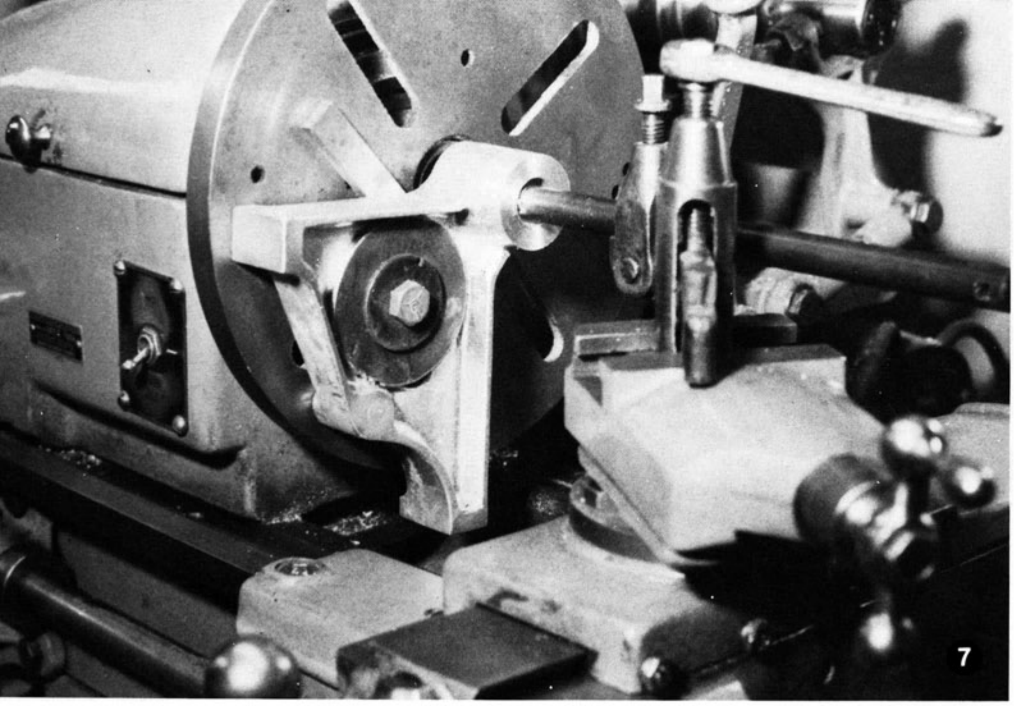


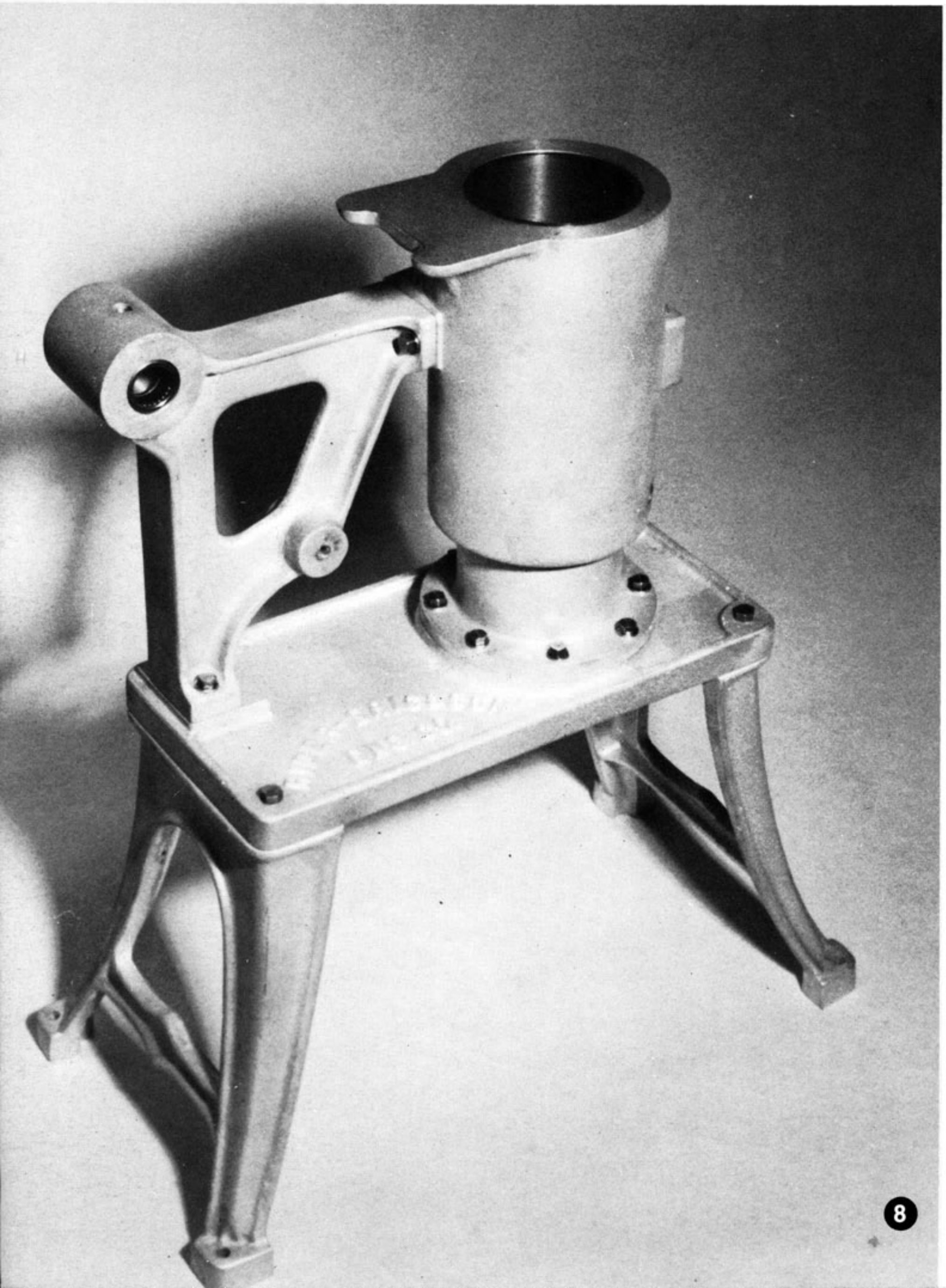
6

4 Blend the narrow portion of the Cylinder into the bottom flange and cast portion of the body with smooth, small radii.

5 With the Cylinder casting turned around, bore the upper and lower bores for the Cylinder Sleeve.

6 Turn the Cylinder Sleeve (104) from cold-drawn seamless tubing, using a center plug in the tail-stock end.





Turn a plug to fit the i.d. and center drill it. Insert it in the bottom for the tailstock center and chuck the top end by the i.d. Turn the o.d. and length. The top and bottom diameters should have a .002″ clearance with their respective bores in the cylinder.

Finishing the bore comes next. A fine-stoned hone, used to clean up automotive brake cylinders, is what I use. They are quite inexpensive. These hones have spring-loaded fingers, to which the stones are attached and they are driven by a flexible shaft. This allows them to track in the bore being honed without exerting any uneven loads on the honing stones. Chuck the hone in a drillpress, insert it into the sleeve and turn the drillpress on, running it about 450 to 500 RPM, while hand-holding the sleeve. Use kerosene as a lubricant and flushing fluid and work the sleeve up and down constantly. The top 4″ is the only portion requiring this treatment, because this will be the only portion in contact with the power piston. Be sure to hone all the way up to the top edge, but be careful not to let the stones come out of the bore while the drillpress is running.

The size of the bore is not too important as the power piston will be sized to it. What is important is that it be of *uniform* size. Using a telescoping gauge, check to prevent a tapered or barrel-shaped bore. Take your time. The stones cut slowly and the removal of a couple of thousandths is slow going.

Once the honing is finished, the sleeve and cylinder casting are ready to be assembled. On my first engine, I used a shrink fit. Even with .004″ interference, due to the differential in expansion between the aluminum cylinder and the steel sleeve, a small leakage would occur after running for about half an hour. Since then, I have relied on a good grade of epoxy cement. As previously stated, about .002″ diametrical clearance is required. The water surrounding the sleeve will keep the cement from overheating.

The **FLYWHEEL BRACKET (105)** is attached to a faceplate and the bearing hole bored (see **photo 7**) to a diameter of .686″ to .687″ for the Torrington bearings. Needle bearings require a press fit because the force exerted on the outer shell of the bearing brings it to a true round shape. *Loctite* or epoxy definitely won't do here! Also, if not for the press fit, the internal clearance between the bearing and the crankshaft journal would be excessive. Surface and drill the mounting pads and tap the 8-32 threaded hole.

Mount the cylinder and sleeve assembly to the base and leg assembly. Position the flywheel bracket and transfer the holes to the cylinder and base, drilling and tapping the two holes required in both mounting places. Bolt the flywheel bracket

7 The Flywheel Bracket (105) is faced and bored in the lathe, mounted to a faceplate.

8 With the Base, Legs, Cylinder, Cylinder Liner and Flywheel Bracket assembled together, the Hot-Air Pumping Engine will look like this. Note the needle bearings, pressed into the Flywheel Bracket. Also note how the upper surface of the Cylinder is contoured to match the base of the Walking Beam Support.

into place. Your engine will really start to take shape and look like **photo 8**.

The oil cup shown on the crankshaft boss portion is from Cole's Power Models, catalog number 29R2/4. On the model, it's purely decorative, the original engine having one located there. The model's Torrington needle bearings need only be lubricated once every 100 hours or so and that's a long time coming! Use a light-grade grease such as *Lubriplate*.

Next comes the **WALKING BEAM (106). Photo 9** shows it chucked in the lathe, having its .502″ bore machined. If you are using .5″ diameter bar stock for the pivot, machine the walking beam bore to suit. Mill the slot .5″ wide x .94″ long. There isn't anything critical about the slot; it only provides clearance around the power piston center. The two .252″ diameter holes on the ends should be added next, along with the two 8-32 threaded holes that intersect the slot. These must be parallel to the .502″ diameter hole previously bored. The tapped holes for the setscrews are the final step. Square-headed setscrews (shown in **photo 11**) are in keeping with the aim of making the model an authentic copy. The 4-40 screws have .12″ square heads and the 8-32 screw has a .18″ square head. It's more work making them, compared to using commercial ones, but it's worth it.

The **WALKING BEAM SUPPORT (107)** is next. Mill or file the base flat. Then set up to mill the notches and top surfaces, as in **photo 10**. Drill the #18 mounting holes, but hold off on the 6-32 tapped holes for now.

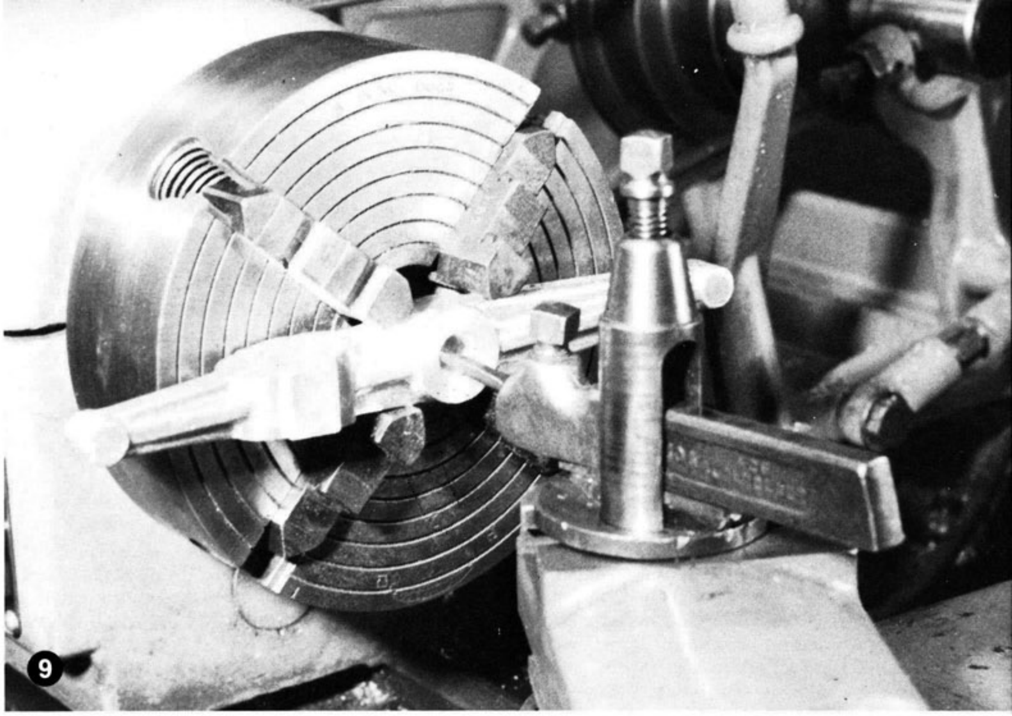
The two **BEARINGS (108)** are part of this assembly. The original engine had bronze bearings that were split on the pivot bore to allow for wear takeup. Our model won't experience this problem, so the bearings are shown in one piece. Machine them as shown, but omit the .253″ diameter bore. Mount the bearings in position on the beam support and transfer and drill the mounting holes. Tap the support, enlarge the holes in the bearings and mount them in place. Brass 6-32 x ⅜″ hex-head bolts should be used.

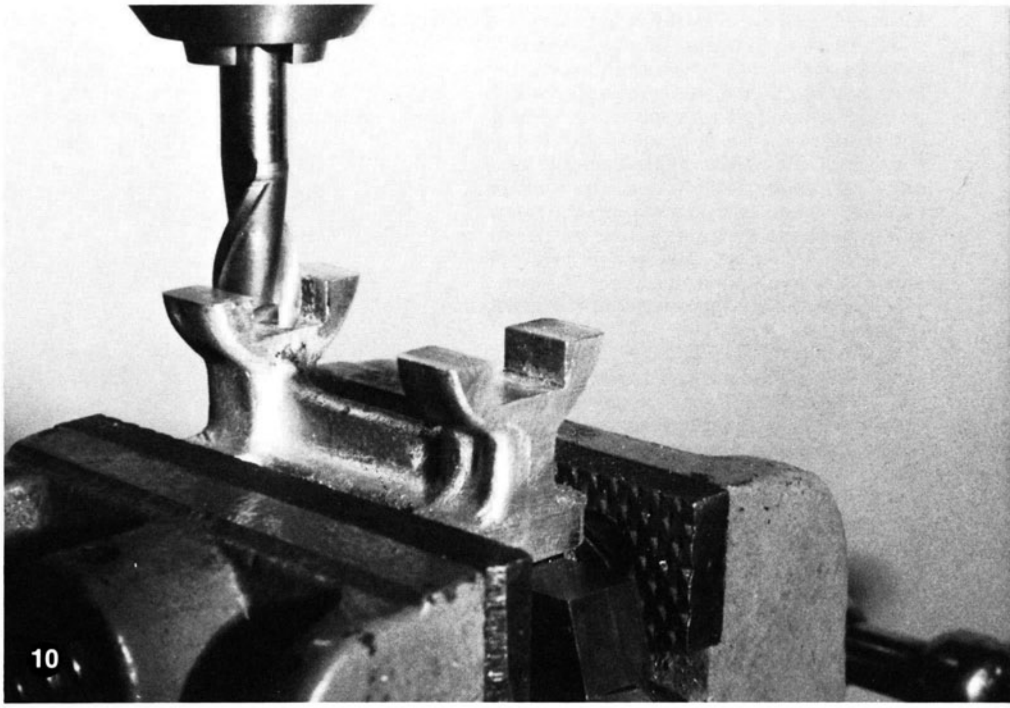
Now, the .253″ bores in the bearings can be line-bored, keeping their axis parallel with the support mounting surface.

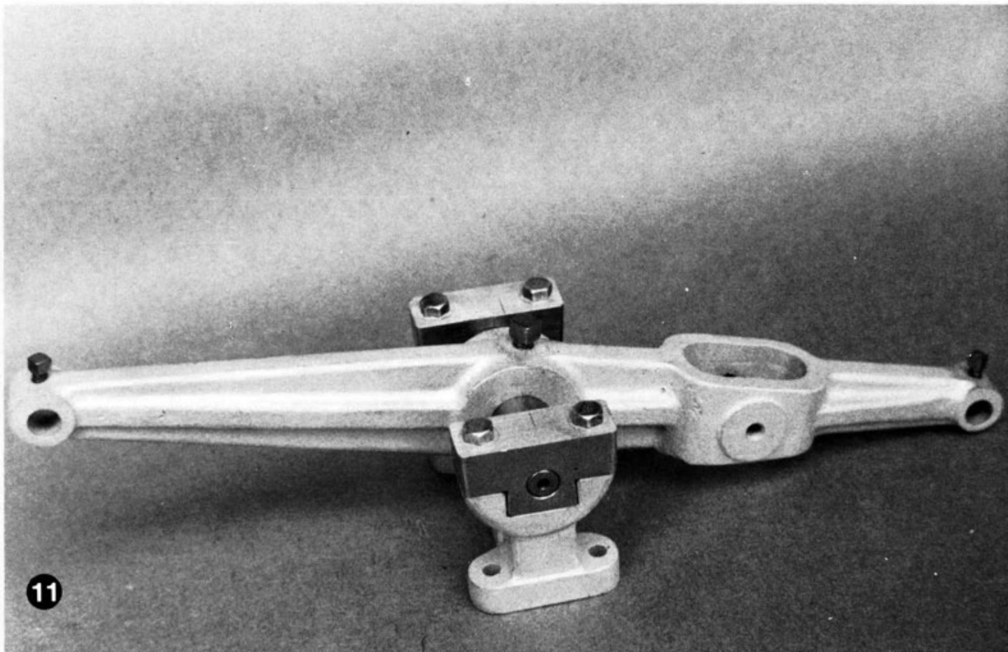
While these parts are assembled, the **PIVOT (109)** should be machined and the 1.53″ dimension checked to see that it will allow about .010″ end shake between the bearing blocks. Size the two .250″ diameter bores to their respective bearings.

The assembly of the walking beam, its support, the bearings and pivot are shown in **photo 11.**

Now is a good time to step back, take a look at all you have accomplished and take a deep breath before tackling the next step.







9 Machining the .502″ bore of the Walking Beam (106) in the lathe.

10 Milling notches in the Walking Beam Support (107) to accept the Bearings.

11 The Walking Beam assembled with its Support, Bearings, Pivot and square-headed setscrews.

The **POWER PISTON CENTER (110)** will be the next item that we fabricate. The body portion is turned as shown, complete with the .189″ diameter bore at the top and the ¼″ x ⅜″ deep bore at the bottom, for the bushing to be pressed in. Note the .22″ diameter bore through the center. Don't be tempted just to bore or ream the .189″ diameter all the way through because without that .22″ diameter relief, the .188″ diameter displacer piston rod would have too much friction due to the extreme bearing length and the viscous drag of lubricating oils. These engines, with their low power, can't tolerate many power-robbing conditions.

The two .50″ diameter bosses are next to be machined. Take .50″ bar stock, chuck and drill with a #29 tap drill. The .30″ radius necessary to make a good contact with the .60″ main body diameter can either be hand-contoured with a file or milled. Tap drill the body portion at the .68″ dimension from the bottom flange. To assemble, make up an aluminum 6-32 stud, 1.25″ long. The major diameter of this stud should be only .134″, which will allow it to be inserted through the tap-drilled holes in the side bosses and the body. With nuts applied to either end of the stud, the parts are now fixed together so that they can be soft soldered in place. With an acid soldering flux applied, bring up to temperature with a propane torch. Be sure the part is at a high enough temperature to allow the solder to flow into the joint by capillary action, so that a minimum amount will be used and the brass will be kept clean.

After soldering, the stud is removed and if it weren't aluminum, you'd have a tough time doing it! Now tap the 8-32 thread in each boss.

The **POWER PISTON NUT (111)** comes next. It's a straightforward turning job. **Photo 12** shows the power piston center with its bushing along with the power piston nut and the spanner wrench, which is used for tightening it when it is assembled to the power piston. The pins for the spanner wrench are .070″ diameter bearing needles from a worn-out automotive universal joint. When a U-joint fails, usually only one or two of the four bearings are ruined, leaving a good supply of hardened pins for many uses.

The **DISPLACER YOKE (112)** is a relatively simple part. The tapped holes and the .250″ to .253″ diameter pivot hole are somewhat forgiving as to their location. Locating them centrally within their respective bosses is sufficient. The main consideration is to obtain a linkage which is true running and this requires that the axes of all the tapped holes and pivot bore be kept parallel with one another and perpendicular to the vertical portion of the yoke. Face the bosses to the dimensions shown. **Photo 13** shows the completed yoke with its pivot screw.

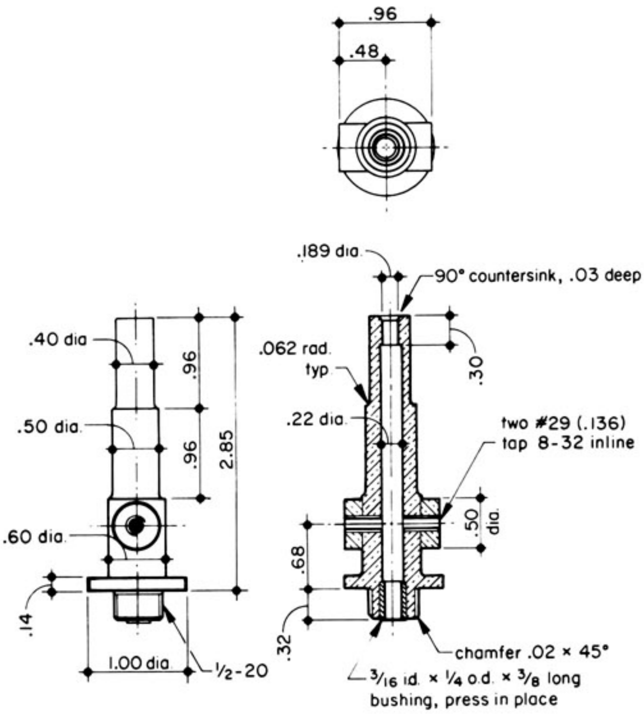
Machining the **FLYWHEEL (113)** is shown in **photos 14 and 15**. First mount it in a four-jaw chuck on the i.d. of the rim, centering it on the cast portion of the rim between the spokes. Machine the front face, both the hub and rim. Take a cut off the o.d. of the flywheel, but not down to the finish dimension. Merely achieve a full 360° cut, then remove the flywheel from the chuck and remount it with the other face to be machined. You will use the rough-machined o.d. as the circular datum on which to indicate and the back face as the perpendicular datum. If you are within about .010″ total indicator reading on the o.d., this will suffice, because you will bore the .499″ diameter bore for the crankshaft and finish the o.d. with the same setup, which will assure you a true-running flywheel.

The **CRANKSHAFT (114)** journal is a .500″ diameter dowel pin. The reason for using a dowel is that it is a good method of obtaining a hardened and ground shaft. The needle bearings which carry the crankshaft and flywheel assembly require a hardened surface of Rockwell C 58 as a minimum to run efficiently. The dowel called for is 3″ long. The amount of extension from the flywheel is 1.84″. This provides for the dowel to engage the flywheel 1.16″. Since the flywheel is thicker than 1.16″, the dowel will end .34″ in from the back side of the flywheel. This allows us to machine a small stub of .50″ diameter cold-rolled steel, which will be fashioned into the remaining portion of the shaft. A keyway is milled or filed into the stub and a dummy gibheaded key fabricated, in keeping with the goal of making our model a proper replica of the original engine.

The crank web is laid out on a piece of .32″ thick cold-rolled steel. Rough saw it to shape and then chuck in a four-jaw to turn the 1.00″ diameter, thinning out the remaining portion to the .25″ thickness. Bore the .50″ diameter hole to allow a light hand press fit when assembled with the .50″ dowel. After removal, hand file the heel end to match the 1″ turned diameter, hand-contour the toe end to the .25″ radius, then blend between the two ends. Drill and tap the 10-32 hole, keeping it parallel with the .50″ bore. The last operation is drilling and tapping for the 8-32 setscrew.

The **POWER PISTON (115)** is chucked on its o.d. A three-jaw chuck will have enough accuracy for both setups needed. The inner contour is completely machined, then the piston is chucked on the i.d. Do not apply too much chucking force, so as not to distort the piston. The outside diameter should be turned so that it is a fairly snug fit into the cylinder sleeve. The four grooves on the o.d. allow oil to be carried down the cylinder wall and also allow any small particles of dirt to migrate to the groove, rather than be trapped in the very small clearance between the cylinder and the piston. Machine the .500″ diameter bore with the same set-up as is used for machining the o.d. Concentricity is thus maintained for the total assembly. The recess for the power piston nut is the last operation.

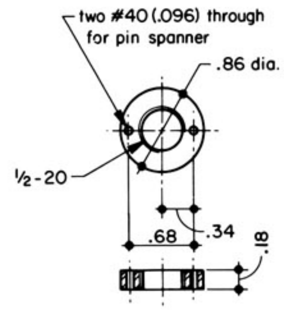
The **POWER PISTON TOP RING (116)** is machined from brass. Be sure that its o.d. does not come in contact with the cylinder. A radial clearance of .010″ is desired.



110 POWER PISTON CENTER
Brass, 1 required

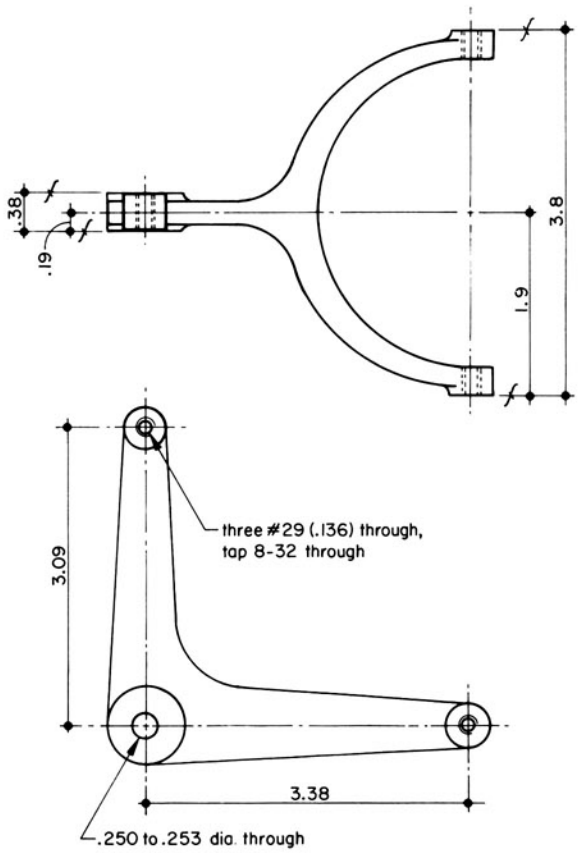
The full-sized engine uses a leather cup ring on the bottom of the piston to do all the sealing. The piston body acts more like a crosshead, for alignment only. Our model cannot tolerate the friction generated by this technique, so we shall lap the piston to fit the cylinder. The teflon packing, shown in the top groove of the piston on the engine layout drawing was purchased from a plumbing supply store. It is intended for valve stem packing, is circular in cross-section and is spiral wrapped with a thin sheath of teflon. With the top ring in place, it should not exert much pressure on the cylinder wall. In fact, if a good fit has been achieved from the lapping operation, it can be omitted. **Photo 16** shows the power piston components. The side links connect the assembly to the walking beam.

The **DISPLACER PISTON (117)** is an all-steel assembly that can either be silver soldered or brazed together. The steel tubing used is welded-seam automotive exhaust tubing. Machine the .25″ thick cap to fit snugly into the i.d. of the tube. The .189″ diameter hole should also be put in now, to maintain concentricity with the piston o.d. When fitting the steel tubing to the cap, be sure that the tubing is cut off square with its o.d. and check true placement of the cap using the .187″ diameter

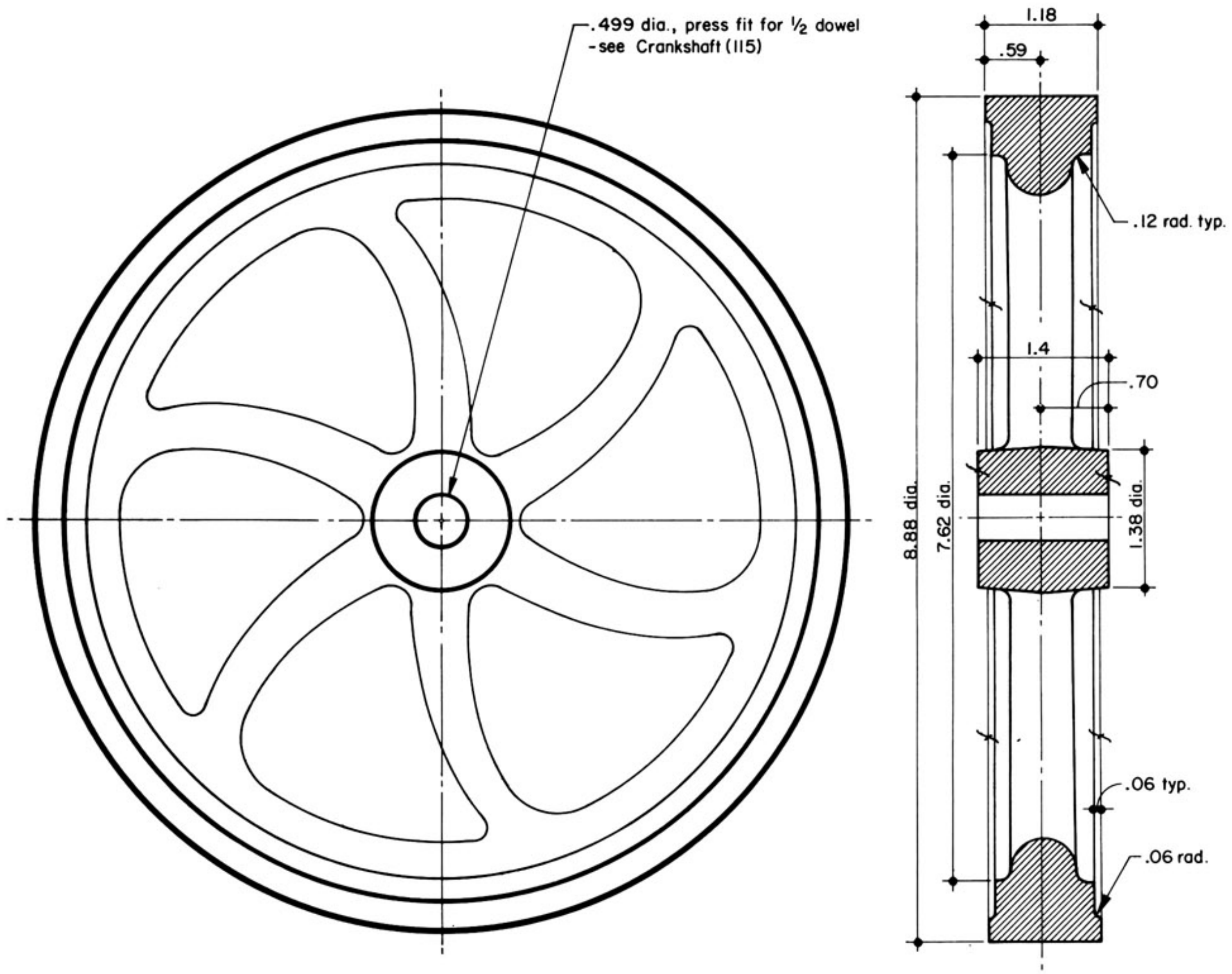


111 POWER PISTON NUT
Steel, 1 required

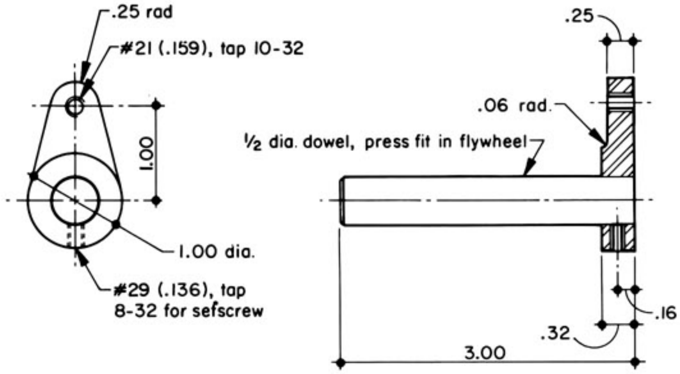
Drawings by
George R. Broad, Jr.



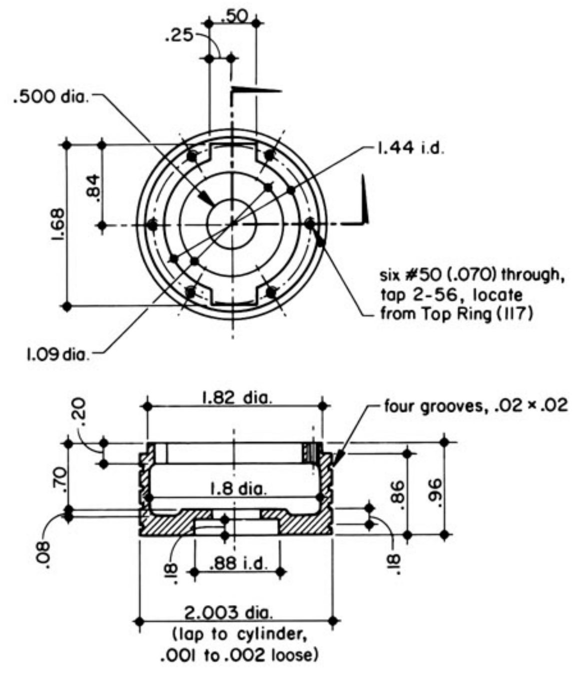
112 DISPLACER YOKE
Cast Aluminum, 1 required



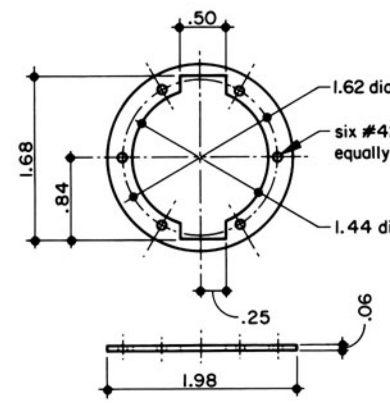
113 FLYWHEEL
Cast Aluminum, 1 required



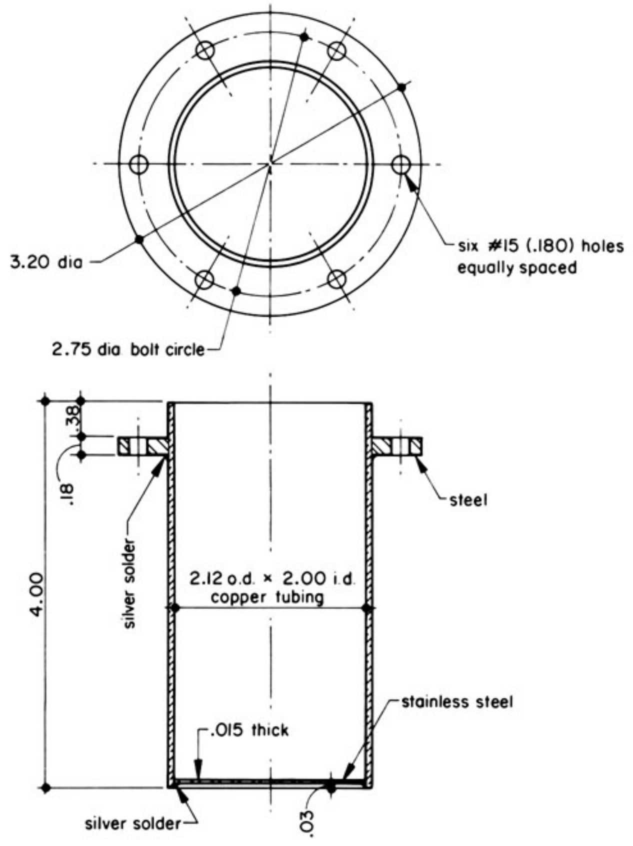
114 CRANKSHAFT
Steel, 1 required



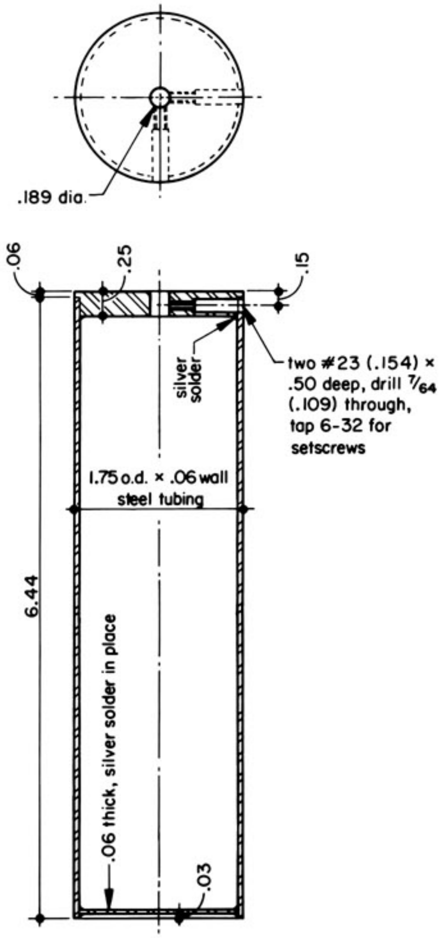
115 POWER PISTON
Cast Aluminum, 1 required



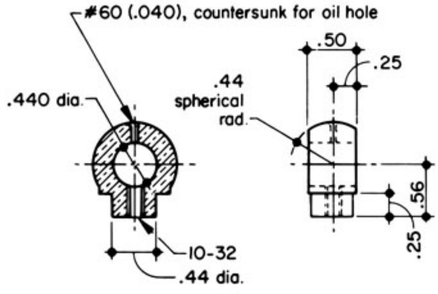
116 POWER PISTON TOP RING
Brass, 1 required



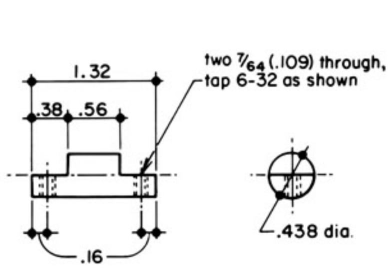
118 DISPLACER CYLINDER
1 required



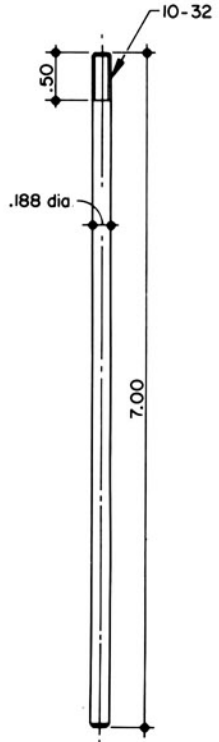
117 DISPLACER PISTON
Steel, 1 required



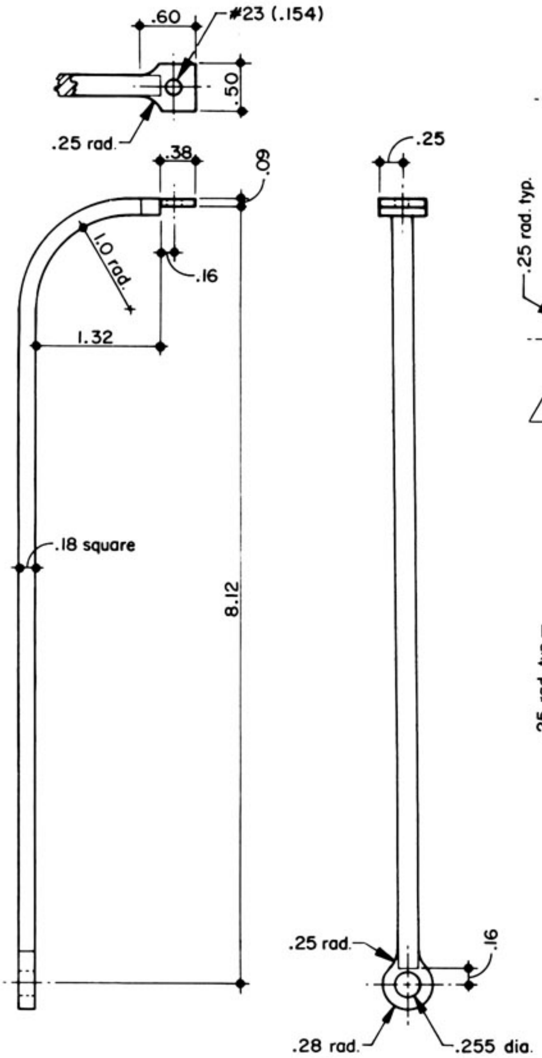
119 DISPLACER PISTON ROD END
Brass, 1 required



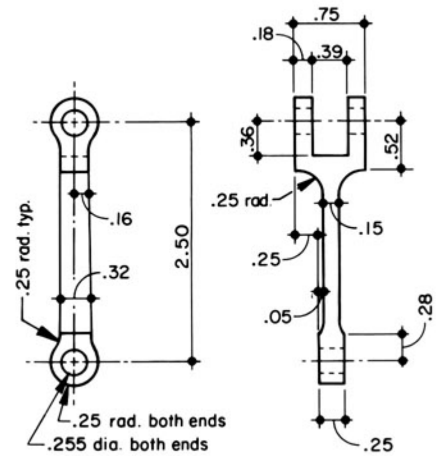
121 DISPLACER PISTON ROD END PIVOT
Steel, 1 required



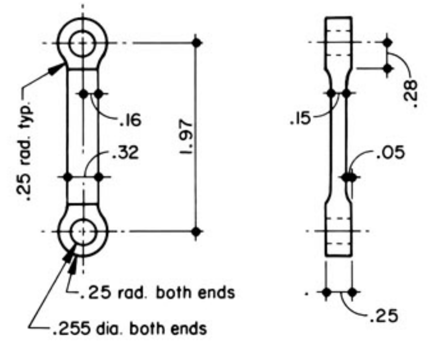
120 DISPLACER PISTON ROD
Steel, 1 required



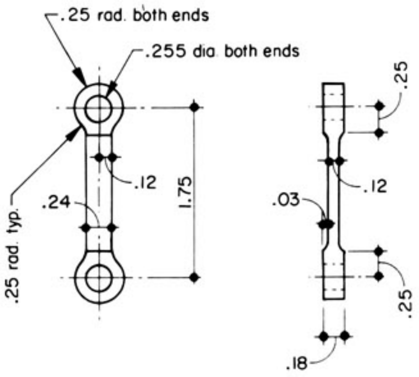
122 DISPLACER PISTON ROD YOKE
Steel, silver soldered construction, 2 required



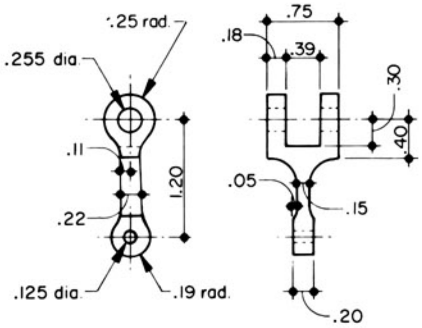
123 CRANKSHAFT LINK
Brass, 1 required



124 DISPLACER YOKE LINK
Brass, 1 required

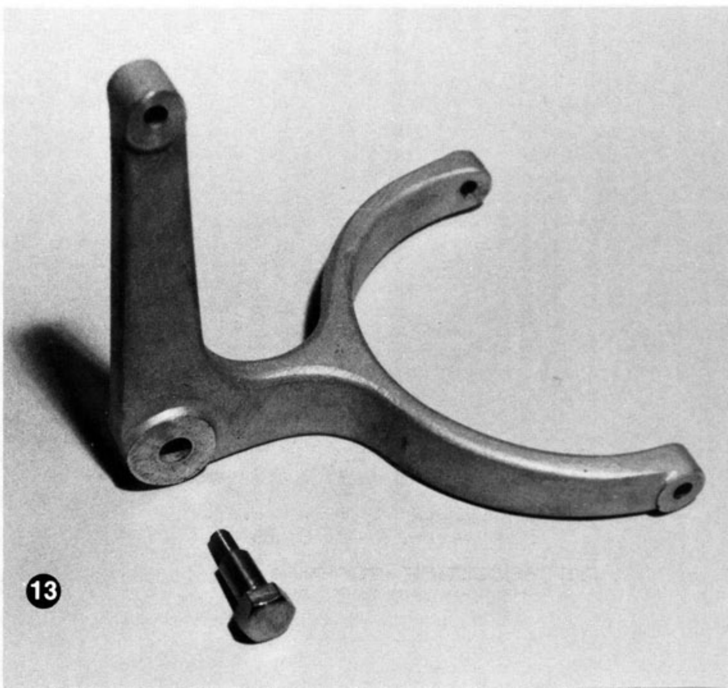


125 POWER PISTON LINK
Brass, 2 required

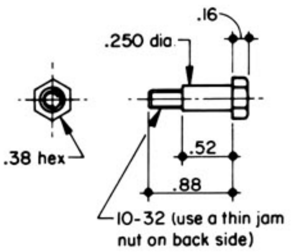


126 WATER PUMP LINK
Brass, 1 required

12 The power piston center and its bushing and the power piston nut and its wrench.



13 The displacer yoke and the shouldered screw which fastens it to the flywheel support bracket.



127 CRANKPIN
Steel, 1 required

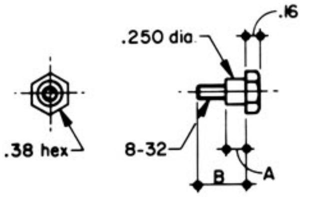
displacer piston rod, inserted into the piston as a gauge to insure that the rod will be parallel with the piston o.d. Silver solder on both ends. It is not mandatory that the piston be totally airtight, inasmuch as our engine is not pressurized. The two 6-32 setscrew holes are the last operation.

The **DISPLACER CYLINDER (118)** consists of three pieces silver soldered together, but the top steel flange and the copper cylinder are the only two pieces to be soldered together at this time. Turn the steel flange so that the i.d. is a snug fit over the copper tube. The tube itself should be cut about .12″ longer than shown. The actual length will be determined during a trial assembly of the power piston and displacer piston with their respective linkages, to insure that a minimum amount of dead volume is allowed into the engine. More about this later on.

While working on the cylinder, let's do something in the quest for greater efficiency. From just below the flange and for a distance down of about 2″, turn the cylinder wall to a thickness of .020″. This forms a heat dam which will minimize losses from heat conduction.

Transfer the flange holes to the base (101) and drill and tap the base for the 8-32 mounting holes, keeping the cylinder concentric with the 2.28″ diameter in the base.

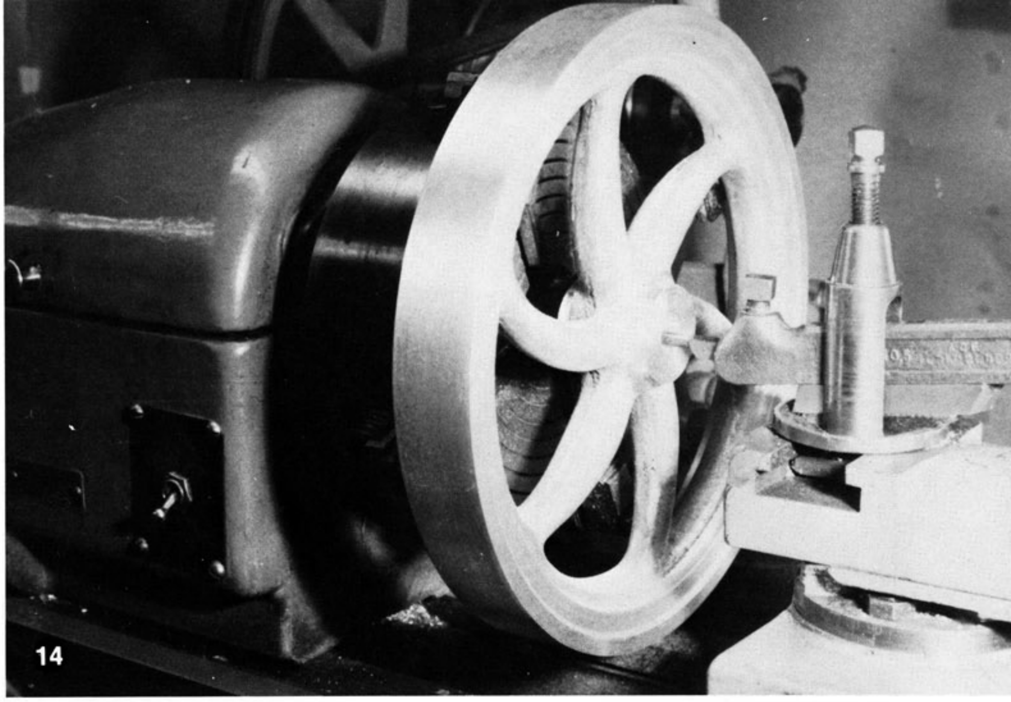
The **DISPLACER PISTON ROD END (119)** is machined from .88″ diameter brass bar stock. Turning can be done in one setup by maching with the 10-32 hole toward the tailstock. Turn the .44″ diameter and drill and tap the 10-32 hole, then use the tailstock with a center to support the piece. Using a template or .44″ radius gauge, turn the spherical radius, leaving about .25″



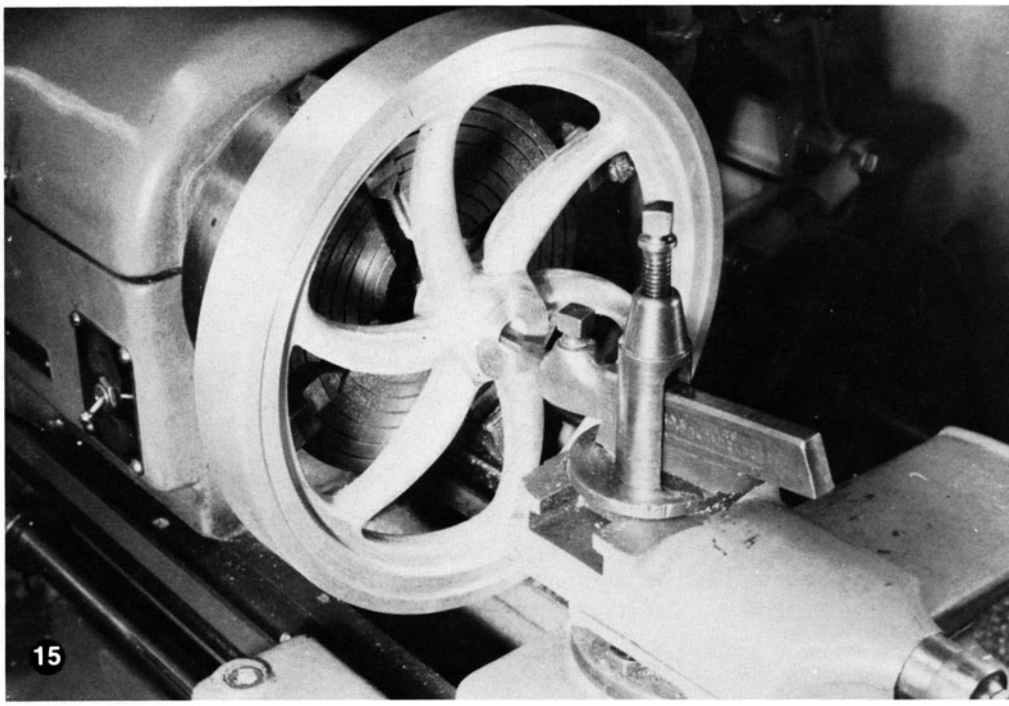
128 SHOULDER SCREW
Steel, 6 required, A=.20, B=.52

129 SHOULDER SCREW
Steel, 1 required, A=.27, B=.65

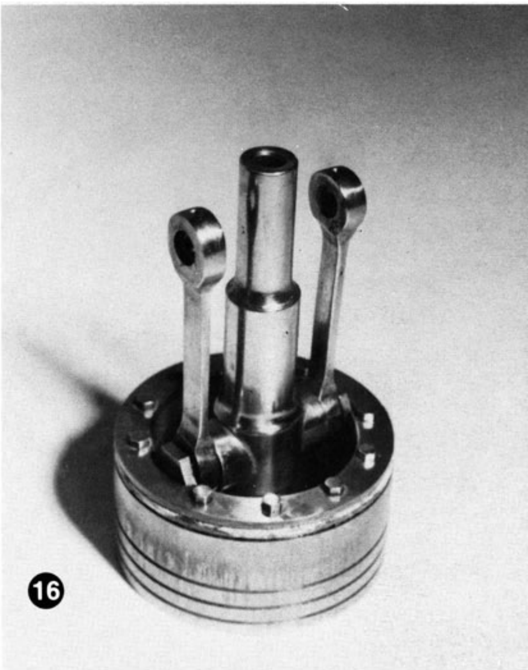
130 SHOULDER SCREW
Steel, 1 required, A=.39, B=.75



14



15



16

14 Facing the flywheel on the lathe.

15 Boring the flywheel hub for the crankpin.

16 The completed power piston, with its center, top ring, packing and matched links.

diameter at the top, which can be parted off and hand finished. Mill or file the two flats to the .50″ dimension. Bore the .440″ diameter, keeping it perpendicular to the 10-32 hole.

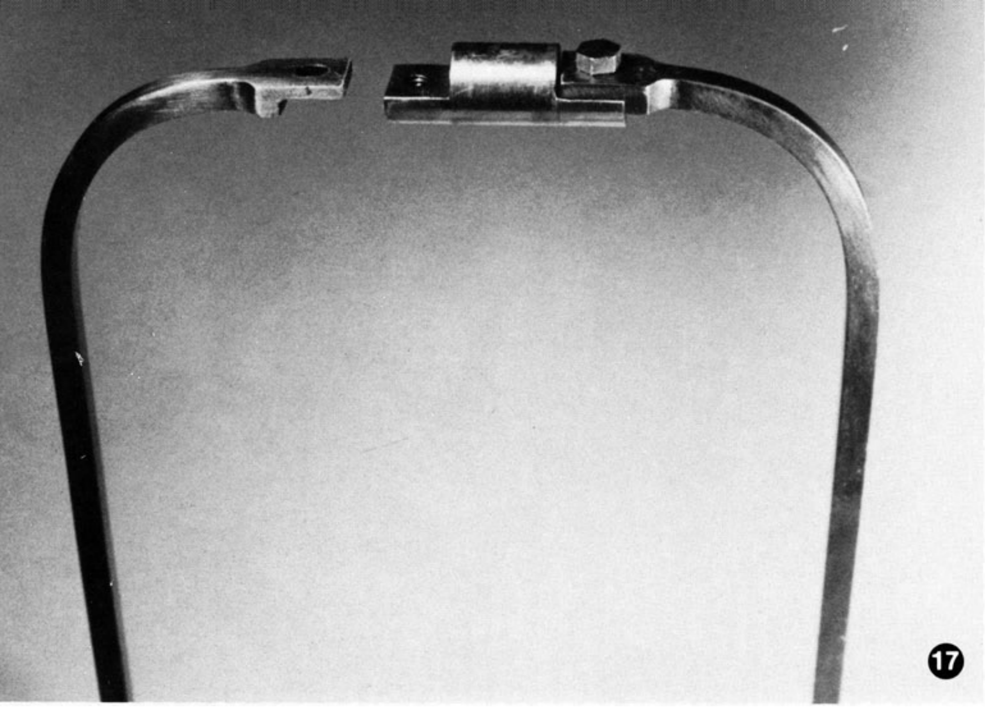
The **DISPLACER PISTON ROD (120)** is a piece of .188″ diameter cold-rolled steel rod. The surface finish should be smooth, inasmuch as it reciprocates within the power piston center. The fit should be around .0005″ to .001″ loose, to minimize air leakage around the rod.

The **DISPLACER PISTON ROD END PIVOT (121)** can be low carbon steel, also. The loads and velocities imposed on all the rods and pivots are so low that hardened surfaces are unnecessary. The .438″ diameter should be a close running fit into the rod end. The flats are then milled parallel with the journal diameter. The two 6-32 holes should wait to be transferred from the top ends of the yoke rods.

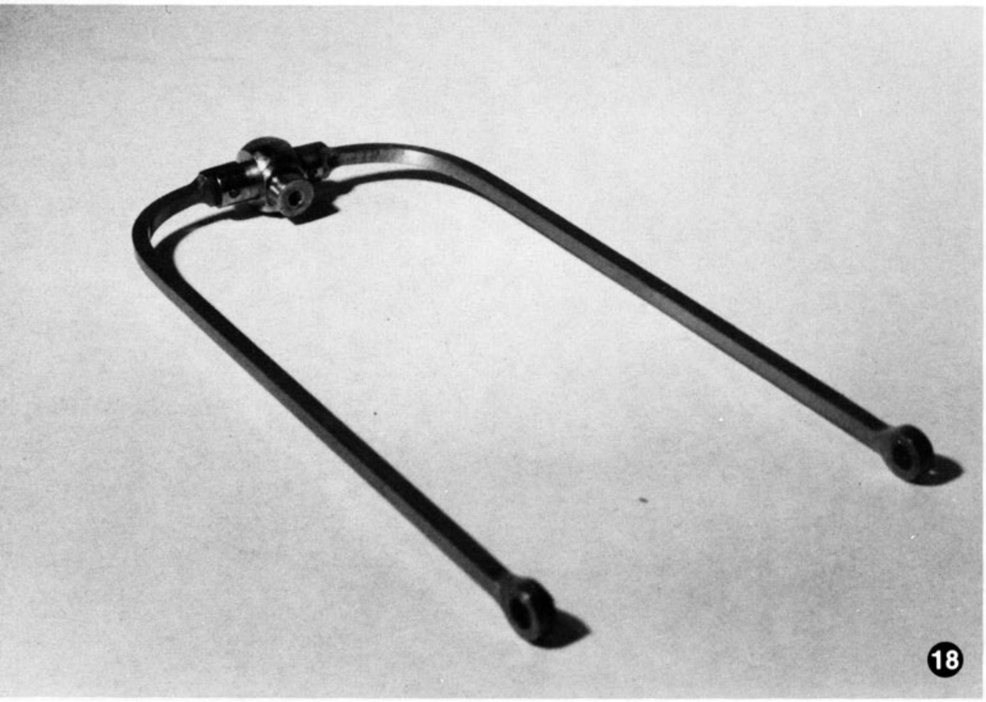
The two **DISPLACER PISTON YOKE RODS (122)** are fabricated from cold-rolled steel and silver soldered together. Bend the .18″ square stock to the 1.00″ radius as shown, allowing about .06″ extra on both ends. Make up the pieces as shown with the .18″ slots filed to a snug fit on the square rod. The ends of the square rod should be trimmed at a trial assembly with the yoke and the power piston placed into the cylinder with the piston rod, rod end and pivot assembly in place. Transfer and tap the 6-32 holes into the displacer piston rod end pivot and bolt the two top pieces of the yoke rod to the pivot. With the lower portion of the yoke rod end mounted to the yoke using the shoulder screws, the ends of the .18″ square rod can be trimmed so that the end result is a free-running linkage. If this process is not followed, the linkage will impose an excessive radial load on the displacer rod, where it rides in the power piston center bearings. **Photos 17** and **18** show the displacer piston linkage components.

The **LINKS (123, 124, 125 and 126)** are milled from brass bar stock. The end bores should be kept parallel. The two power piston links (125) should have their .255″ diameter bores put in simultaneously while the two are clamped together to insure even loading of the power piston. The profiles of the links can be milled to the proper contours, leaving the end radii to be hand filed, using a couple of filing buttons. Make them from drill rod, .50″ diameter and .12″ thick, with .25″ diameter center holes. After machining, harden them. By placing them on either side of the link ends and bolting them in place, the ends can be filed to a uniform size. **Photo 19** shows the finished links.

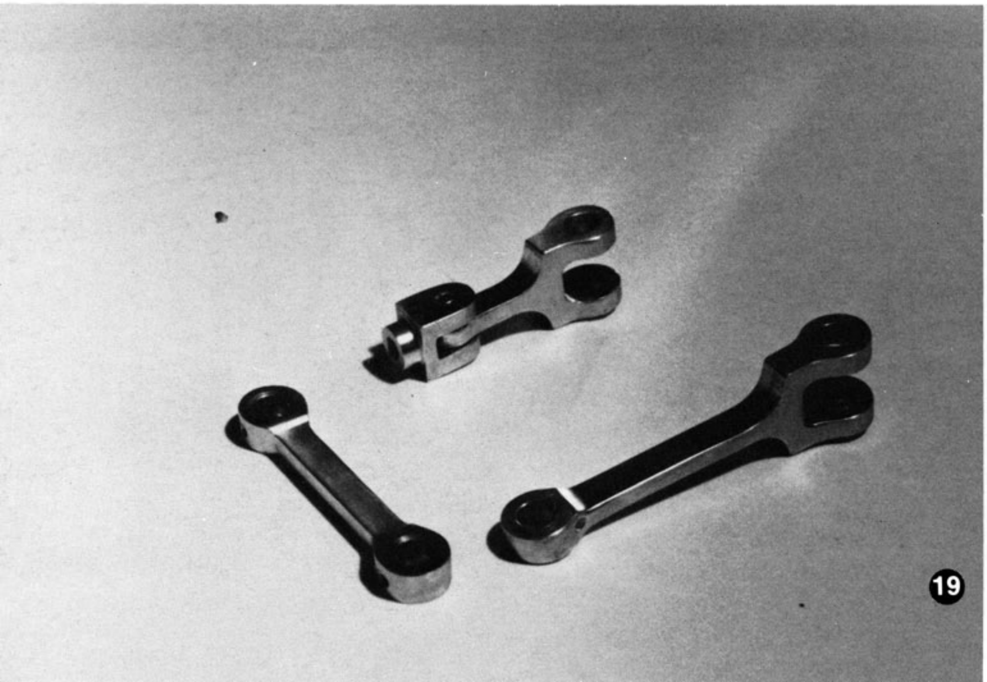
The **CRANKPIN (127)** and **SHOULDER SCREWS (128, 129 and 130)** are turned from cold-rolled .38″ hex stock. They can be left soft. A smooth finish with approximately .001″ to .003″ loose fit with their respective links is all that is necessary, due to the low velocities at which the linkage operates.



17 The displacer piston rod yokes fasten to the displacer piston rod end pivot with 6-32 hex head screws.



18 The completed displacer piston yoke assembly: two yokes, the end pivot and the displacer piston rod end.



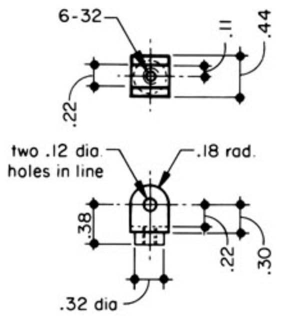
19 The crankshaft link, one of the power piston links and the water pump link.

The **FIREBOX (131)** is laid out from the full-sized pattern supplied with the casting kit and also reproduced here. Cold-rolled steel of .045″ thickness is used. **Photo 20** shows the blank, after cutting. All the .62″ radius corners are hard-formed around a piece of bar stock placed in a vise, 1″ diameter stock being used to allow for springback. Put the hole for the door in after welding, to minimize distortion. The welded seams should be finished either by hand filing or by using an auto body grinder.

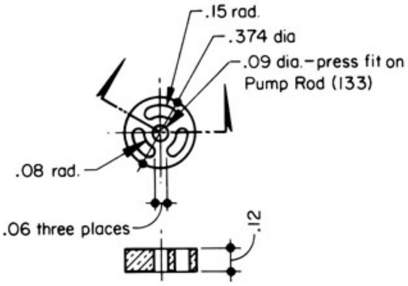
The .12″ square stock should be formed around the perimeter of the box. On the full-sized engine, this is a flange on the lower firebox casting; the upper half of the firebox is trapped between this flange and the engine base plate. The square rod is brazed in place with the brazing rod applied only to the bottom side, allowing a fillet on the lower side of the square rod and a sharp corner on top, to simulate the original joint. The bosses for the four tierods that suspend the firebox from the engine base plate are then brazed on.

The door (**photo 21**) is fabricated from .12″ thick stock.

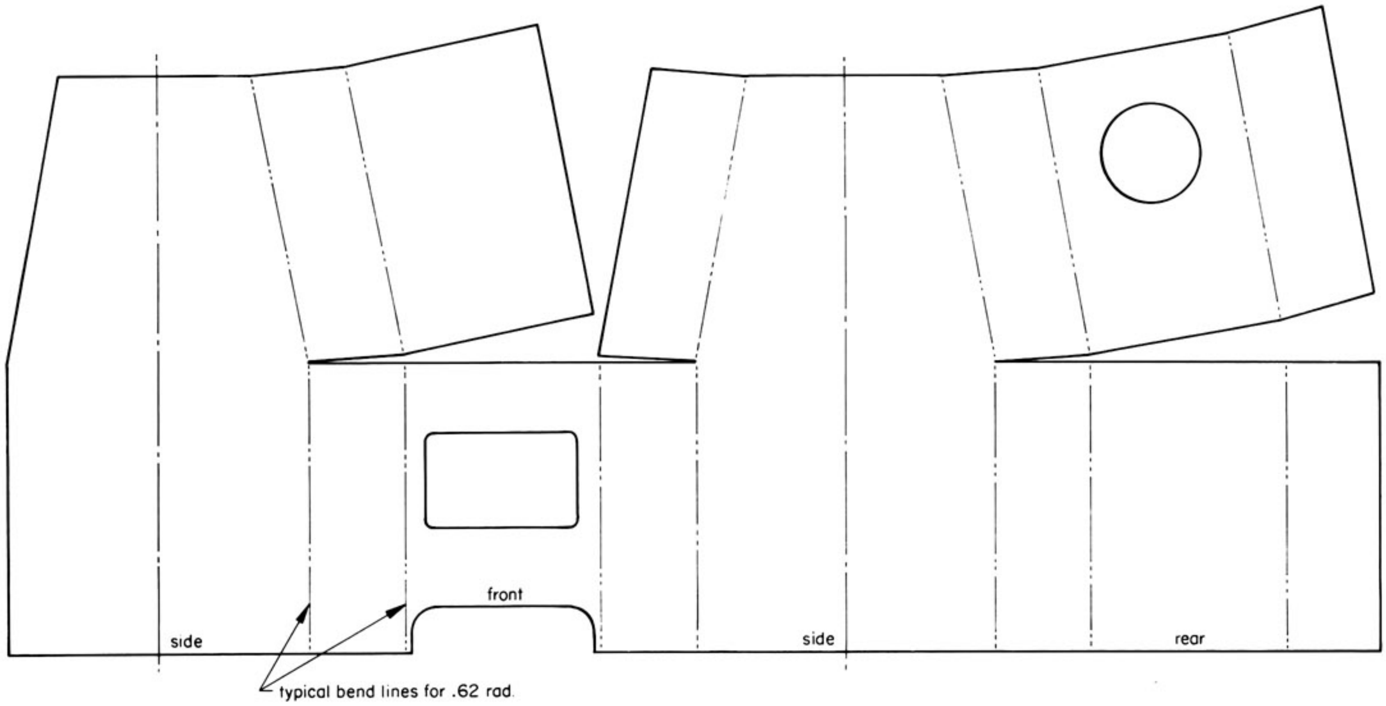
Photo 22 shows the completed firebox with the elbow for the chimney silver soldered in place. I prefer a two-piece stack which allows the vertical section to be removed for transportation purposes. The elbow shown is a 1¼″ diameter brass sink drain, purchased from a plumbing store. It



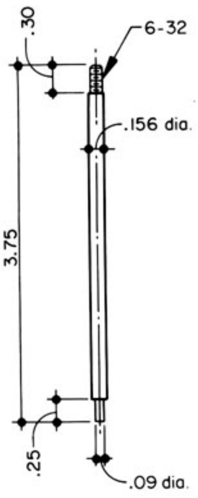
134 PUMP ROD CLEVIS
Brass, 1 required



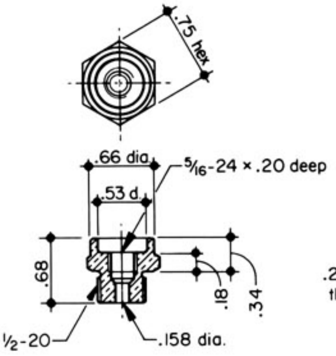
135 PUMP PISTON
Brass, 1 required
Shown actual size



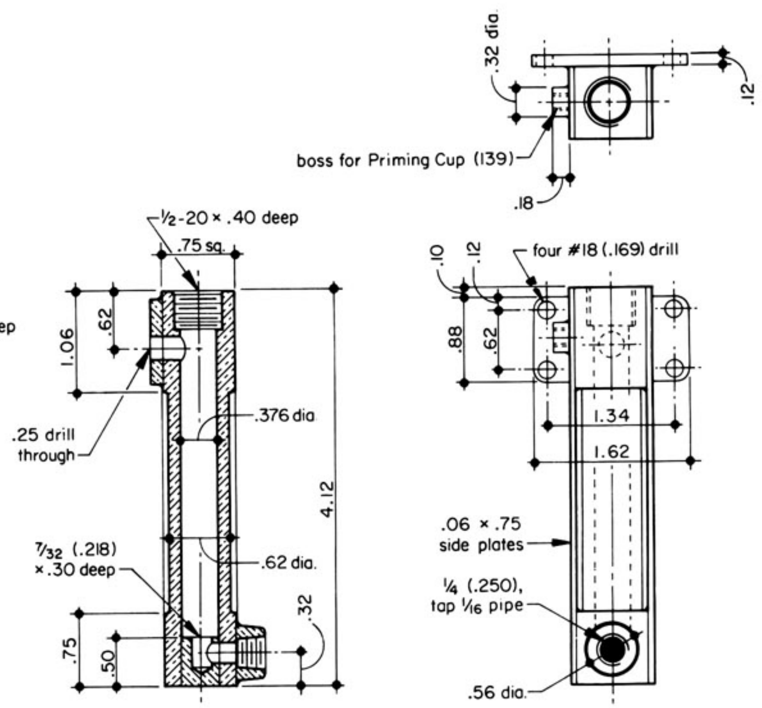
131(A) FIREBOX PATTERN



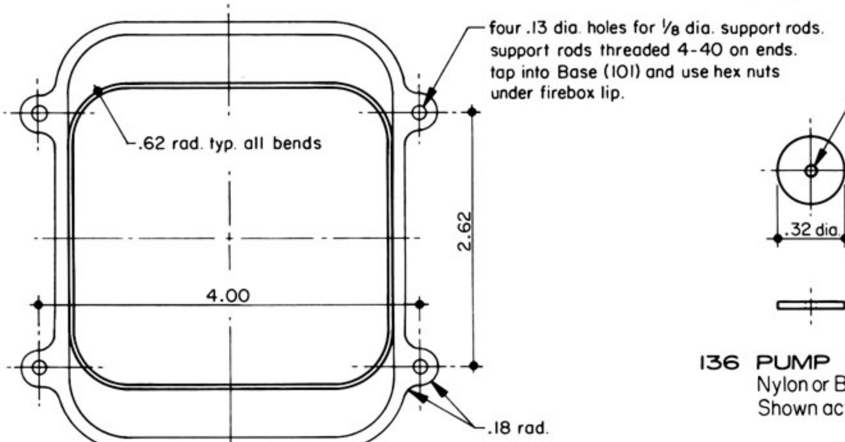
133 PUMP ROD
Stainless Steel, 1 required

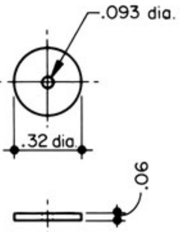


137 GLAND NUT
Brass, 1 required

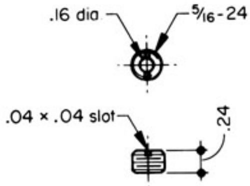


132 PUMP BODY
Brass, 1 required
Soft-soldered construction

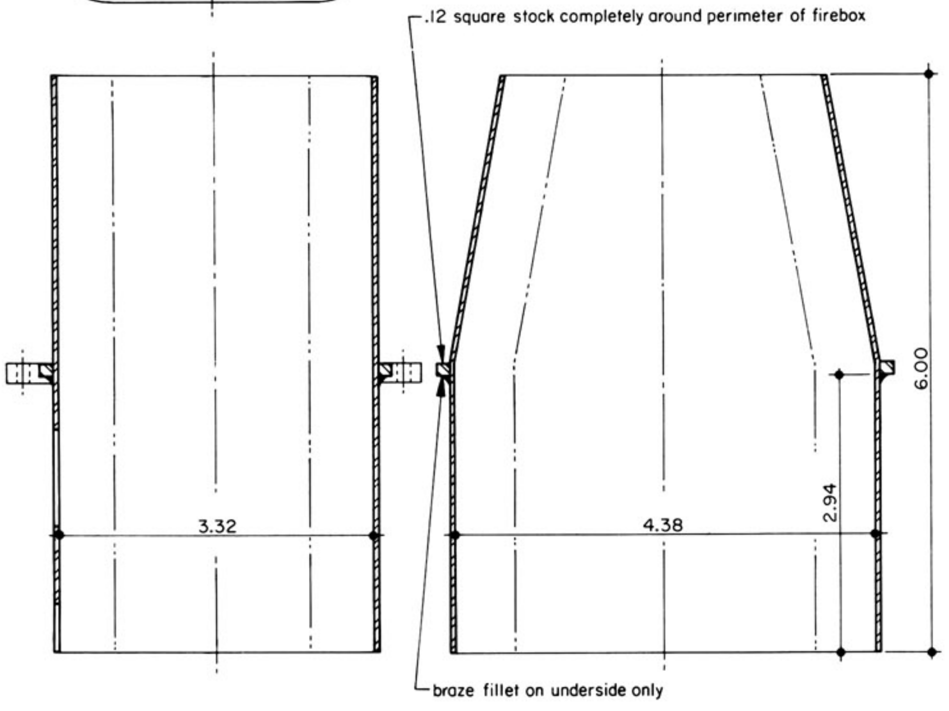




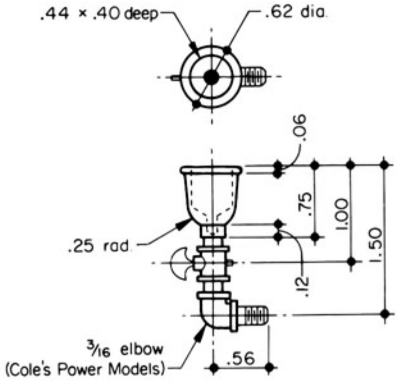
136 PUMP VALVE
Nylon or Brass, 1 required
Shown actual size



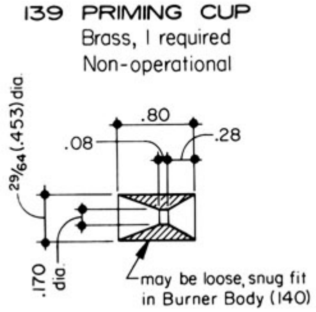
138 PACKING NUT
Brass, 1 required



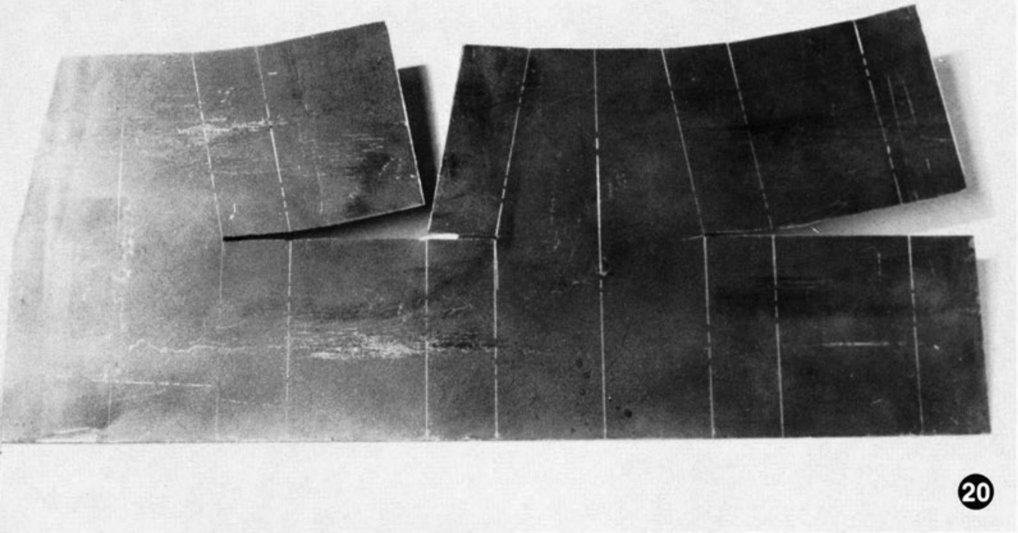
131(B) FIREBOX ASSEMBLY
.045 Cold-rolled Steel, 1 required
Welded and Brazed Construction

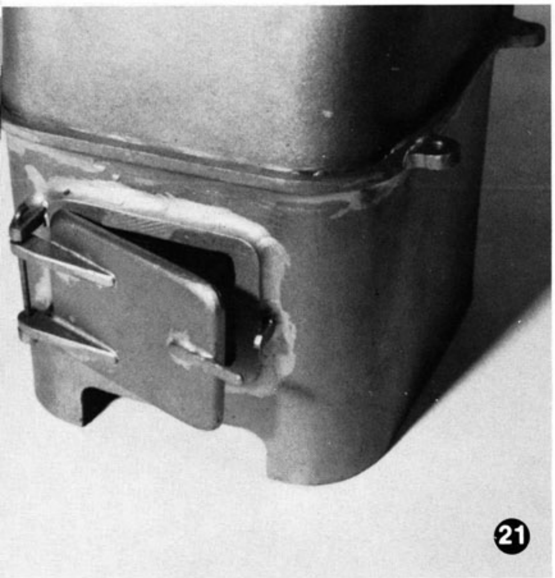


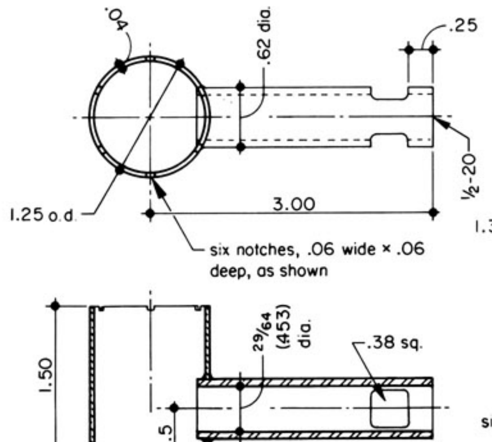
139 PRIMING CUP
Brass, 1 required
Non-operational



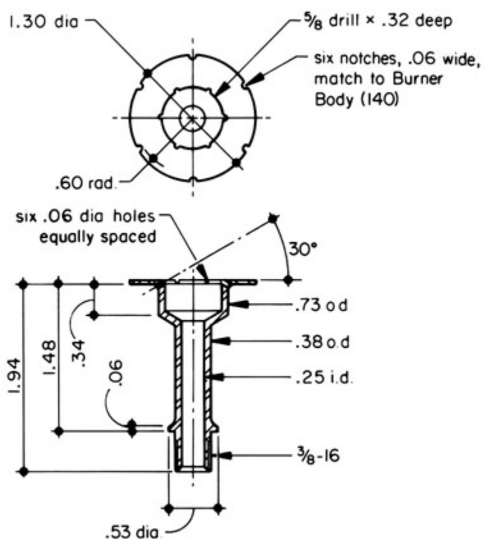
141 VENTURI
Aluminum, 1 required







140 BURNER BODY
Cold-rolled Steel and Brass, 1 required
Silver-soldered construction



142 TOP PLATE AND STEM
Cold-rolled steel, 1 required
Silver-soldered construction

provides a tight bend radius and a joint for the vertical stack to be slipped on.

Now that all parts for the engine proper are made, you're probably anxious to see the fruits of all your labor function, so let's put it together. We haven't yet built the water pump, but I prefer to assemble the engine and get it running before doing any final filing, filling or painting of the castings or finishing and buffing the brass components.

Using the assembly drawings as your guide, assemble the parts. The predetermined geometry of the linkage establishes the phase angle of the pistons, that is, the relationship of one piston to the other. The displacer piston on a Stirling engine will lead the power piston by 90°. The only thing yet to be done is silver soldering the displacer cylinder bottom, which can be done as soon as we determine its location. Adjust the displacer piston on its rod so there is .06″ to .10″ clearance between it and the power piston bottom, when the power piston is at dead center. Tighten the two setscrews in the displacer piston, which affix it in place. Now, advance the displacer piston to bottom dead center and note the relationship of the displacer piston to the end of the displacer cylinder. The end cap should be placed so there is .06″ to .10″ clearance from the piston bottom to the end cap. (Be sure the gasket between the flange and engine base is in place, because it affects the clearance.) By using this technique, the dead volume of the cylinder is minimized. (Dead volume is anything other than swept volume.)

Now, oil all the joints and power piston with a light grade oil; if an automotive type oil is used on the piston, too much drag is generated and it will keep the engine from operating. Put some water into the water jacket, to keep the epoxy cement from overtemperaturing. If you run the engine for over 15 minutes at a time, the water should be circulated.

Using a propane torch, spirit burner, sterno or some similar heat source, you are ready for start-up. It will take about 5 to 10 minutes to come up to operating temperature. Simply give the flywheel a turn and she will be running!

The water pump is not essential to the operation of the engine, except that water is necessary to cool the cylinder. This can be accomplished by using a separate water container of approximately one pint volume and plumbing it to the top and bottom of the water jacket, relying on the thermo-syphon method for circulation. But in the interest of having an authentic model, the pump is a necessity. And seeing the pump discharging water, even though it is only recirculating it from a small tank, completes the picture inasmuch as you can actually see it doing work.

The pump, as I have designed it, is a small departure from the original, mainly for simplification. Also, I have chosen to

20 The firebox blank (131-A), cut according to the pattern supplied with the casting set and with bend lines scribed in place.

21 Details of the built-up firedoor and door ring are easily seen in this photo.

22 The completed firebox, with the elbow for the stack extension silver soldered in place.

make it entirely from brass. The original had only the cylinder portion of the body in brass, along with the top gland nut, the body being an iron casting.

The **PUMP BODY (132)** is comprised of seven individual pieces, soft soldered together. The mounting flange is a good place to start, because it can be used as a template for locating the four 6-32 mounting screws and the .25″ diameter water transfer hole in the cylinder. The cylinder portion itself is machined from a piece of .75″ square brass stock. The .376″ bore should have a smooth finish which is best achieved by reaming. A few imperfections are allowable, as long as they are not of a nature that would score the piston. The inlet boss at the bottom is turned on its o.d. only, having the .250″ diameter hole and 1/16″ pipe tapping operation done after the soldering. The ball check valve seat at the bottom must have a uniform contact with the ball. To accomplish this, before inserting the seat into the body, place a ball over the .218″ drilled hole and give it a light tap with a hammer. This will brinell a narrow, spherical seat that matches the ball.

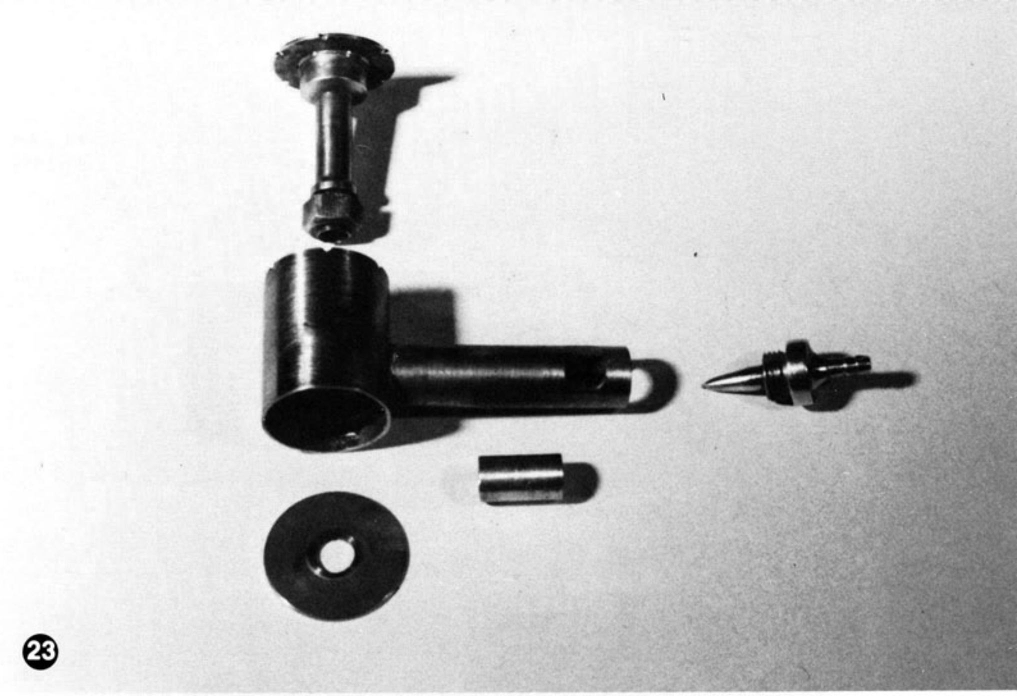
On my pump, I didn't solder on the two side plates. This allowed me to polish the complete body. After polishing the side plates, I attached them with epoxy cement and then clear lacquered the assembly to prevent tarnishing.

The **PUMP ROD (133)** is made from a piece of 5/32″ diameter stainless steel. If stainless is not readily available, then cold-rolled will be acceptable. (Incidentally, when running my engine, I usually add a small amount of water-soluble oil to the pump water to prevent rust or corrosion from forming on the steel cylinder sleeve. This would also protect a cold-rolled pump rod.) The rod's outside diameter should be smooth to minimize friction in the packing gland. The **PUMP ROD CLEVIS (134)** is made of brass.

The **PISTON (135)** is a small brass wafer that is a press fit onto the piston rod. The ports for the passage of water can be drilled and filed to final shape. Some care should be exercised in not exceeding the .15″ radius dimension, to insure a proper seal with the valve.

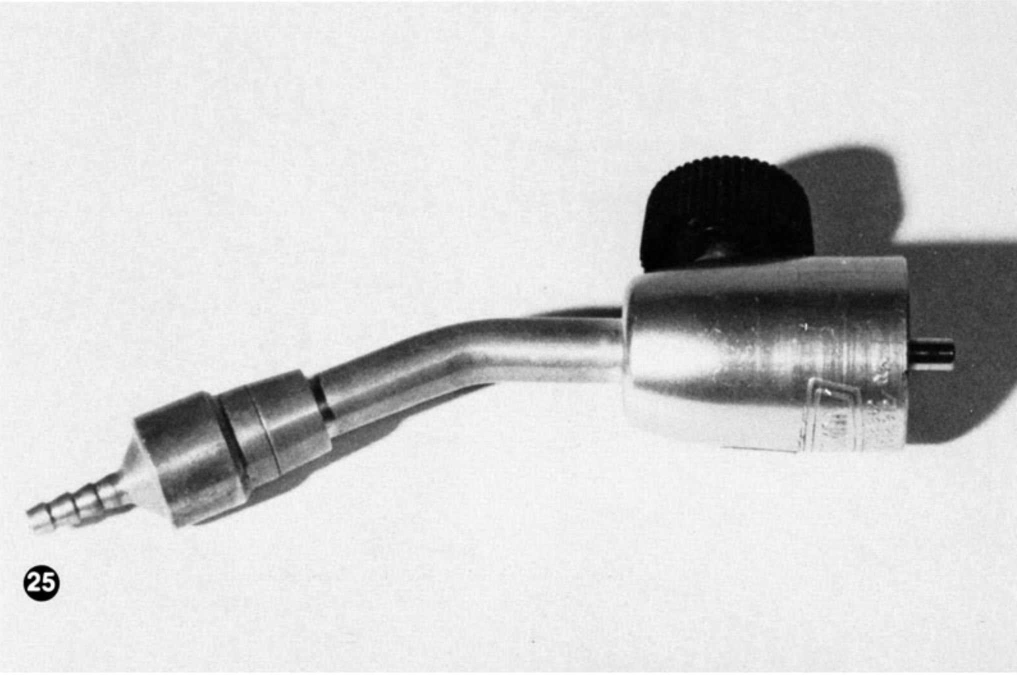
The **VALVE (136)** simply is a small wafer of brass or nylon. I prefer nylon because it does away with the clacking sound of metal on metal as the valve closes at the start of the upstroke and makes for a quieter-operating pump. This may seem like a small thing, but in the absence of other engine noises, it can be annoying. The valve must have the ability to slide freely on the .09″ diameter of the piston rod, but not cock or bind on the rod. The .32″ outside diameter must just cover the ports in the piston, but not be so large as to impede the flow of water around it.

The GLAND NUT (137) is turned from .75″ hex stock. It would be best to size the .158″ diameter to the already-constructed pump rod,



23

24

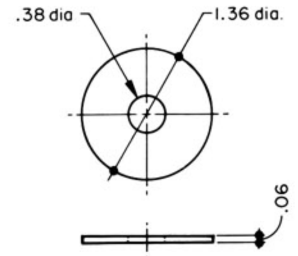


25

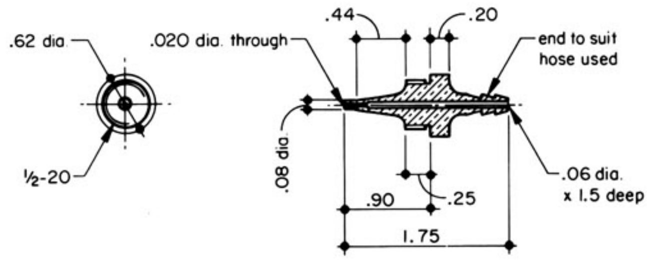
23 The various parts of the burner are seen in this exploded view.

24 The completed burner assembly (145).

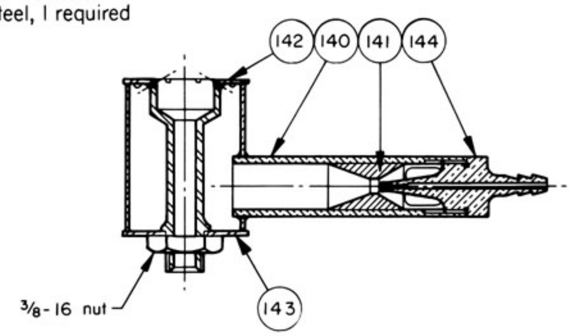
25 Gas regulation is accomplished by this modified Sears propane torch.



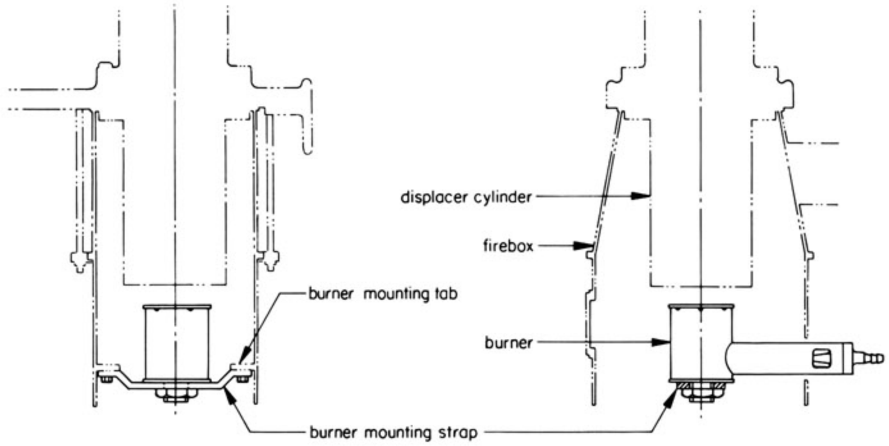
143 BOTTOM PLATE
Cold-rolled Steel, 1 required



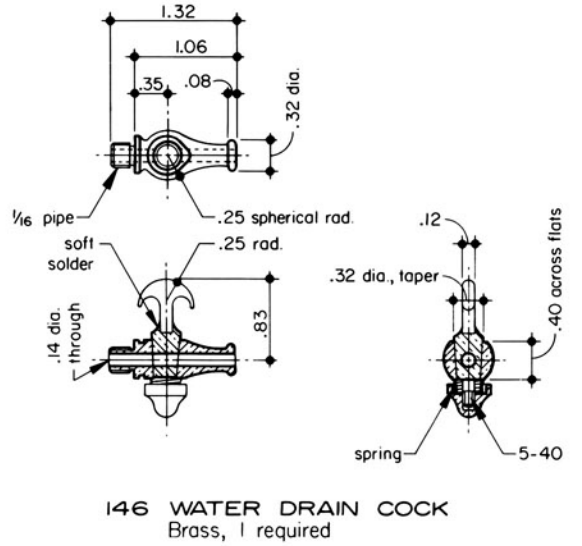
144 GAS JET
Brass, 1 required



145(A) BURNER ASSEMBLY



145(B) BURNER MOUNTING DETAIL



146 WATER DRAIN COCK
Brass, 1 required

to allow a smooth running clearance.

The **PACKING NUT (138)** screws in from the top, trapping a little teflon or similar packing beneath it. Do not apply too much load on the packing, because the friction generated can be enough to keep the engine from running.

The **PRIMING CUP (139)** is non-functional and is made purely for aesthetic purposes. It is turned from one piece down to the 90° elbow. A small hole is drilled through at the shut-off valve and a handle fabricated as shown. Pass it through the valve body and solder a small washer on the opposite side, allowing it to be rotated.

The air chambers shown on the engine cross sections at the inlet and outlet are non-functional also. Their purpose on the full-sized engine was to provide an air cushion to minimize water hammer. They can be turned from 1″ diameter brass bar stock.

The tubing used for all the water piping is 5/16″ o.d. x 7/32″ i.d. brass tubing, threaded 1/16″ NPT.

Only one last detail remains, the propane burner, and for some, it will be an option; if you prefer to use a spirit burner or some other flame source, the burner may be omitted, but personally, propane is by far the simplest and best fuel. It is readily available in small bottles and is comparatively neat and clean. The amount of gas consumed by the burner is small; a 14-oz. cylinder should last for eight to ten hours of operation.

The **BURNER BODY (140)** is a silver-soldered assembly. The 1.25″ diameter tubing is a piece of brass tubing cut off the elbow used on the firebox. The .62″ diameter stem is tap drilled 29/64″ through and threaded as shown on its end.

The **VENTURI (141)** may be machined from aluminum and is made to be a light slip fit in the 29/64″ i.d. which will allow for a fore-and-aft adjustment relative to the gas jet, to optimize the gas-to-air mixture. The flame notches on the top are best sized by starting out with smaller notches and working larger by trial, lighting the burner until satisfied with the flame shape.

The **TOP PLATE AND STEM (142)** is also silver soldered and is made from cold-rolled steel. The hole down the center is for secondary air circulation. The six .06″ diameter holes should be sized by the same trial-and-error method used to size the notches in the body.

The **BOTTOM PLATE (143)** is secured to the threaded end of the stem by a ⅜-16 hex nut. The same nut can also mount the burner to a bracket in the firebox.

The **GAS JET (144)** is turned from brass, as shown. The .020″ diameter hole can either be drilled to size or a piece of hypodermic tubing .020″ i.d. and .032″ o.d. can be inserted into the end. The connection end is machined to suit the hose used.

Photo 23 shows the parts to the propane burner. The complete assembly is shown in **photo 24.**

Photo 25 shows the modified propane torch, which I use to regulate the gas. This torch was purchased from Sears because of its somewhat unique design. It has its metering orfice built into the base, allowing the torch end to be cut off and an adapter for the connecting hose to be soldered on. If a different make of torch head is used, be certain that the metering orfice is used.

Your quarter-size replica of an Ericsson Hot Air Pumping Engine is now complete.