Elmer's Engines

by Elmer Verburg

Contents

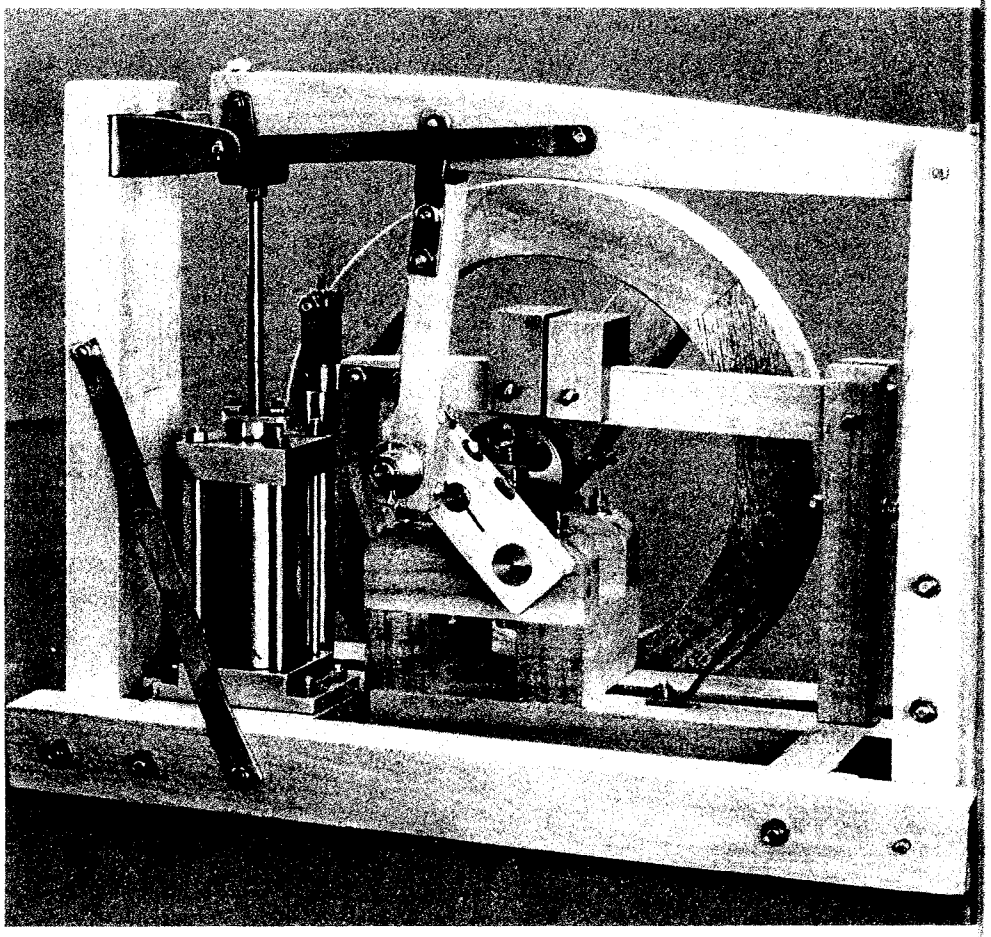
1 Wood Beam Engine. 1
2 Twin Vertical Wobbler 9
3 Open Column with Reverse 11
4 Four Square 14
5 Geared Steam Engine 17
6 Slider 24
7 Square 27
8 Scotty 29
9 H Twin 31
10 Wooden Grasshopper Engine 33
11 Radial Engine 44
12 Turbine and Centrifugal Pump 49
13 Open Column Twin with Poppet Valves 53
14 Wobble Plate Engine 60
15 Fancy 65
16 Baldy 67
17 Pumping Engine 69
18 Fancy II 80
19 Standby 85
20 Kimble Engine 87
21 Kimble Engine Rotary Valve 95
22 V Twin 97
23 Tiny 99
24 Beam 101
25 Wobbler 105
26 Live Steam Boiler and Engine 107
27 V4 Wobbler 111
28 H-Quad Engine 116
29 Mine Engine 123
30 Opposed Piston Steam Engine 129
31 The Engine Showcase 133
32 Tall Vertical Open Column 135
33 Mill Engine 141
34 Cross Twin Engine 147
35 Steam Pump 155
36 Vertical Reversing Wobbler 160
37 Grasshopper Engine 165

38 VR 75 171
39 Rope Drive 179
40 Generator 189
41 Factory Engine 193
42 Oscillating-Cylinder Engine 198
43 Horizontal Mill Engine 203
44 Open Column Twin 207
45 Single Cylinder Compound 212
46 Comber Rotary Engine 217
47 Model Boat Engine 222
48 Una-Flow Engine 225
49 Vauxhall Donkey Pump 230
50 Educational Model 235
51 V3R 242
52 Reversible Vertical Twin Wobbler 247

Appendix 252
Create Your Own Designs 253
Odds & Ends for Beginners 258
Cutting a Tapered Keyway 261
Modelmaker's Depth Gauge 263
Modelmaker's Thickness Gauge 264
Sheet Metal Punch 265
Beam Compass 267
Simple Turning and Machining Hints 269
Adapting 270
Hardening 270
Ball Turning Tool 271
Close Tolerance Holes 273
Carriage Stop 274
Cross-Slide Milling Attachment 275
Scribing Bolt Circles 276
Parallel Clamp Vise 277
Offset Tailstock Center 279
Handy Scale 281
This is just the beginning! 281
Index 282

CHAPTER

1 Wood Beam Engine



They are called **BEAM** engines so why not make one of wooden beams? There were no pictures on hand of the early engines, only a hazy photograph of a pewter model in a magazine ad. The design here is based on the thinking, materials and skills that might have been used. It runs and is a fine conversation piece. This engine is before Watt's famous parallel motion. However, you will find inconsistencies such as socket setscrews, cotter pins, a setscrew driving a large flywheel, spring pins and hex nuts instead of old square nuts.

Walnut was used for all the wooden parts except hard maple for the Flywheel. All the long bolts were made from finishing nails and brazing rod. A supply of 2" nails was found to be .081" in diameter and some 2-1/2" were .100". When threaded, they served the purpose for #2-56 and #3-48. 3/32(.094") brazing rod also made #3-48. These smaller-than-nominal diameters produced satisfactory threads in this case.

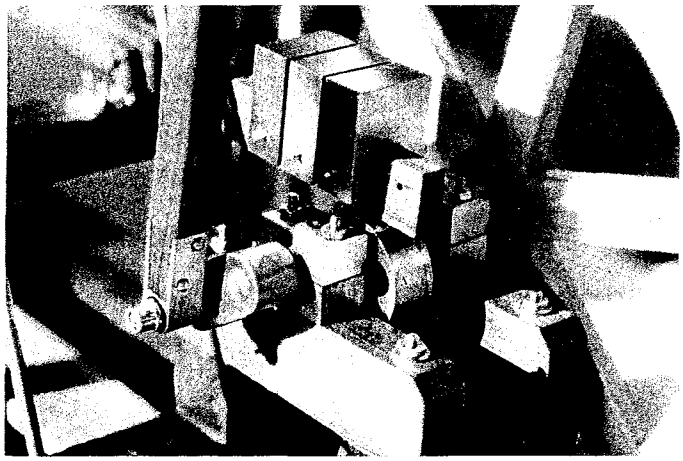
The **CYLINDER** is tubing cut squarely and set in the lower Head with Loctite. The remaining Cylinder parts need no explanation. The **VALVE ASSEMBLY** is mostly tubing. The flanges are silver soldered to the cross tubes and mounted on the Cylinder assembly when soldering the ValveTube. Cut and try until you are satisfied that the Valve Tube is parallel and the right distance from the Cylinder. Make two close-fitting aluminum pins to guide the Valve Tube while soldering. The solder will not stick to the aluminum. The **VALVES** and **VALVE ROD** are a solder job. Make the fit close enough to make the two Valves a close free fit in the ValveTube. There is no attempt to control the exhaust. It just escapes out both ends of the Valve Tube.

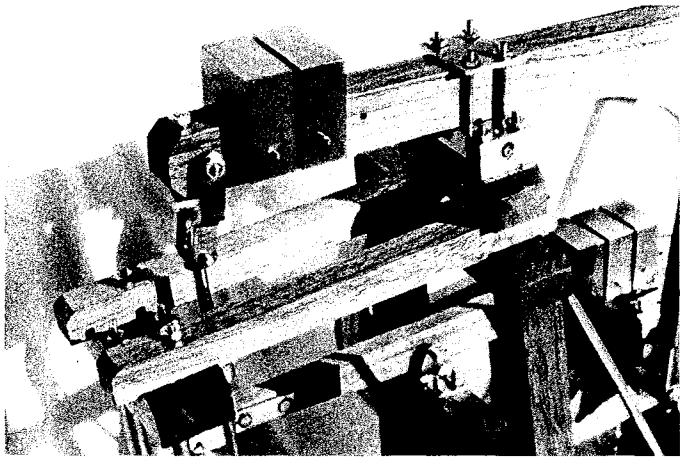
The **BEAM** and fittings are simple. The weights are optional, although they do seem to help. A weight of a sort was shown on the pewter model. The Bushing is set with Epoxy glue. The **ECCENTRIC** is steel. A socket set screw is spotted on the centerline through the offset and Shaft at the greatest throw. When adjusting the Valve, a hex wrench helps locate the Eccentric 90° from the Crank.

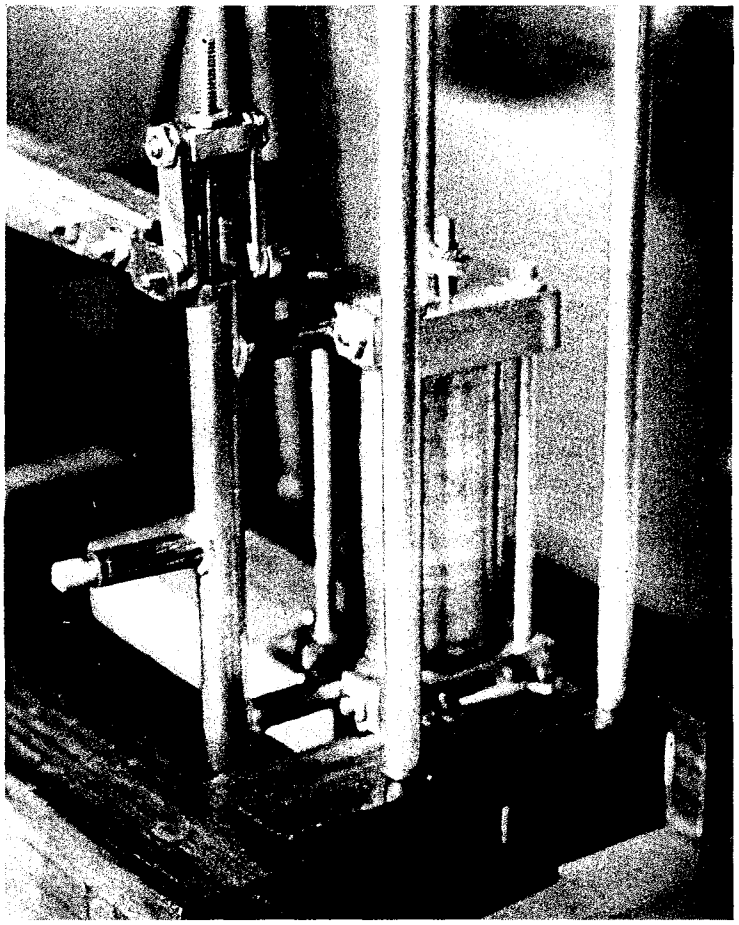
The **VALVE BEAM** needs the weights shown to keep it in contact with the Eccentric. The wear pad, if it was ever a part of such an engine, would probably be rawhide. The wood seems to hold up, so no pad was used. When, at assembly, the Valve Beam location is established the bushing can be set with Epoxy. The screws soldered into the fork can be roundhead screws with the slot filed away after soldering.

The **WEIGHTS**, **CRANK COLLAR** and **PIVOT SHAFT** at the upper end of the Connecting Rod use cotter pin retainers. Spread the pins apart then hold together when inserting. Do not bend the ends over; let the springiness hold them in place. The thickness of the two spacers at the Crank Bearing can be determined at a trial assembly. The Bearings are solid blocks. You can make split Bearings to be a bit more authentic.

The **FLYWHEEL** is made of hard maple to gain all the weight possible from common wood. Lay the six segments of a hexagon on a sheet of waxed paper on a **flat** board. Apply fast-setting glue to each joint and press together. Nails can be driven around to help hold the shape while setting. File away the glue ridges and dress flat. Scribe fine accurate lines for the O.D. and I.D. of the rim. Saw and file to these lines. Do the same with the center layer. Assemble the spokes first, holding each in place with a nail. Carefully squeeze the six segments against the spokes. When set, lay out, saw and file to the exact O.D. of the above rings. Saw and file







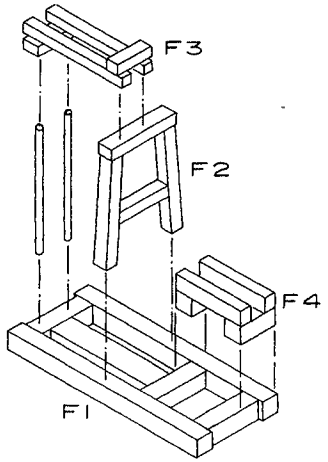
to the inside line as shown. Opiton: Pierce the center layer in 6 places, add 1/4" x 1/4" x 1-1/2" steel weights to improve Flywheel action. Glue all three pieces together, breaking joints. Bore the 3/8" hole as accurate as you can to prevent wobble and eccentricity. The hub is set with Epoxy and rivets.

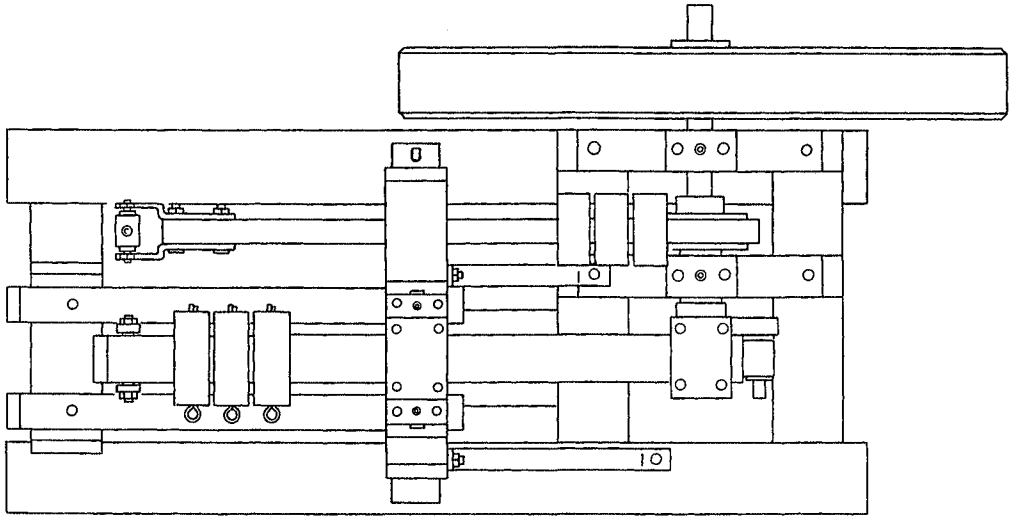
Now, if you made this Wheel and it runs true without wobble, you did a better job than on the one shown. It really calls for some expert woodworking. This is a way that will be tried if another is made: Bore the hub to 7/32" instead of 1/4". Chuck the wheel in a 3-jaw on the rim I.D. and bore 3/8" for the hub. Make a light chalk mark on the rim at the #1 chuck jaw. Remove from the chuck and set the hub with Epoxy and rivets. Rechuck with the chalk mark at the #1 jaw. Make skin cuts on the wheel O.D. and faces. Use a tiny boring bar and bore the hub to a 1/4" close fit on the Shaft using very light cuts. Filing, rounding corners and sanding will make a fine surface for a transparent coat of lacquer or varnish. There is a chance such a Wheel made in those days would show some signs of wobble or irregularities. Since they ran so slow it would hardly be noticeable. Try to imagine a temporary tool rest and someone on a platform holding a heavy chisel truing up the rim of a big wheel. Maybe someone can tell us how such a wheel would have been made. Also, it is more likely that a large pulley or wheel of this size would have a split hub with tiebolts to clamp onto the Shaft instead of a screw or pin.

The **CONNECTING ROD** can be a straight piece or tapered as shown. Make the two end pieces of brass. Spread the ends to match the taper. Cement with Epoxy. When set, dress wood and metal even and flush for good appearance. Drive four escutcheon pins or round head nails in to represent rivets in each end. Lay out the two pivot holes, drill and ream.

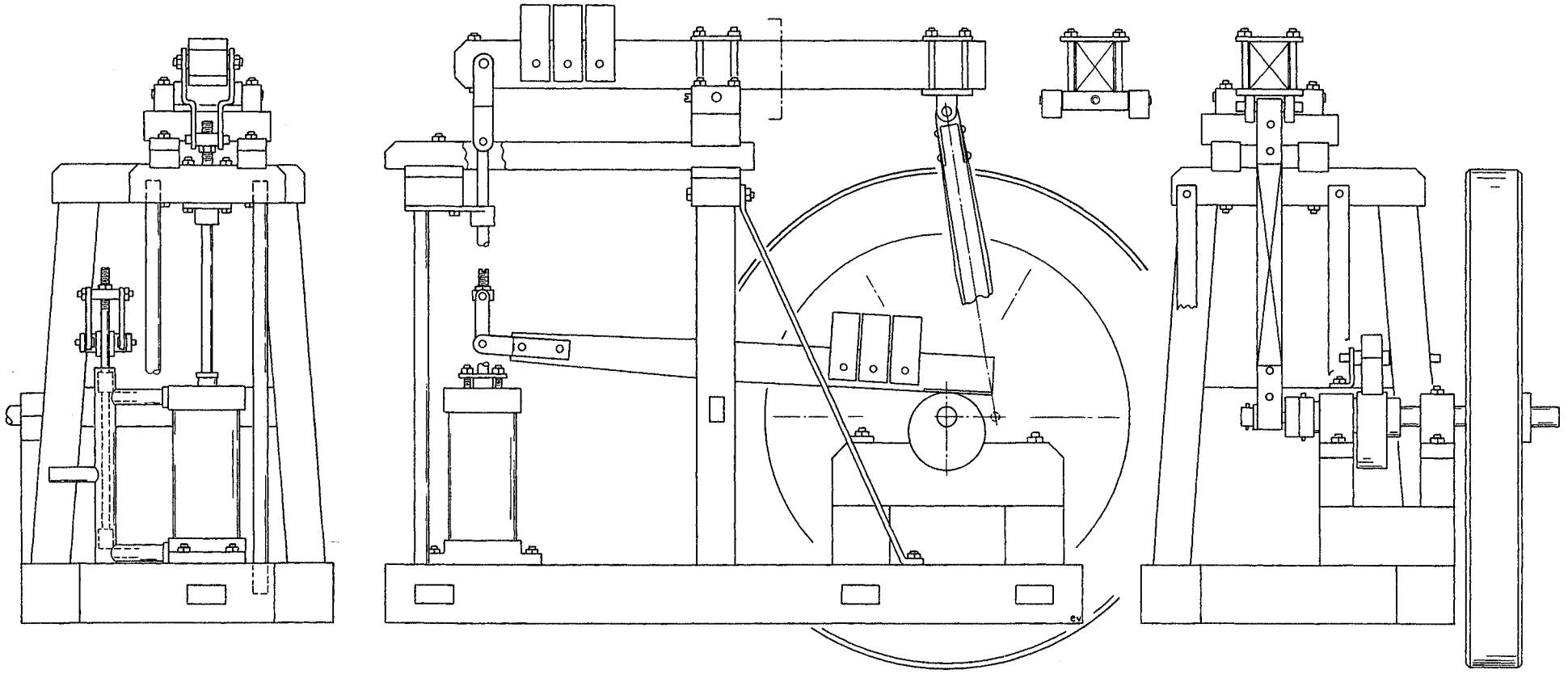
If the temporary assembly runs free and the engine operates satisfactorily on 5 pounds of air, you can go back and complete the final cementing and assembly. The finish is up to you. If the metal is bright and the wood has a fine surface, the entire assembly can be sprayed with a transparent sealer. If there is a trace of oil on all the pivots, bearings, slides, etc., there will be little drag caused by the spray.

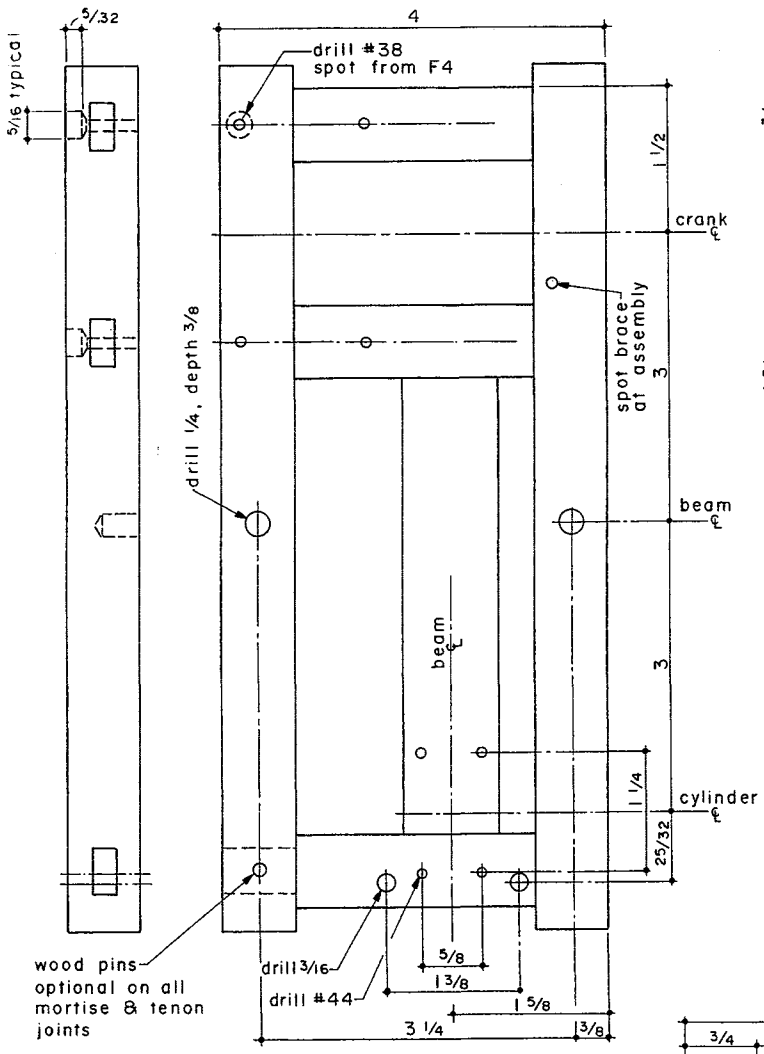
These giant engines ran on less than 100 rpm but you will be lucky to keep this one under 100. The speed is one item that is hard to scale down.



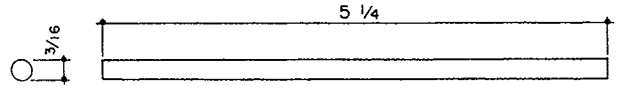


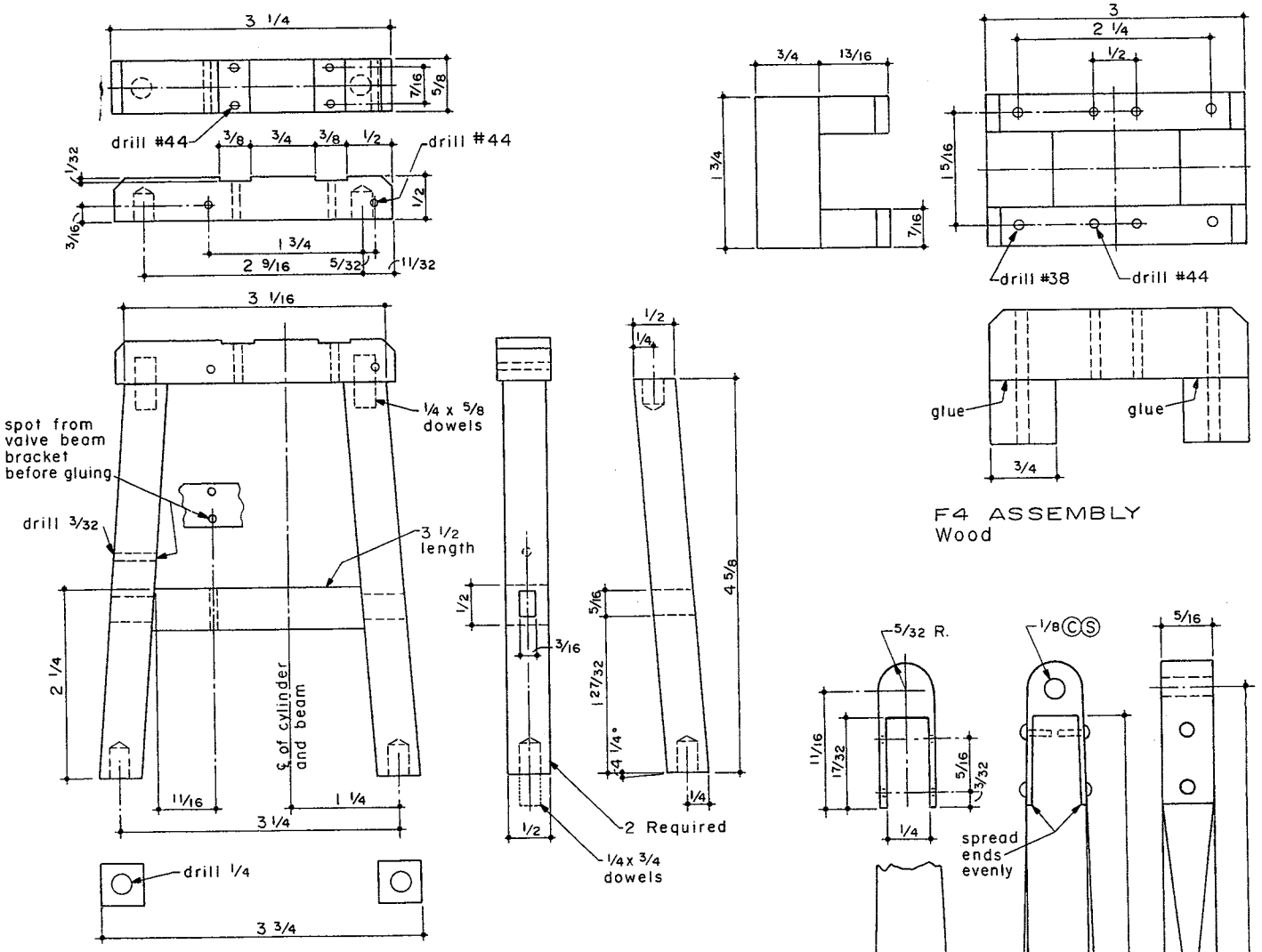
WOOD BEAM ENGINE

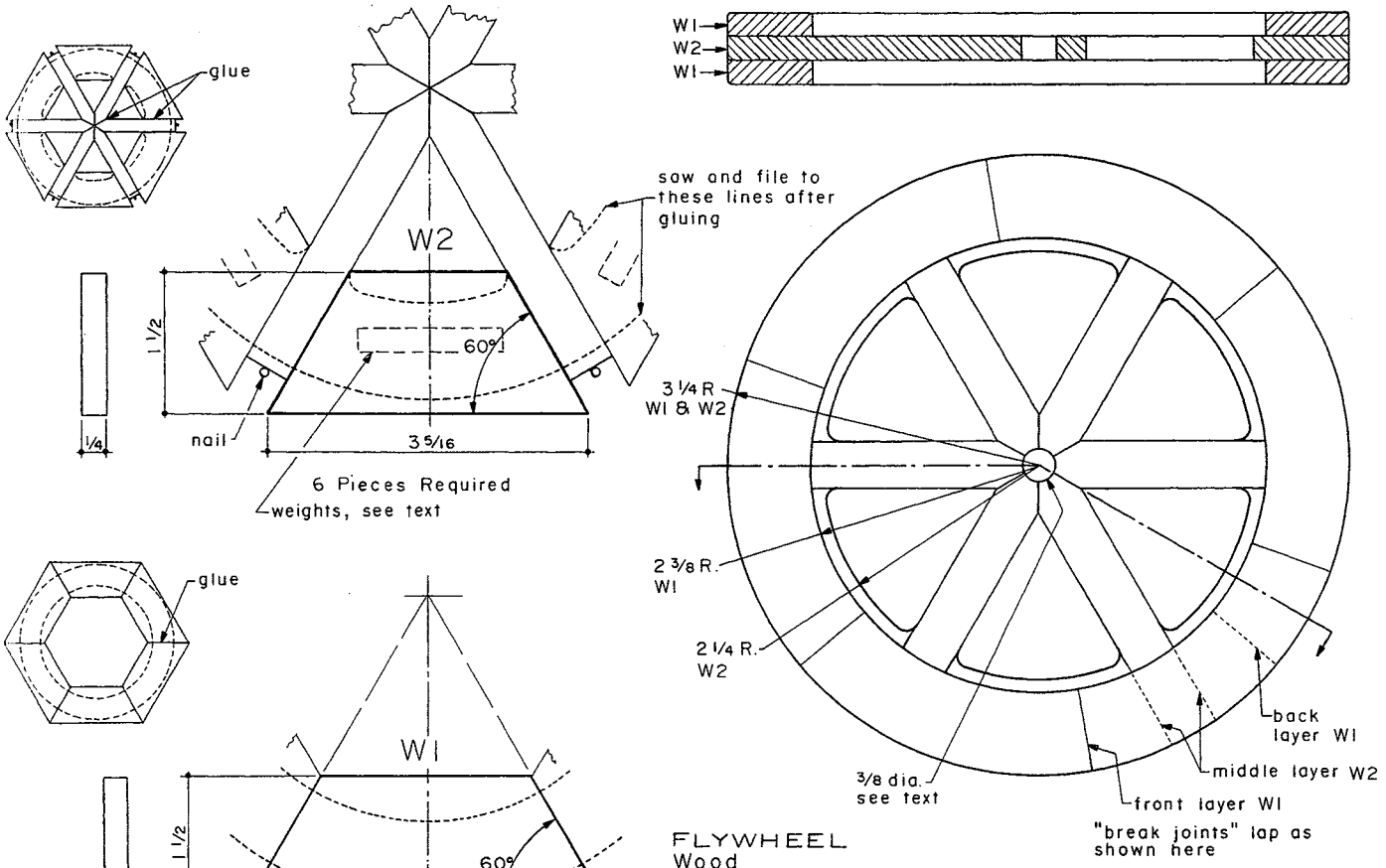


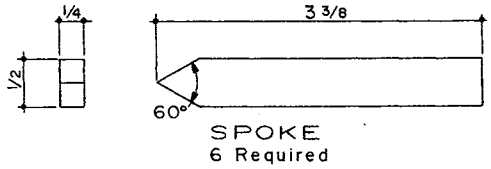


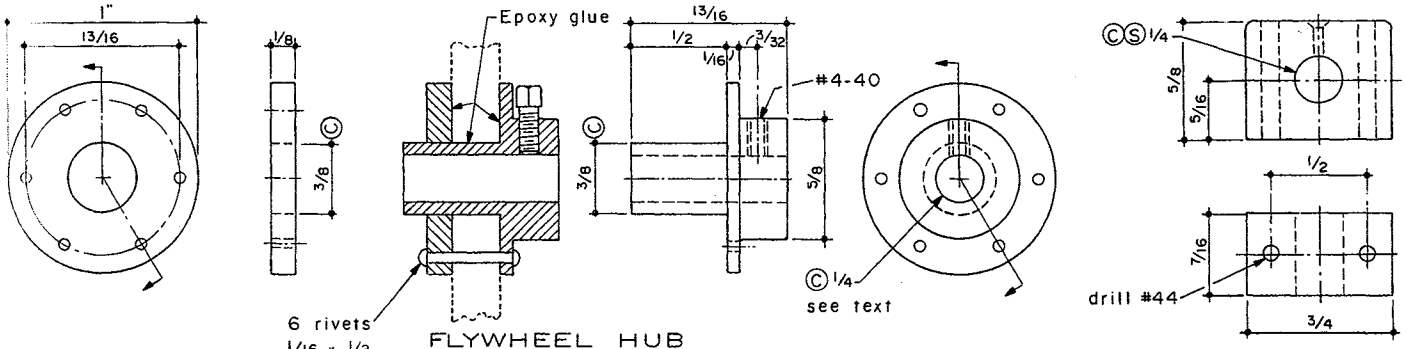
F1 ASSEMBLY (BASE)
Wood

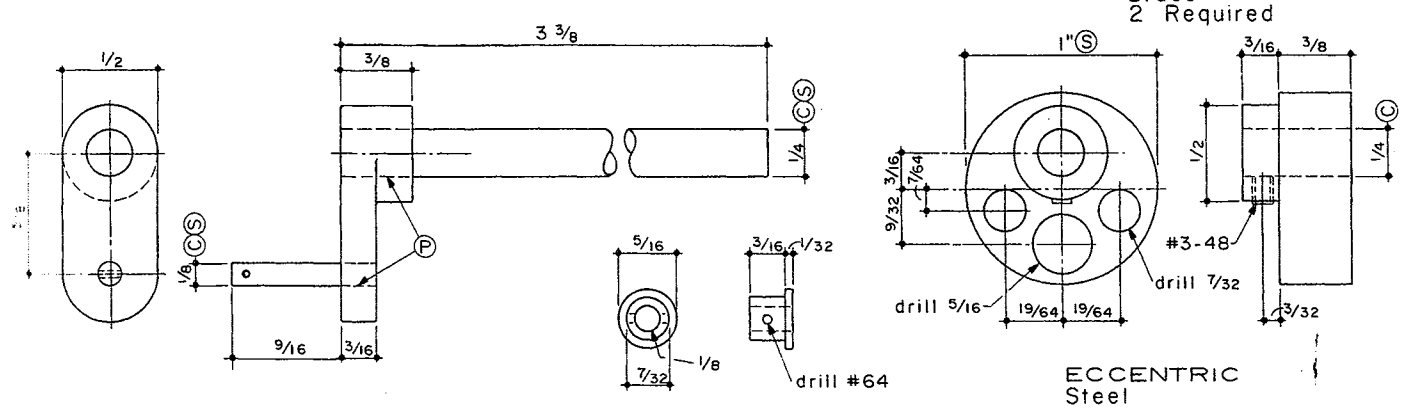


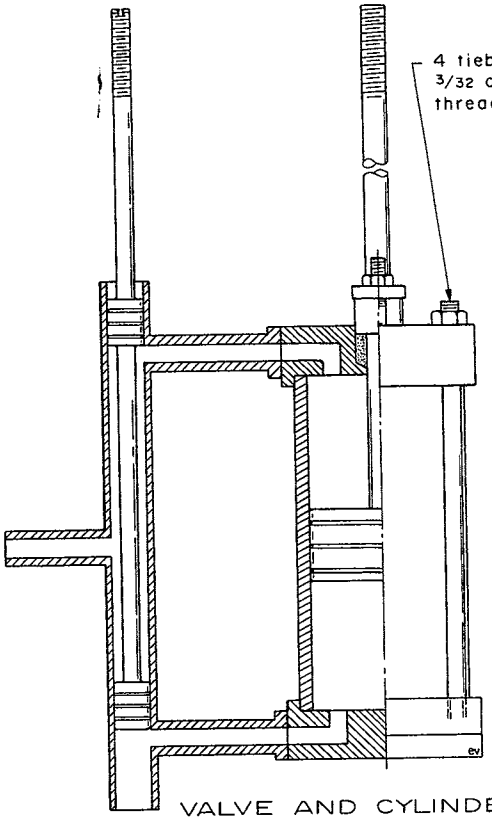

3 1/4
drill #44
drill #44
3/8
3/4
3/8
1/2
1/32
3/16
1/2
1 3/4
2 9/16
5/32
11/32
7/16
5/8
3 1/16
spot from valve beam bracket before gluing
drill 3/32
1/4 x 5/8 dowels
3 1/2 length
2 1/4
11/16
1 1/4
3 1/4
drill 1/4
3 3/4
℄ of cylinder and beam
1/2
1/4
3/16
1/2
2 Required
1/4 x 3/4 dowels
5/16
1 27/32
4 1/4°
4 5/8
1/4
3/4
13/16
1 3/4
7/16
3
2 1/4
1/2
1 5/16
drill #38
drill #44
glue
glue
3/4
F2 ASSEMBLY
Wood
F4 ASSEMBLY
Wood
brass bushing
3/16 OD, 1/8 ID, set with Epoxy glue
9/16
1/2
#2-56 bolt (optional to prevent splitting)
5/8
3/8
11/16
15/32
15/32
drill #51
6 7/8
BEAM
Wood
Epoxy glue
7/16
1/4
2 1/4
brass bushing
3/16 OD x 3/32 ID
drill #51
5/16
3/16
1/2
5/32
1/2
2
1 11/16
13/32
13/32
13/32
6 1/4
drill #44
plastic pad (optional)
VALVE BEAM
Wood
5/32 R.
1/8 CS
5/16
11/16
17/32
5/16
3/32
1/4
spread ends evenly
3 11/16
4
Wood
Epoxy glue
17/32
1/32
5/16
1/8 CS
5/16
7/16
Brass
2 Required
Escutcheon pins or round head nails
CONNECTING ROD


glue
W2
saw and file to these lines after gluing
1 1/2
60°
1/4
nail
3 5/16
6 Pieces Required
weights, see text
W1
W2
W1
3 1/4 R
W1 & W2
2 3/8 R.
W1
2 1/4 R.
W2
back layer W1
middle layer W2
front layer W1
3/8 dia.
see text
"break joints" lap as shown here
FLYWHEEL
Wood
glue
W1
1 1/2
60°
ev
1/4
3 15/16
12 Pieces Required

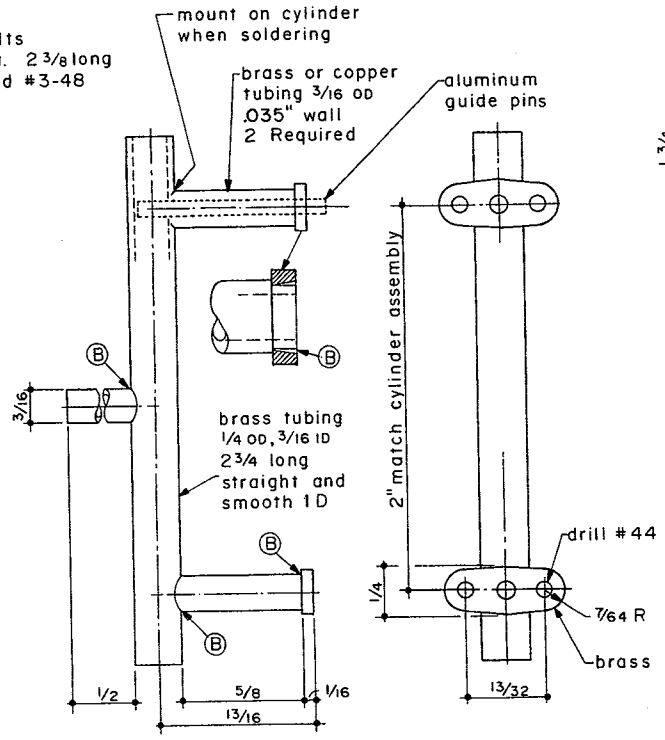

1/4
1/2
3 3/8
60°
SPOKE
6 Required


1"
13/16
1/8
3/8
Epoxy glue
6 rivets
1/16 x 1/2
FLYWHEEL HUB
Steel or Brass
13/16
1/2
3/32
1/16
#4-40
3/8
5/8
see text
1/4
5/8
5/16
1/2
7/16
drill #44
3/4
BEARING (crankshaft)
Brass
2 Required

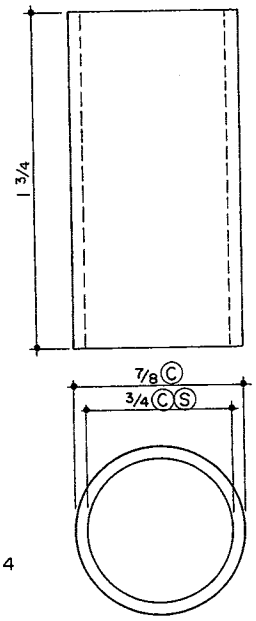

1/2
3 3/8
3/8
1/4
1/8
9/16
3/16
CRANKSHAFT
Steel
5/16
3/16
1/32
1/8
7/32
drill #64
COLLAR
Brass
1"
3/16
3/8
3/16
7/64
9/32
1/2
1/4
#3-48
drill 5/16
19/64
19/64
drill 7/32
3/32
ECCENTRIC
Steel



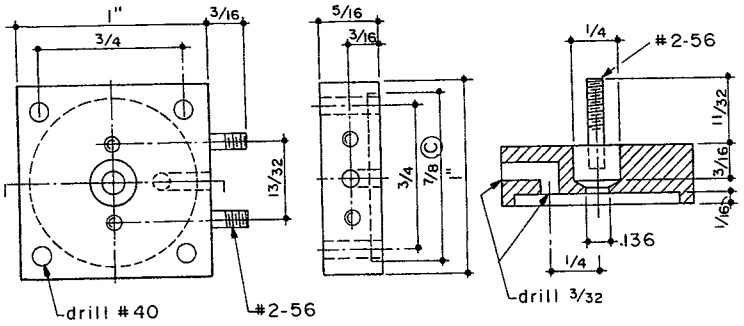
VALVE AND CYLINDER ASSEMBLY



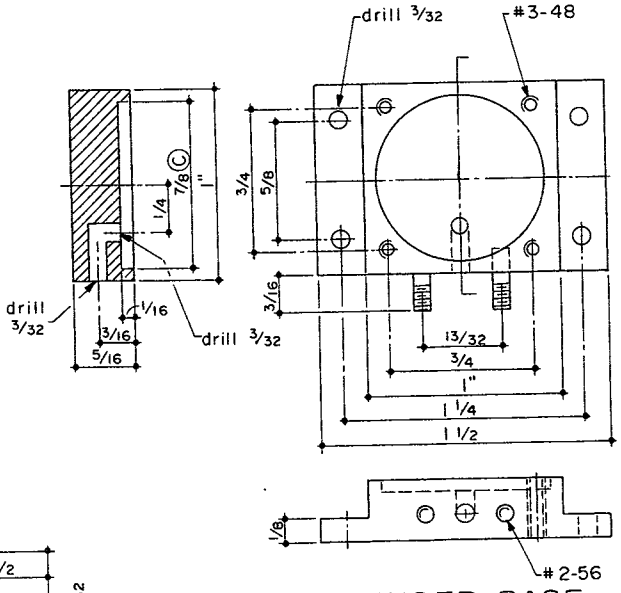
VALVE ASSEMBLY



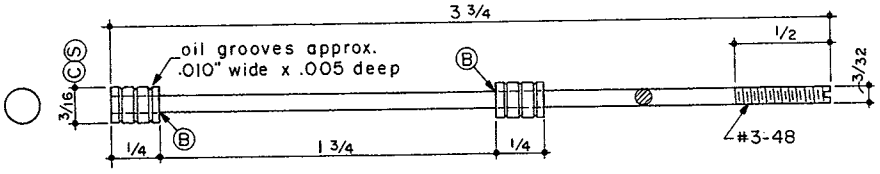
CYLINDER
Brass



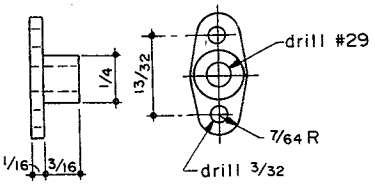
CYLINDER HEAD
Brass



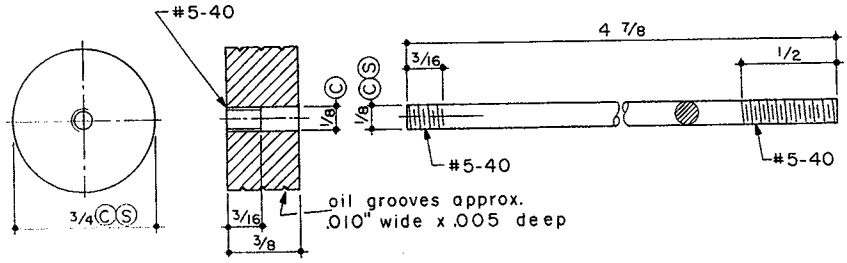
CYLINDER BASE
Brass



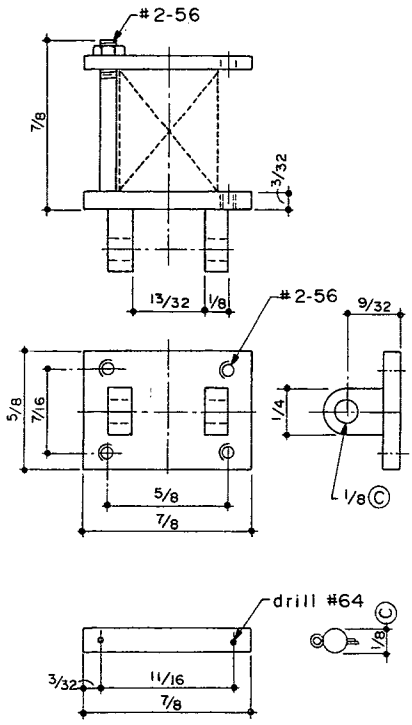
VALVE
Brass



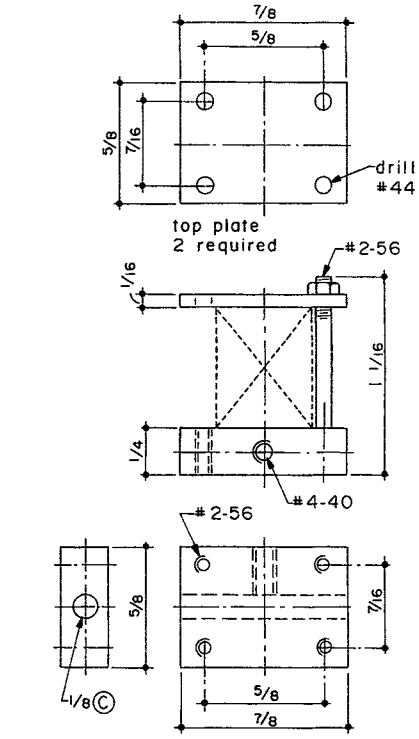
GLAND
Brass

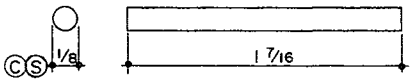


PISTON AND ROD
Brass

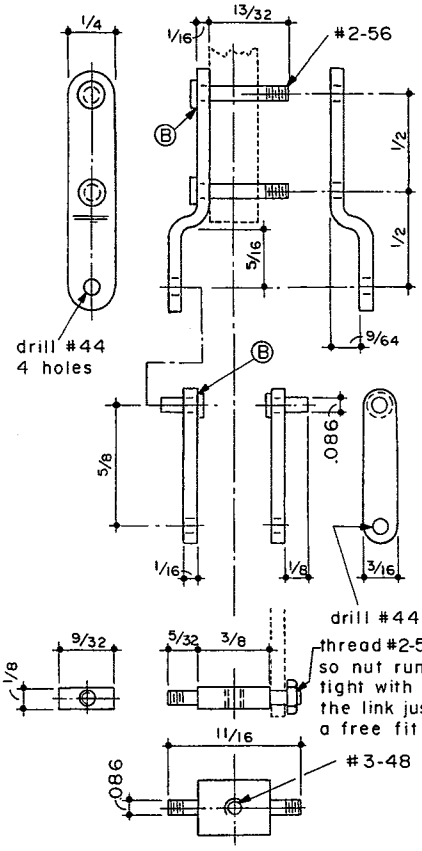


BEAM FITTINGS
at connecting rod
Brass

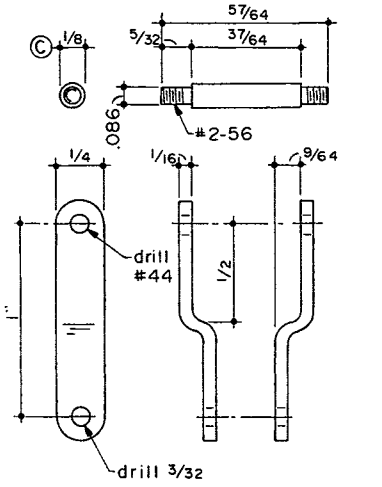




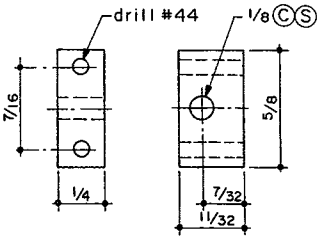
BEAM FITTINGS
at beam pivot
Brass



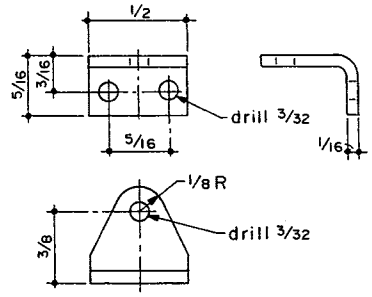
VALVE BEAM FITTINGS
Brass



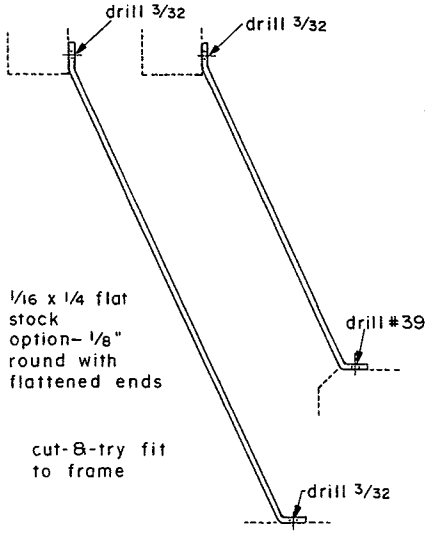
BEAM
FITTINGS
at cylinder
Brass



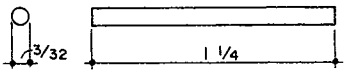
BEARING
Brass, 2 Required



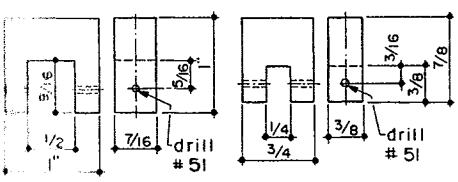
BRACKET
Brass



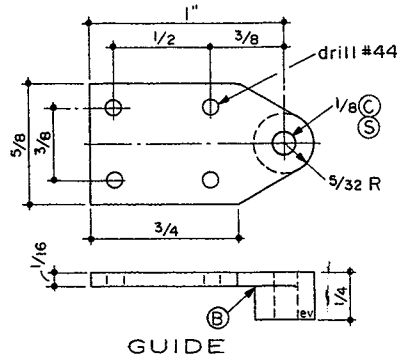
BRACES
Brass



PIVOT
Brass



WEIGHTS
Steel or brass, 3ea. req.



GUIDE
Brass

CHAPTER

2

For a simple stationary engine, try this

Twin Vertical Wobbler

This is a simple Twin Vertical Wobbler made from scrapbox material. It features extended guides to reduce wear on the pistons.

The **BASE** and **COLUMN** need no explanation except for the porting in the Column. Lay out, drill and ream the two 1/8" Shaft holes. This is a good job for the lathe milling attachment. Pick up the hole center with a drill chuck and wiggler in the headstock. Set up one hole on center and zero the collar. Feed across 1-5/8" for the second hole.

Make a **DRILL JIG** from 1/16" steel. Calculations show the centerline through the Pivot and Valve holes at maximum throw to be 3/16" from the O.D. of the Crankshaft. 1/64" was added to gain a few thousandths more seal between the port holes. In use, the Jig is put over the Pivot Shaft and against the Crankshaft as shown. Turn the Jig over to get the other port hole. Please note that on the through hole for the intake, you should drill from each side of the Column. Do not go all the way through from one side. This is the reason for the Jig; to guarantee the location of the hole on the face of the Column. Pick up the centerline of these port holes and transfer them to the 1-1/4" faces of the Column and drill the 3/32" exhaust holes and the 3/16" intake.

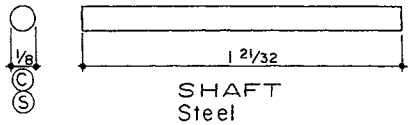
The two **CYLINDERS** are made from 1/2" square stock. First, lay out the 1/4" bore 1/16" off center and center punch. Chuck in a four-jaw and center the bore with a center test indicator. Turn the 3/8" diameter portion and bore and ream 1/4". File or mill the 3/8" diameter projection to form the **A** and **B** sections. Drill and ream the 1/8" pivot hole and counterdrill for the Spring.

Next, let's proceed with making the two **PISTONS**. Mark or stamp them so they can always be assembled in their own Cylinder the way they were fitted and worn in. Insert the Pivot Pin through the Cylinder and Jig. Insert the Piston for this Cylinder. Run a 1/16" pin through the Jig and the Crankpin hole in the Piston. The other 1/16" jig hole locates the steam port.

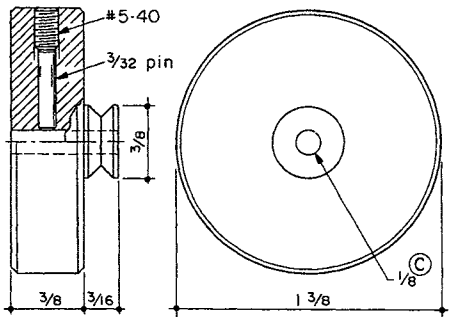
The **CRANK SHAFT** and **PIVOT SHAFT, 3/16" STEAM CONNECTION**, the **CRANK DISKS** and **FLYWHEEL** and the **CRANK DISKS** need no explanation.

The **SPRINGS** were found in the salvage box. The one chosen measured 1-1/2" long and, when cut in two, each piece was about right for the job.

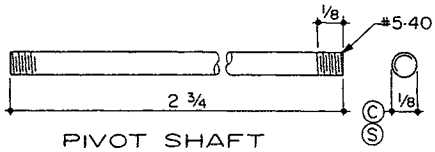
This engine performs quite well on as little as 5 to 10 psi air. It was a pleasure to build and a continuing pleasure to operate.



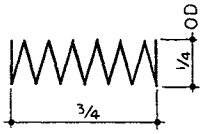
SHAFT
Steel



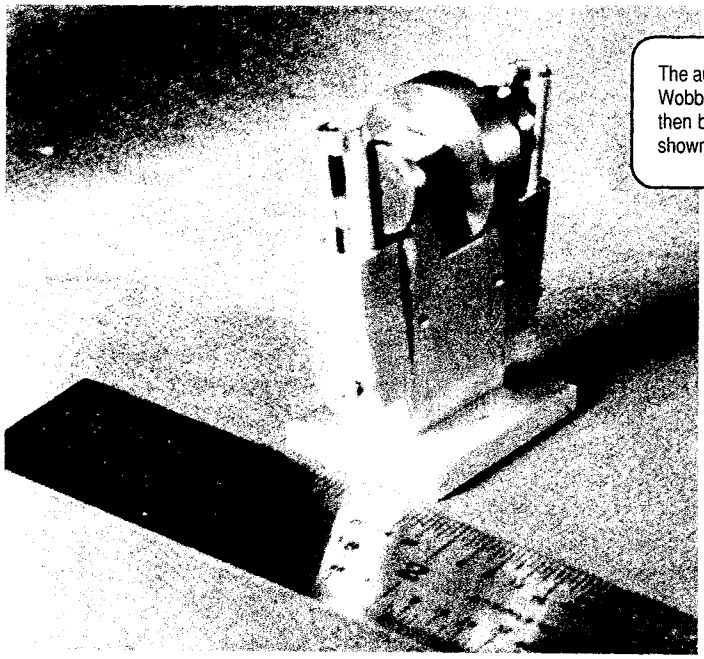
FLYWHEEL
Any Metal



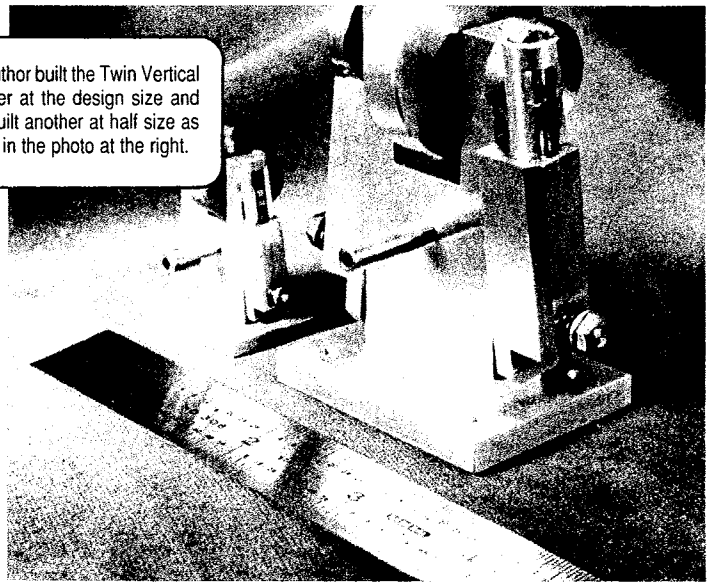
PIVOT SHAFT
Steel

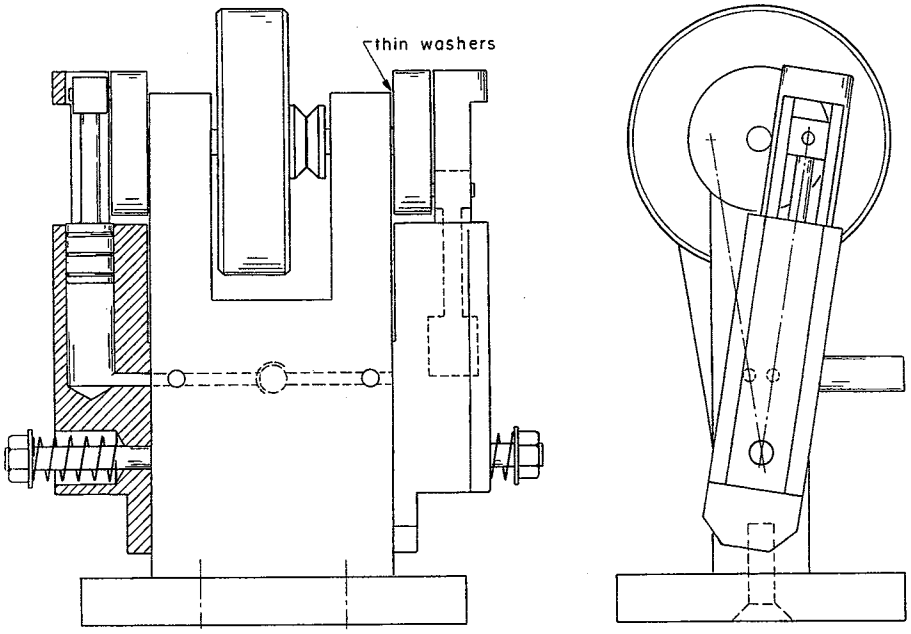


SPRING
Steel
.020" wire
2 Required

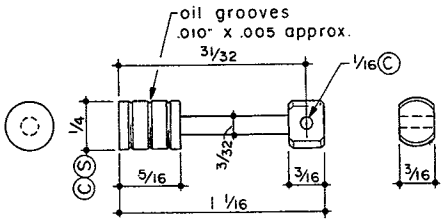


The author built the Twin Vertical Wobbler at the design size and then built another at half size as shown in the photo at the right.

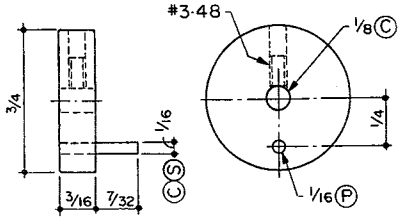




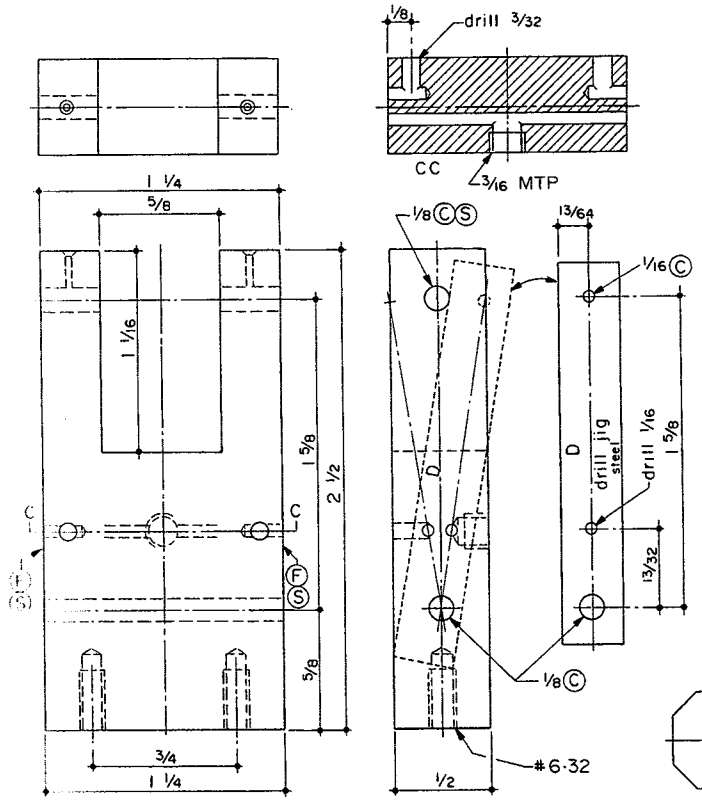
TWIN VERTICAL WOBBLER



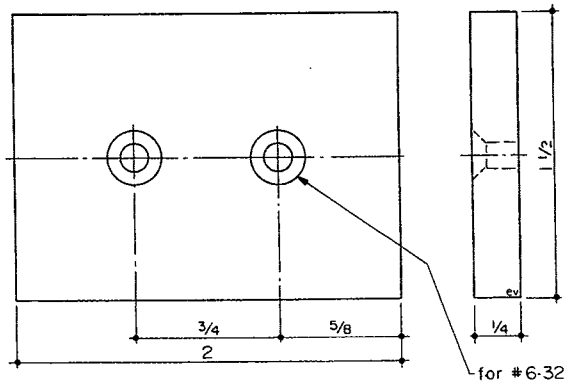
PISTON
Brass
2 Required



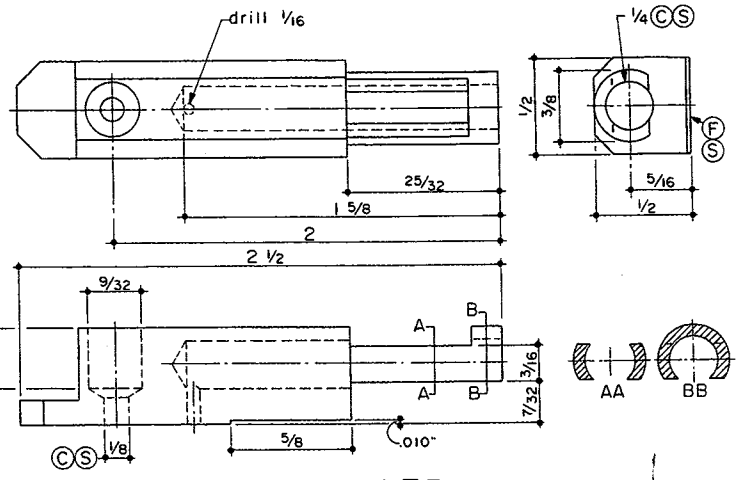
CRANK
Steel
2 Required



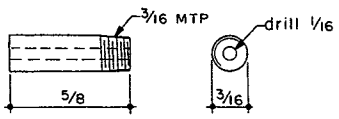
COLUMN
Aluminum



BASE
Any Metal



CYLINDER
Hard Aluminum
2 Required



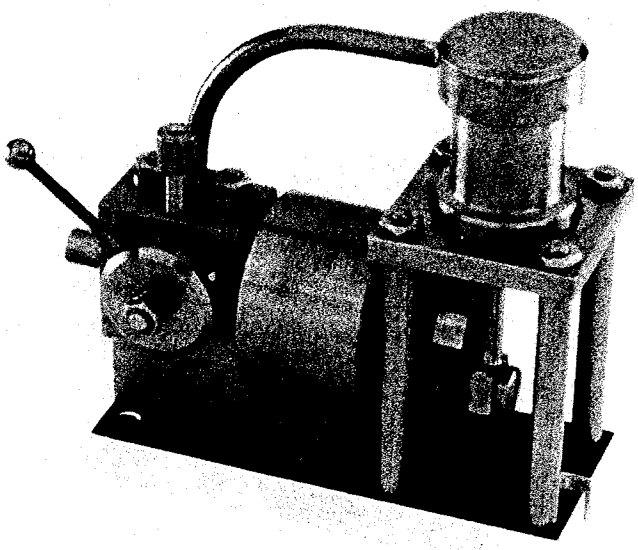
STEAM CON.
Brass

CHAPTER

3

A bit more complicated:

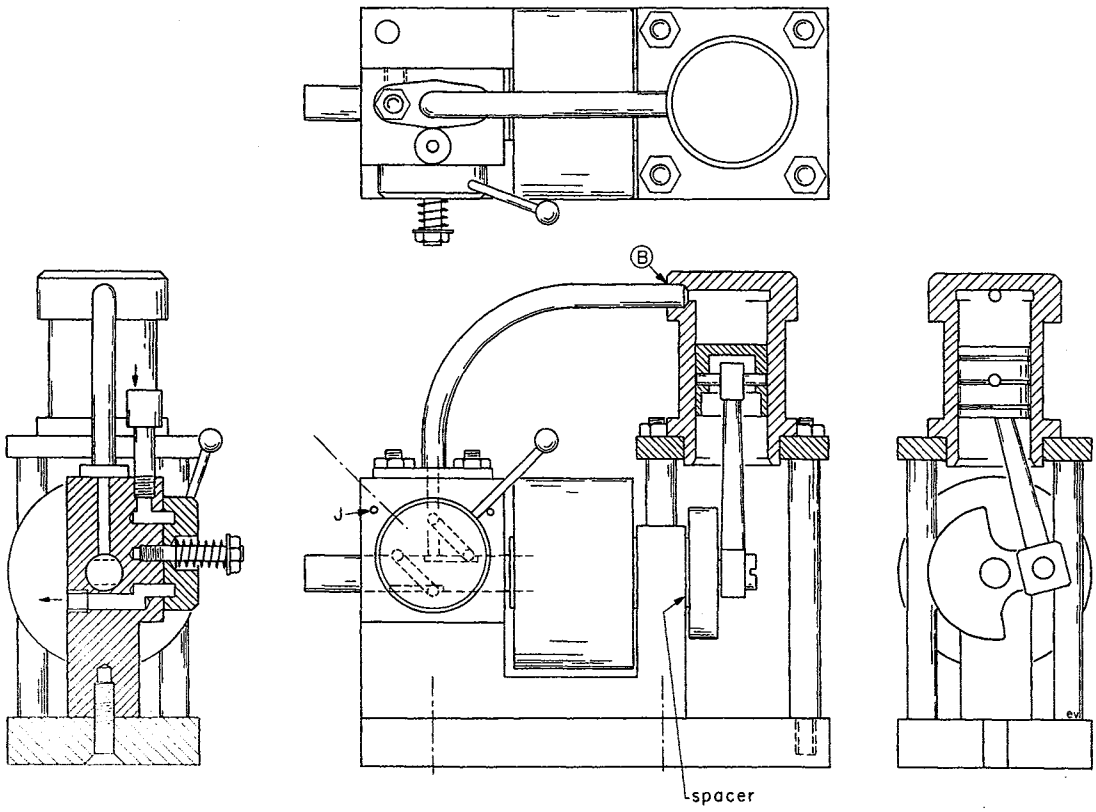
Open Column With Reverse



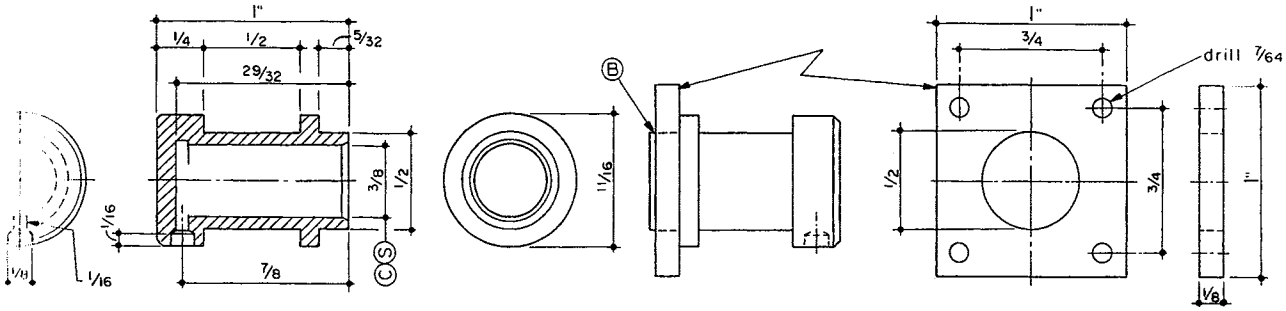
Perhaps the Open Column With Reverse model is more novel and interesting than practical, although it could power a small boat. It is single-acting and capable of fair speed. It is sensitive in the shaft-valve area which requires close fits to reduce leakage. Any small model using the flats on the shaft as valving will have a bit of leakage along the shaft. Many small models depend on the close fit on the piston and valve rods to avoid making tiny packnuts and stuffing boxes.

The **CYLINDER** and **SUPPORT** are straight turning and machining operations. After soldering, use the square Support to locate the tubing hole.

The **BEARING** is made from an accurate 3/8" x 1-1/4" x 1-11/16" block and the 1/8" x 3/4" x 3/4" projection soldered on to provide the thickness rquired for the porting and Valve. When cutting the 11/16" gap,

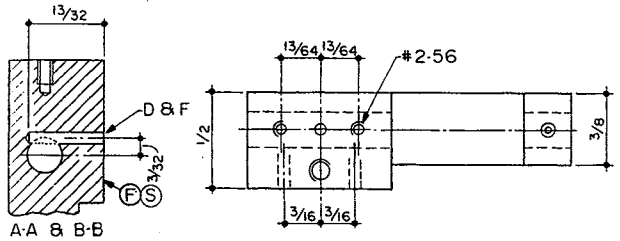


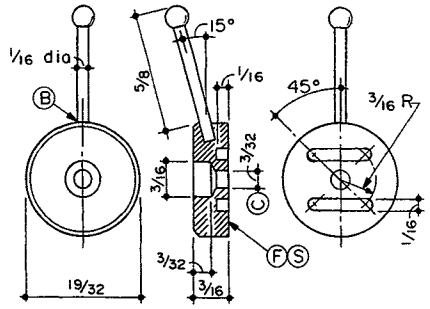
OPEN COLUMN WITH REVERSE



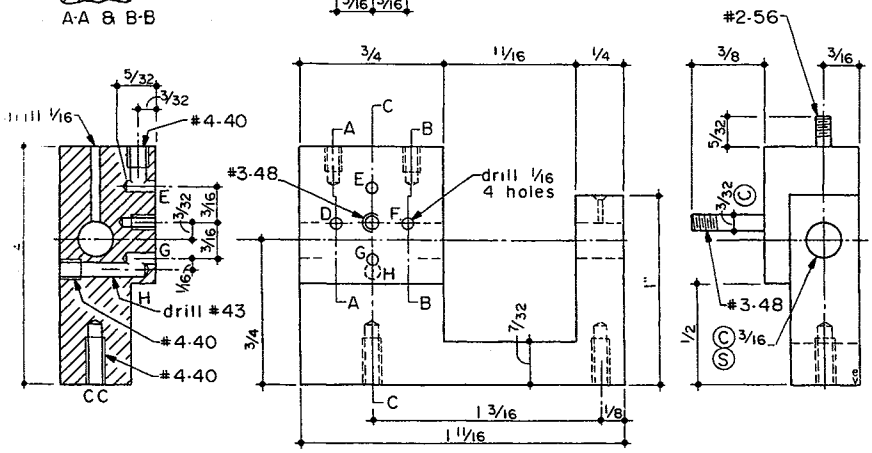
CYLINDER
Brass

CYLINDER SUPPORT
Brass

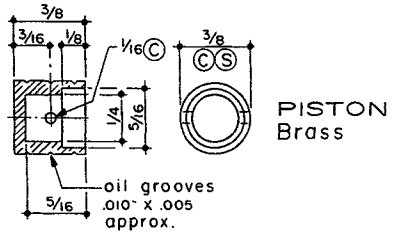




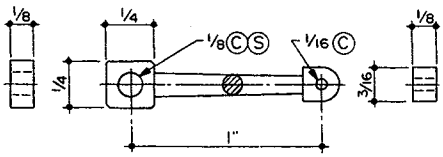
REVERSING VALVE
Brass



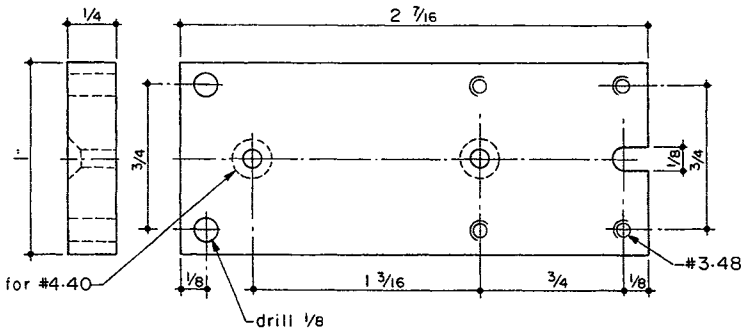
BEARING
Brass



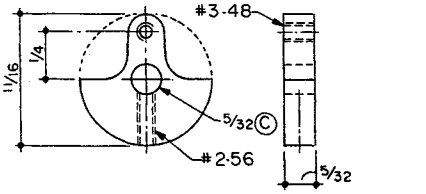
PISTON
Brass

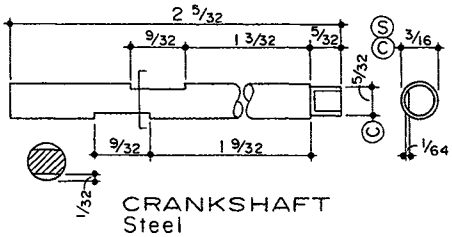


CONNECTING ROD
Brass

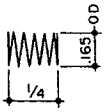


BASE
Any Metal





CRANKSHAFT
Steel



SPRING
Steel
.025" wire
5 coils

tensions may be released, causing the **U** shape to spread apart. Check and, if necessary, use the vise as a press and bend it back to a square condition. Lay out and ream the Shaft hole. Complete laying out all the remaining holes.

Drill and tap all the threaded holes except the Exhaust hole. Insert a close-fitting 3/16" rod in the Shaft hole and drill the deep Port holes **D** and **F** that break into the Shaft opening. Drill the shallower holes **E** and **G** for Intake and Discharge. Drill the Discharge hole **H** until it makes a good cut into the 1/16" hole **G**. Clean this out with a tiny round file for a good exhaust passage. On this piece, the Shaft must be a close fit in the Bearing to keep leakage to a minimum. It is advisable to start out with a slightly tight fit and run it until free.

Make the **VALVE** of brass. There isn't much more than straight turning involved. The two slots should match the four Valve holes in the Bearing. At assembly, insert a 1/16" diameter free-fitting pin in the **E** hole with about 1/32" to 3/64" projecting to enter the Valve. Place the Valve over the stud and this 1/16" pin and spot the two pins **J** to limit the Valve travel.

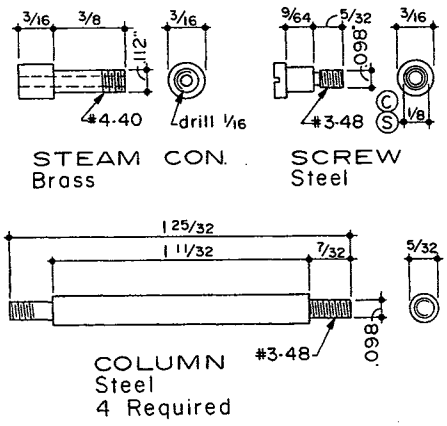
The **PISTON** is simple and straight machining. The **CONNECTING ROD** is turned from 1/8" x 1/4" stock. The **WRIST PIN** should be a smooth piece of drill rod about .010" less in length than the Piston diameter. Two carefully-placed prick pin marks will keep the Pin in place. Use an oil stone to remove any metal that has raised above the Piston O.D.

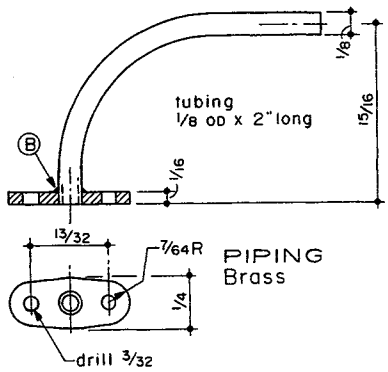
The **CRANK SHAFT** is a close fit in the Bearings, as mentioned above. To keep the flats centered in the Bearing, a fibre spacer is used. The thickness will run about .020" to .025".

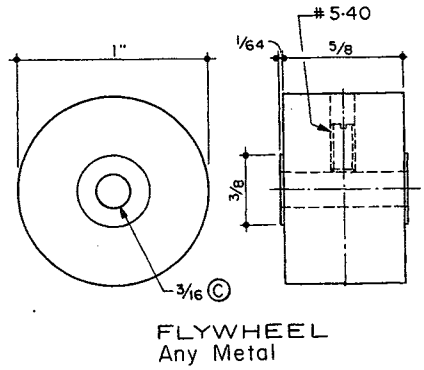
The **CRANK DISK** is a simple carving of steel. The set screw is used to anchor this because of the importance of centering the throw midway between the flats. It allows you to adjust so timing can be made equal for both directions of rotation.

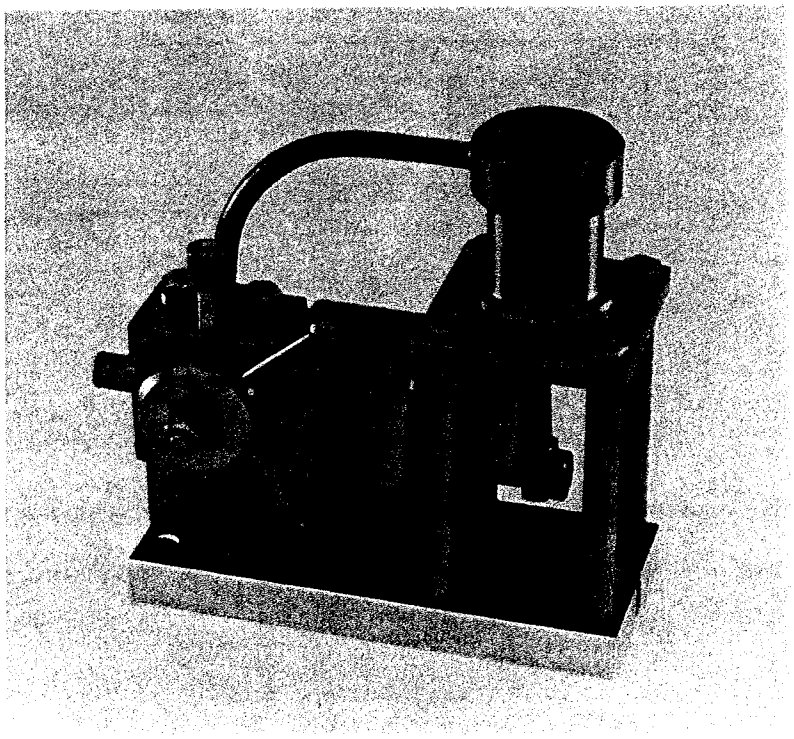
The **PIPING** is a solder job and must be fitted at final assembly.

It is not a self-starter. You will have to give it a start if it stopped on dead center the last time it ran. This, however, is a fair-running engine after it is broken in.









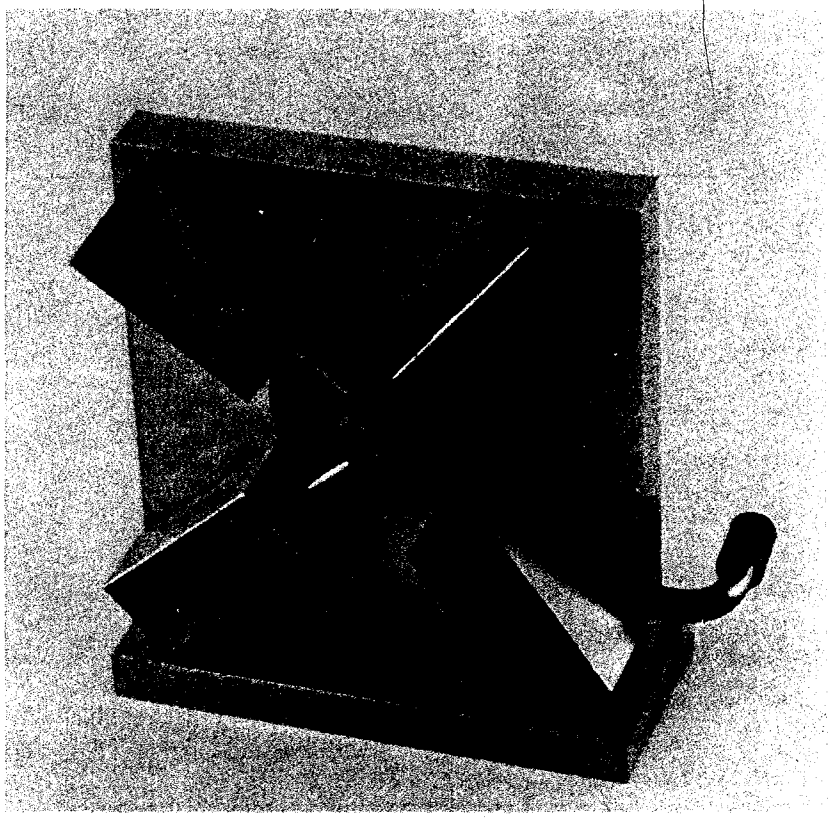
CHAPTER

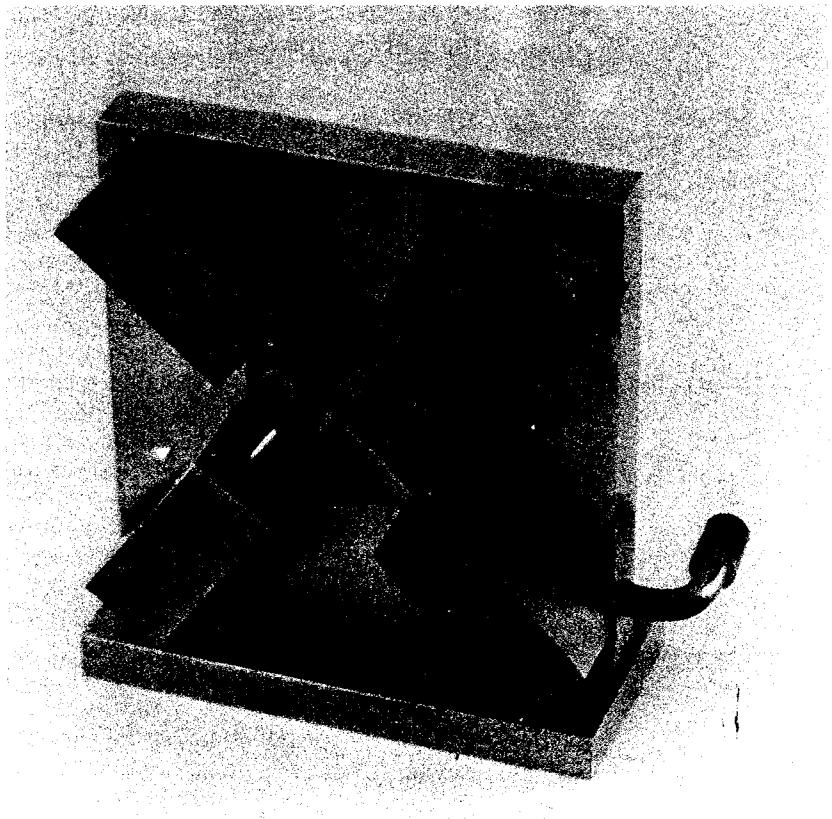
4 Four Square

Four Square is a simple four-cylinder engine with no outside tubing to the steam ports; a simple radial design using four wobbling cylinders. It is an interesting engine with some challenges and it is self-starting. The Column, or main body, calls for some accurate layout and deep drilling. The #45 drills just barely reach the required depth. The machining of the Piston/Rod units will require patience.

The **COLUMN** starts out as an accurate block, 1/4" x 2" x 2-1/16". Lay out, drill and tap the foot holes. The **FOOT** itself needs no comment. Lay out the Shaft center at 1-1/16" from the bottom and centered in the width. Related to this center, lay out the four pivot holes and machine as shown. Chuck this piece in a 4-jaw, centering on the Shaft center, and turn the 7/8" recess and ream for the Bearing. Bevel the 3/16" Bearing hole a bit to take the peening of the Bearing at assembly. Make the Bearing a press fit in the Column.

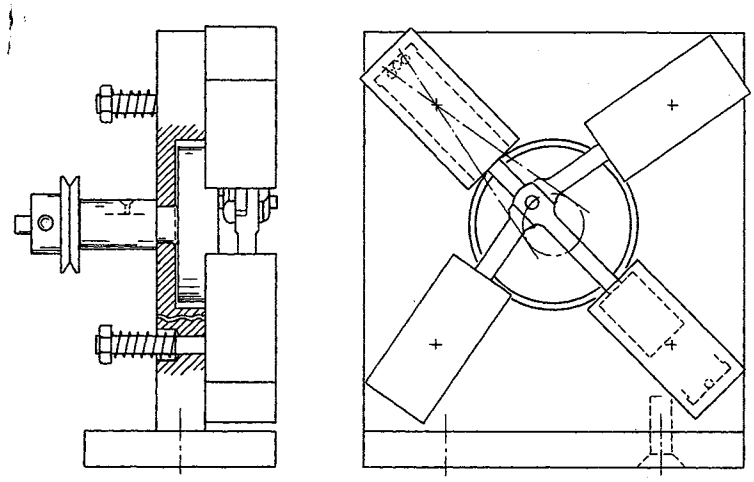
After pressing in the Bearing, peen the rim into the bevel with a small ballpeen hammer or use a punch to flare the end for a more secure anchor in the Column. Make the drill jig. Insert a 3/32" close-fitting pin through the jig and the pivot hole in the Column. Hold the jig against another 3/32" close-fitting pin in the Crankshaft Bearing and drill the #56 steam passage 1/32" deep. Turn the jig over to get the other port. Do this on all four pivot positions. Note: for now, make these holes only 1/32" deep. If they are deeper, they may deflect the deep drilling later. Use a small dab of layout dye to mark the four **S** (steam) holes. With a sharp red-leaded pencil, run a line from the upper **S** holes down through the lower **S** holes. This is the angle of the drill. To prevent this drill from breaking into an **E** (exhaust) hole, tilt the angle just a very tiny bit more for insurance. Transfer the point where the centerline through the **S** holes meets the lower edge across the bottom and center punch in the center of the stock. Hold in a drill vise with this centerline squared up with the vise jaw. As a check, bring the Column up behind a drill in the chuck and sight the clearance of the drill past the **E** holes. Using an accurate-pointed centering pin in the drill chuck, center and anchor the vise. It might be well to start the hole with a 1/16" drill as deep as possible, later enlarging and drilling to the final depth. Drill the crosshole 5/16" up from the bottom and then tap 5-40 for the steam connection. If all is



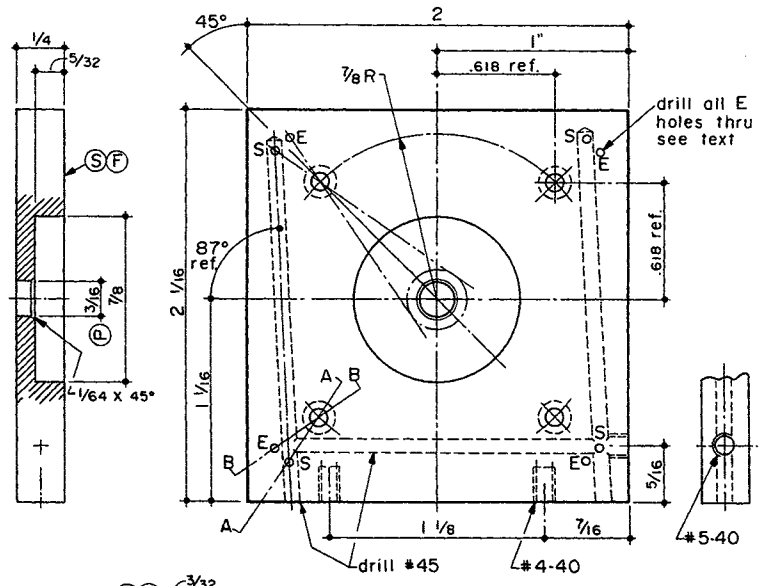


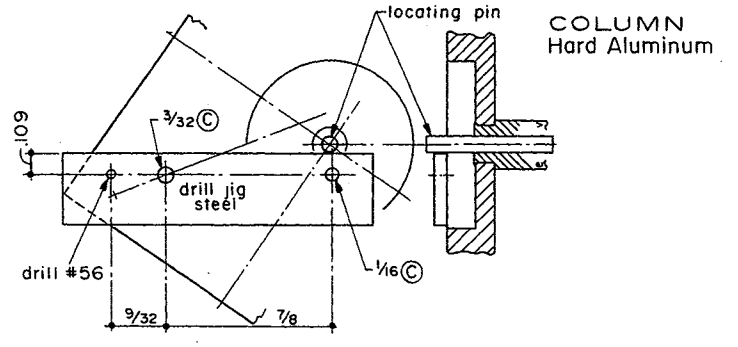
well, the #56 holes will break into the steam passages. In case the deep drill wandered, take it slow so as not to break a drill. The **E** holes can be drilled on through.

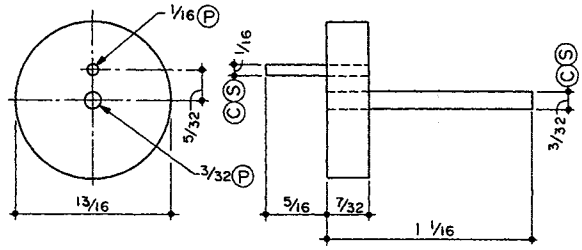
For the **CYLINDERS**, make four accurate, square brass blocks 3/8" x 3/8" x 13/16". Lay out the centers for the 1/4" bore 7/32" from one face and center punch. Center in the 4-jaw using a center test indicator. On the last pass before reaming, make an undercut at the bottom for reamer runout. There should be no shoulder that might hold up the Piston. Lay out and centerpunch the center for the Pivot Shaft. Protect from jaw marks when chucking in the 4-jaw, and center with a center test indicator. Check that the face runs true and then face, undercut and drill the 3/32" hole for the Shaft. Make four 3/32" x 21/32" brass Pivot Shafts. Thread one end 3-48. Make a close-fitting aluminum pin to enter the 1/4" bore. Apply a thin coat of flux to the pin and hole. Cut a tiny piece of 1/16" 430 degree solder, lay it against the Shaft and apply heat to the Cylinder until the solder melts and flows around the Shaft. Too much solder may keep the Cylinder off its seat. The solder will not stick to the aluminum pin. When the Piston/Rods are done, insert each into its own Cylinder and keep them together from now



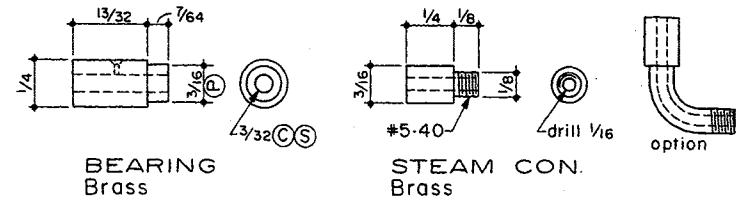
FOUR SQUARE

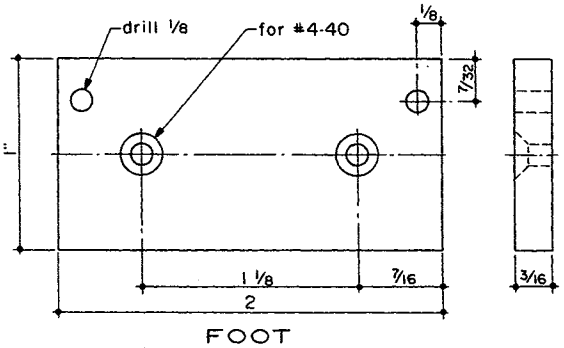






CRANKSHAFT
Steel





FOOT
Any Metal

on. Here, it is well to plan the final relationship of the Connecting Rod offsets and maintain it through to final assembly. If a Piston is given a half turn after drilling the Cylinder, or transferred to another Cylinder, small errors can change the match of the steam passages. Make a trial assembly to show these conditions before you drill the Cylinder steam passages. Place the jig over the 3/32" Pivot Shaft. Run a 1/16" close-fitting pin through the jig and the eye of the Piston/Rod. Drill the #56 steam passage in the Cylinder.

All of you machinists who like to twirl the handles and read the dials will get a workout here if you make your **PISTONS** the way these were made. If you have other ideas, try them. Maybe you can make them by bending the offset or soldering. Some 1/4" brass rod was found to be a few tenths under .250 and a good fit in the reamed Cylinders. The stock was held in a V-groove in the milling vise and a 1/8" end mill used for all the cuts. Remember to favor the 1/4" diameter that will fit in the Cylinder. All the dimensions given are from some original, or already machined, surface so you have solid material to "mike." The cuts were made in the order shown. No. 1 makes the cut 7/16" back from the end leaving 11/64" material. No. 2 makes the 7/32" cut down to 1/16" remaining. No. 3 and 4 bring the stock down to 5/32" using the side of the cutter not the end. No. 5 and 6 plunge into each side bringing the neck down to 3/32". So far, there is a similarity in the operations for the **A** and **B** type ends. The **B** type needs one more cut No. 7 which required rotating the stock in the V-groove 90 degrees and cutting with the side of the cutter. Except for this last No. 7 cut, all passes were made without loosening the stock in the vise or changing cutters.

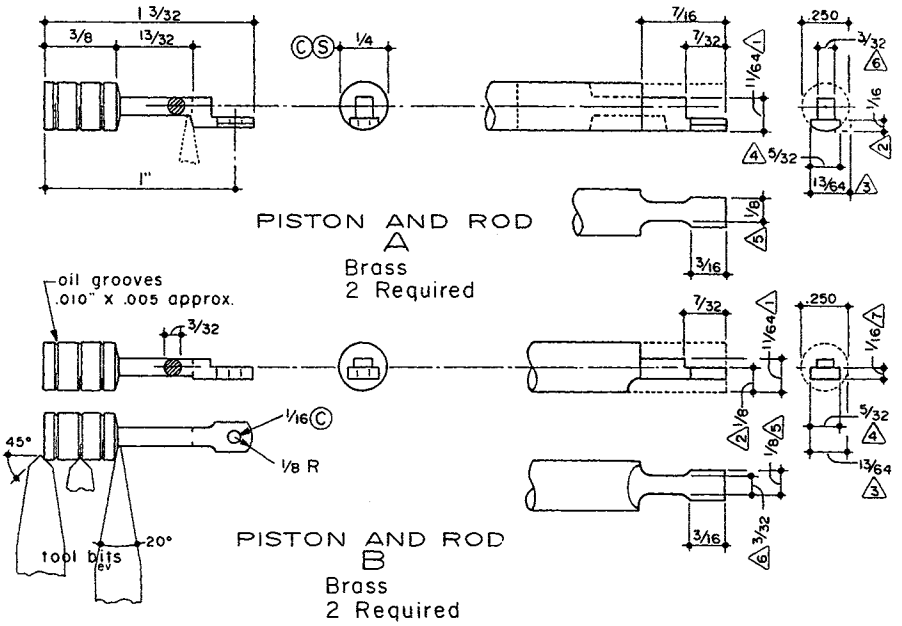
We have talked only of milling so far. In making the four Pistons, the end of the stock was milled as we have stated and then taken to the lathe and turned and, then, the stock milled for the next and that turned, etc., to avoid wasting stock. You can decide how you will do this. In turning, the stock projects out of the 3-jaw or collet about 1-3/8", so leave some length for chucking. You should have a toolbit ground as shown at about 20 degrees with about a .010" radius on the end honed keen and smooth. You can complete the neck or rod part of these pieces with one toolbit setting, leaving a little slant at each end and a small fillet just right for this part. Take care with light cuts; there is no tailstock support. Near the offset end you will have jump cuts so be extra careful. The 3/32" diameter is carried down to 5/16" from the end. Make a parting cut 1-3/32" from the end about halfway through the stock. Change to a 90 degree V-toolbit as shown. This is also a handy bit to have on hand. Break the corners and make the three oil grooves with this bit. Polish the 1/4" Piston area only enough to remove burrs and brighten it. Complete the parting cut. Round the offset end to about a 1/8" radius with a file. Lay out and make the 1/16" Crank pin holes.

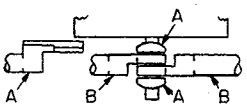
The **CRANKSHAFT** is made of steel assembled with Loctite.

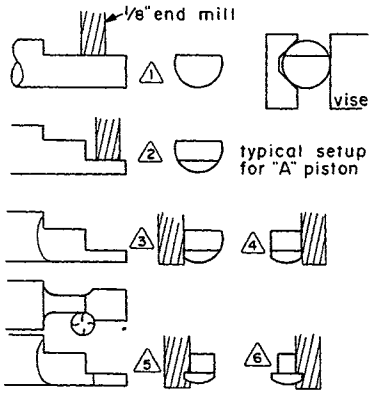
The **SPRING** drawing shows the proportions of the salvage springs that work fine in this model.

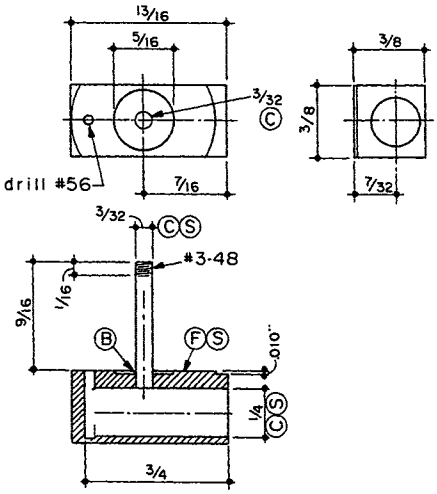
The **STEAM CONNECTION** is optional. Those shown are for use with 3/16" plastic aquarium tubing.

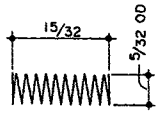
Now you've completed another example of steam power.

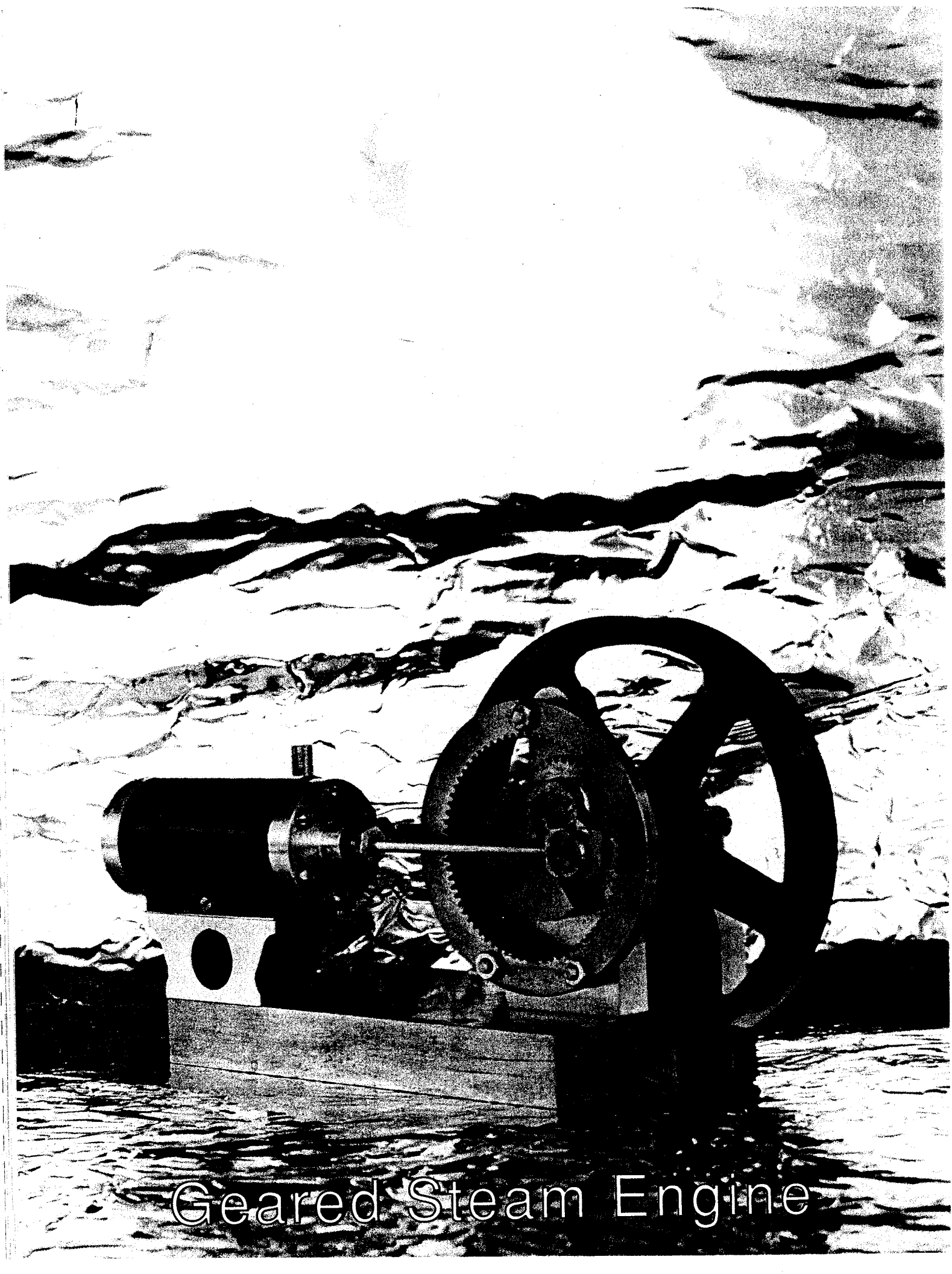








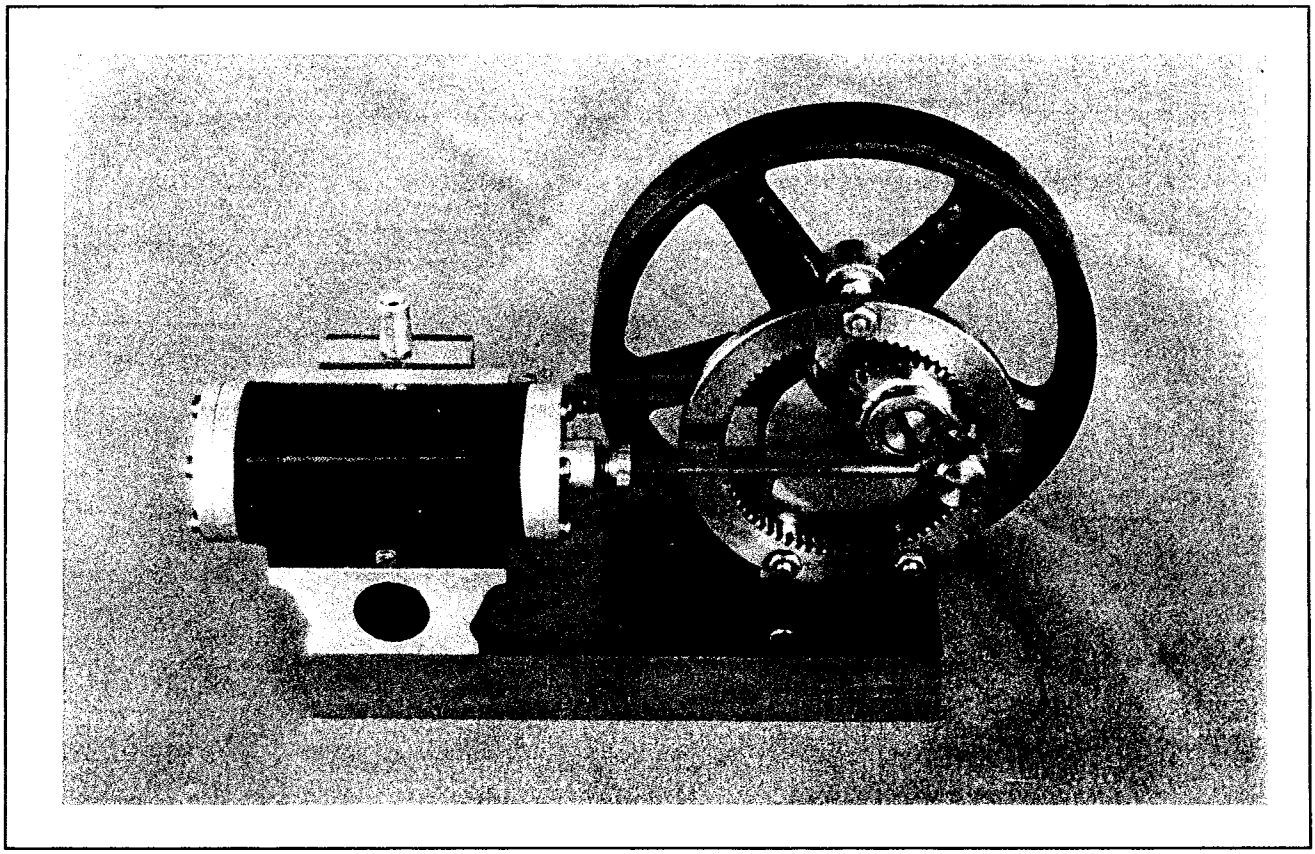




Geared Steam Engine

CHAPTER

5 Geared Steam Engine



This is an engine with an internal gear producing straight line motion to the piston rod. It required careful machining to prevent binding and is a bit more challenging than a simple crank engine.

First, the gears shown were purchased from Boston Gear and cost $38.00, which may discourage some builders. It is a fascinating engine to watch when running at slow speed and will not be found in many exhibits.

If you strike out on your own there are a few rules that must be followed:

1. The two gears must have the same pitch and pressure angle. Twenty degree pressure angle teeth will not mesh with 14-1/2 degree PA teeth.
2. On this engine the pitch diameter of the internal gear must be two times the PD of the orbiting gear and will have two times as many teeth. The PD of the internal gear is the piston stroke of the engine. Pitch diameters are the imaginary circles, or outside diameters of two wheels, one driving the other by friction. To make the drive positive, "teeth" are laced across these pitch circles.
3. The mounting of the internal gear must be with centerlines passing THROUGH THE TEETH CENTERS, and the piston rod screw CENTERED BETWEEN TWO TEETH as shown or you will get binding and not straight line motion.

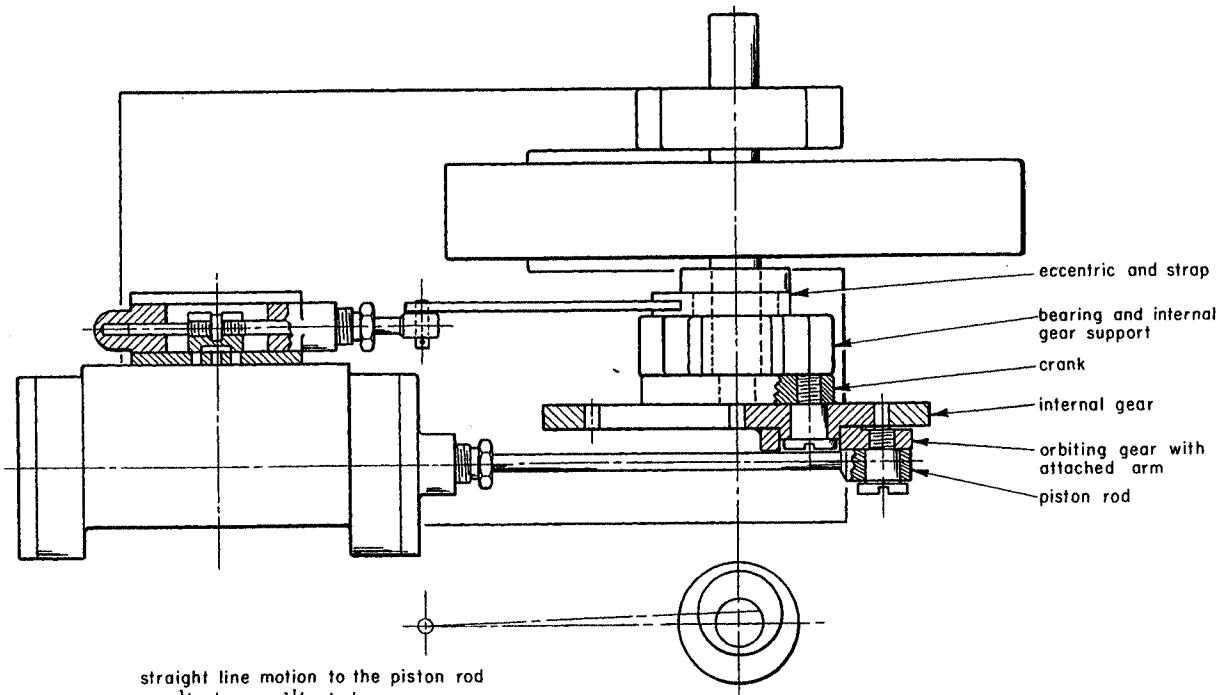
The critical dimension is the .375" dimension on the crank. Also try to hold the .375" dimension on the gear arm. A few thousandths full on the crank will cause binding. It is better to aim for a couple thousandths under on these two dimensions. Remember the tooth working depth for 48 pitch teeth is only .041" and you do not have much leeway.

The **BASE** calls for aluminum though the model shown has a steel base. The weight makes it more stable if not anchored down.

The **BEARINGS** are simple machinging except the tall Bearing should be laid out completely, the three gear mounting holes drilled and the #5-40 holes tapped. Locate these three holes very carefully for sake of gear alignment. Mount the two Bearings on the Base and hold this assembly squarely in the cross-slided milling attachment. Pick up the bearing center with a wiggler and drill in easy stages and line-ream to size for the crank shaft. Bushings are optional.

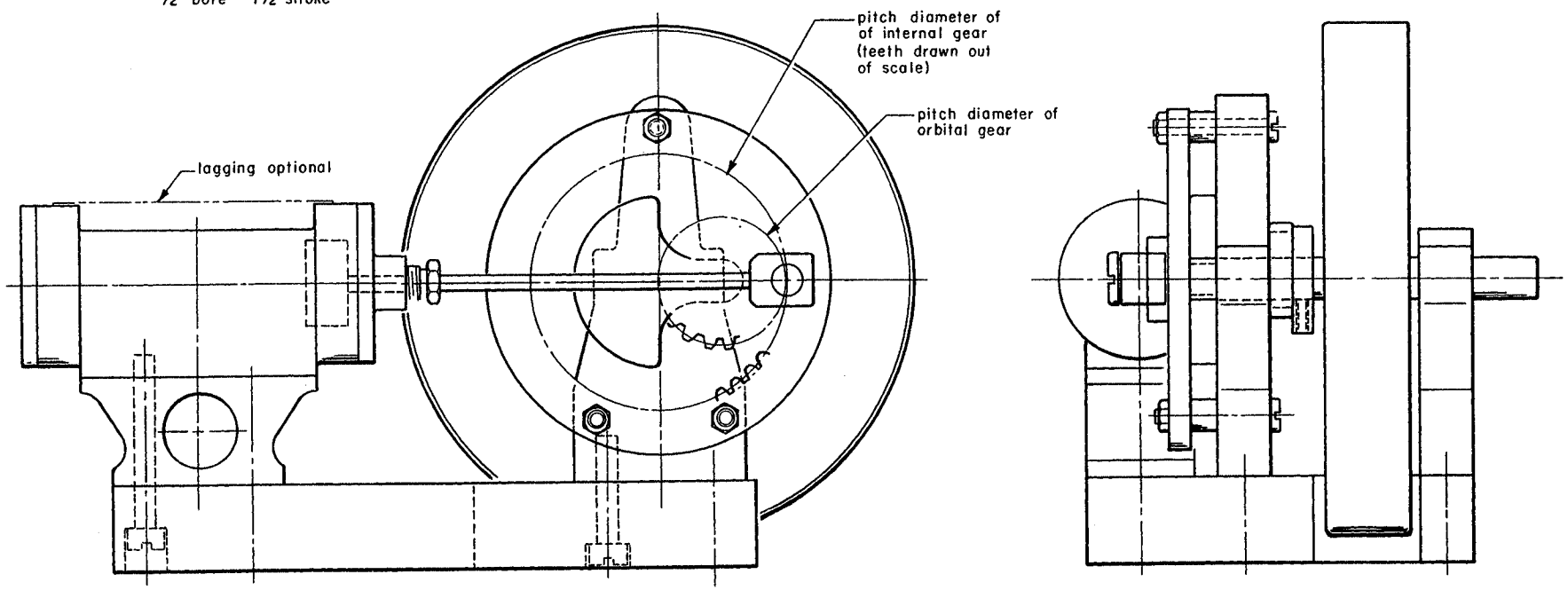
On the **PISTON ROD**, solder the 3/16" thick block in place and then mill to 9/64".

The **VALVE ROD** is 3/16" stock turned with tailstock support. Mount in the cross-slide milling attachment and mill the flats. It is well that the #2-56 thread fit the nut closely to

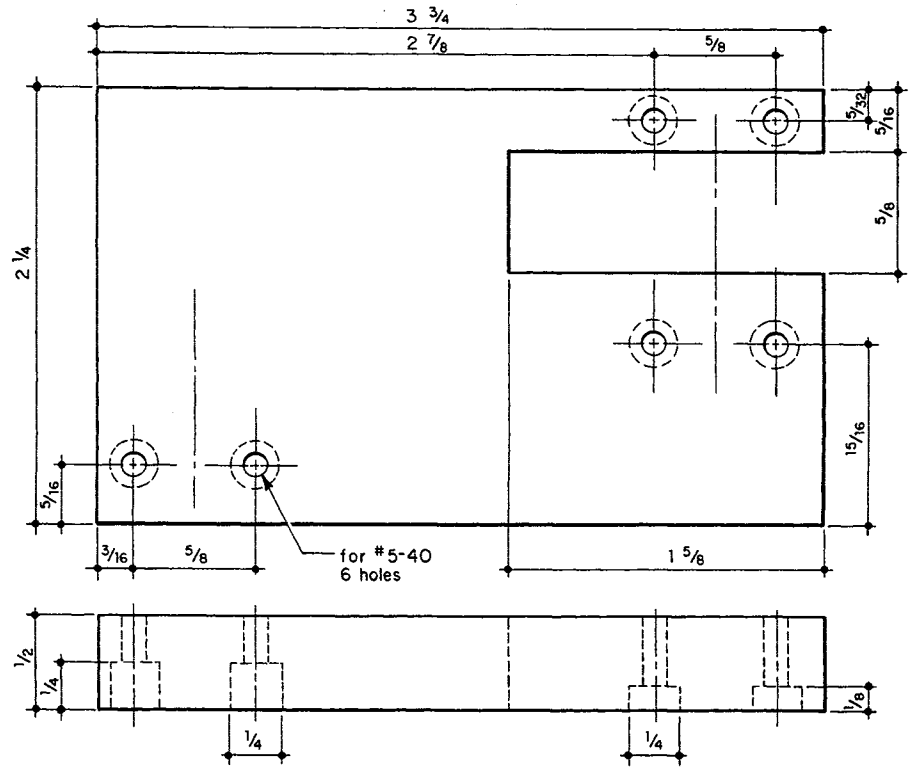


straight line motion to the piston rod
½ bore 1½ stroke

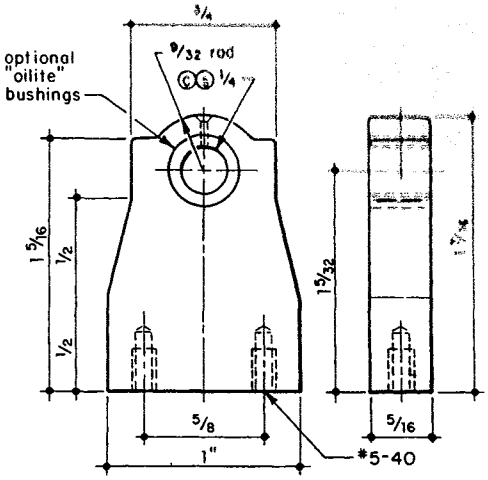
BOSTON GEAR		
TYPE	SPUR GEAR	INTERNAL GEAR
catalog number	Y4836	Y14872
pressure angle	20°	20°
pitch	48	48
number of teeth	36	72
pitch diameter	.750	1.500
outside diameter	—	2
face	1/8	1/8
hole	3/16	—
hub diameter	1/2	—
hub projection	1/4	



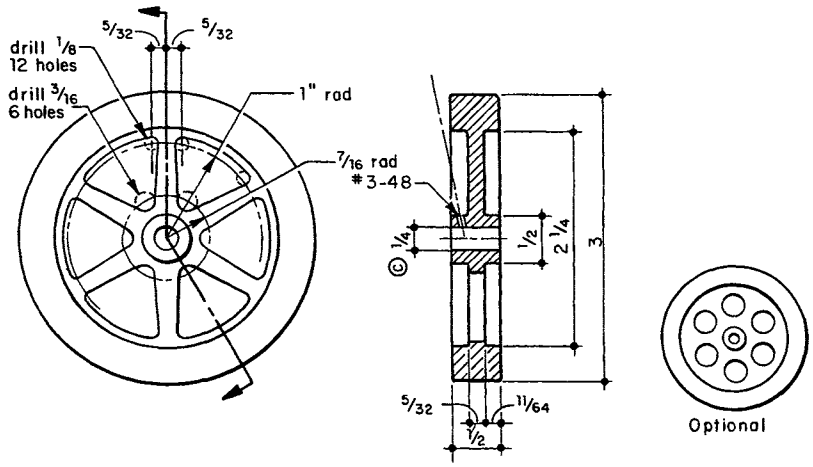
ENGINE WITH GEAR MECHANISM



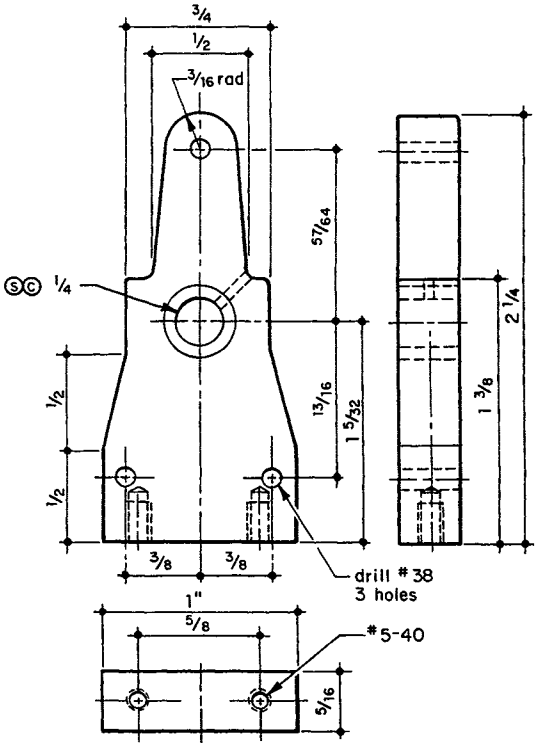
BASE
Aluminum



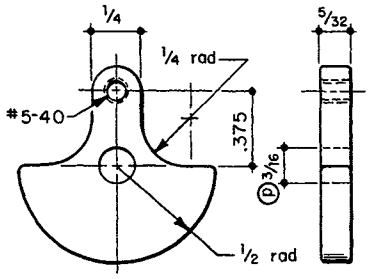
REAR BEARING
Aluminum



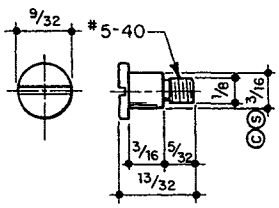
FLYWHEEL
Aluminum



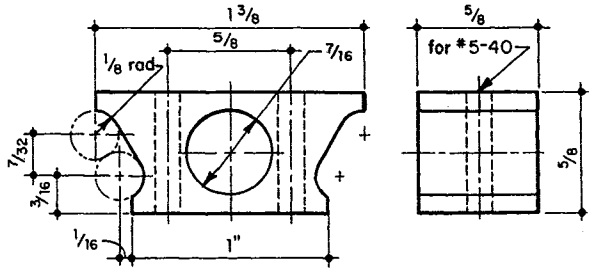
FRONT BEARING
Aluminum



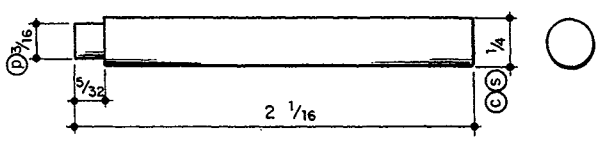
CRANK
Steel



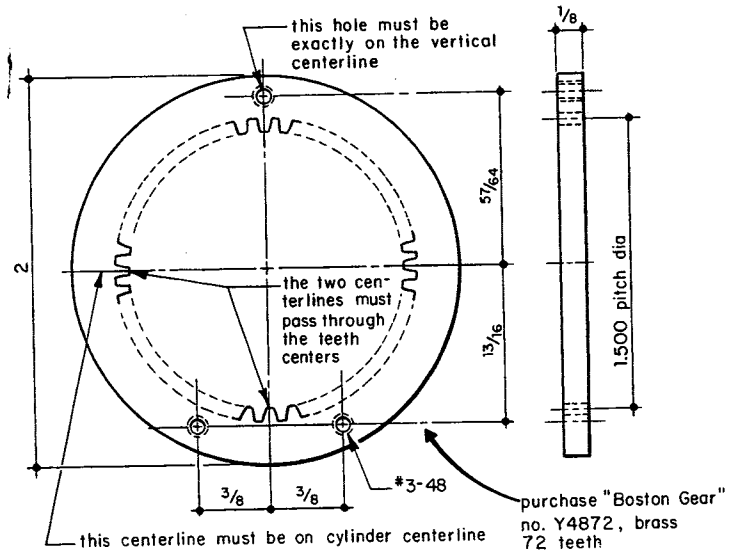
CRANK SCREW
Steel



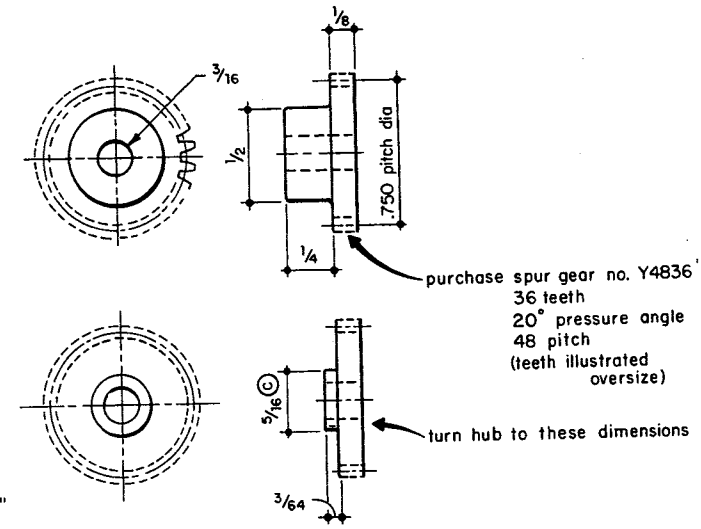
FOOT
Aluminum



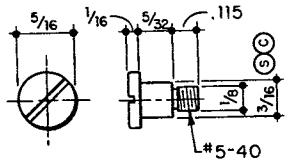
SHAFT
Steel



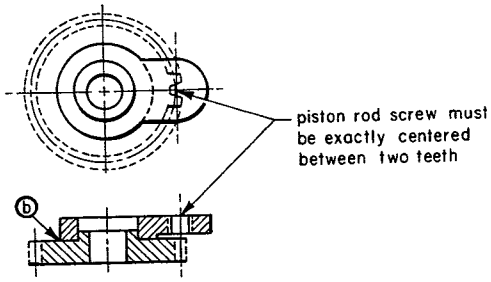
INTERNAL GEAR
Brass

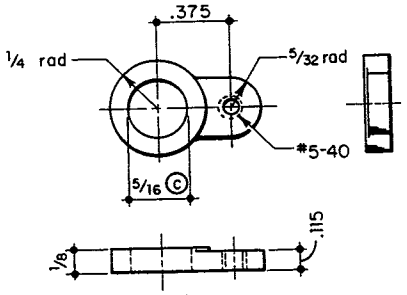


ORBITING GEAR
Brass

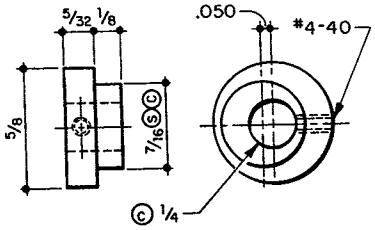


PISTON ROD SCREW
Steel

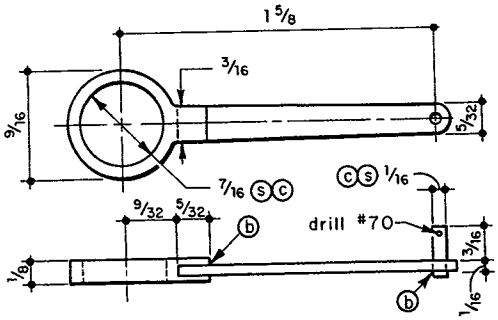




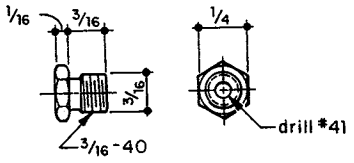
GEAR ARM
Brass



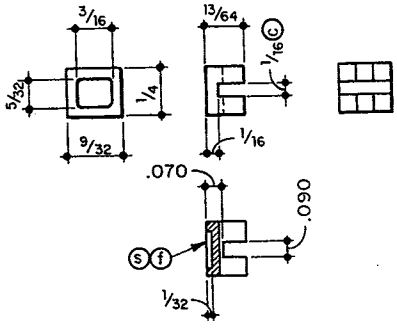
ECCENTRIC
Steel



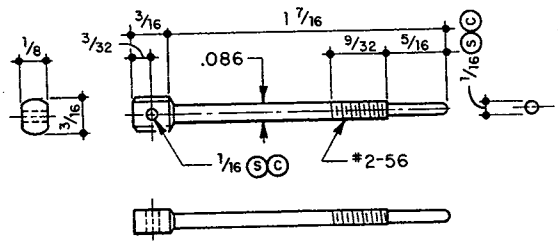
ECCENTRIC STRAP
Brass



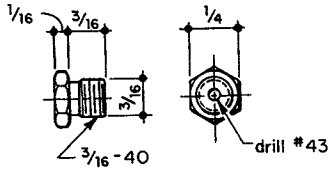
CYLINDER PACKNUT
Brass or Aluminum



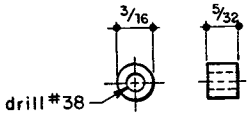
VALVE
Brass



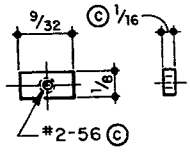
VALVE ROD
Brass



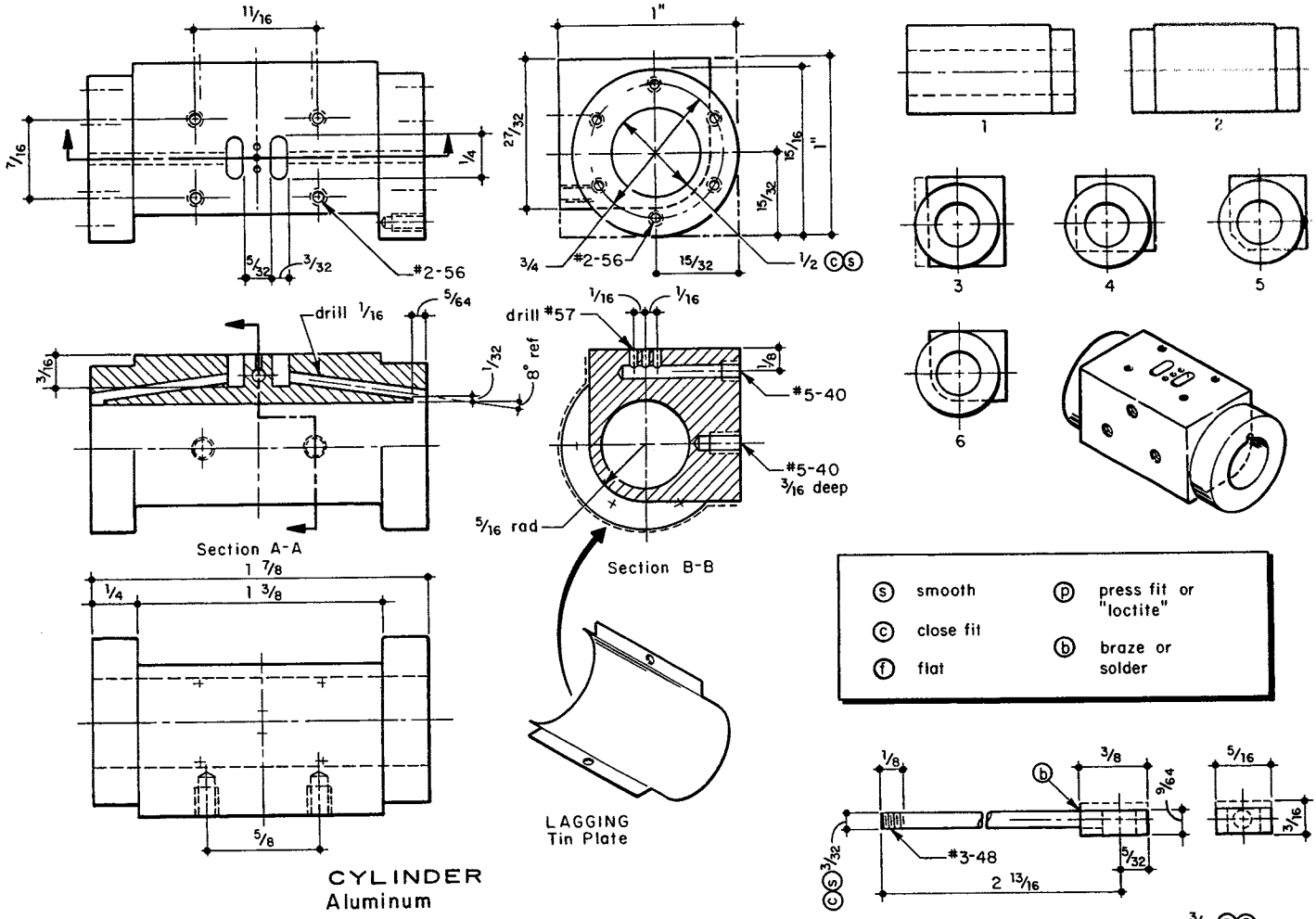
STEAM CHEST PACKNUT
Brass or Aluminum

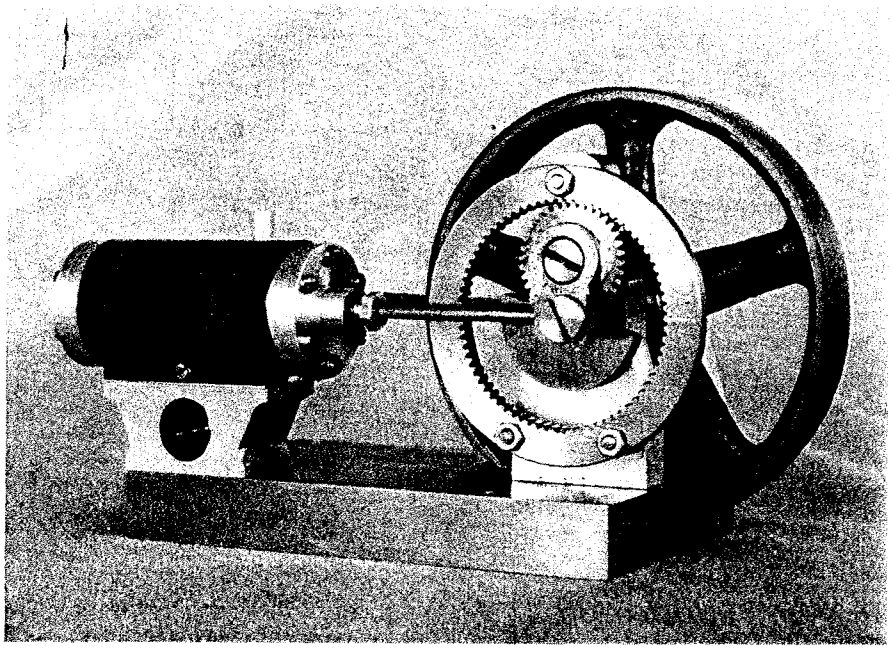


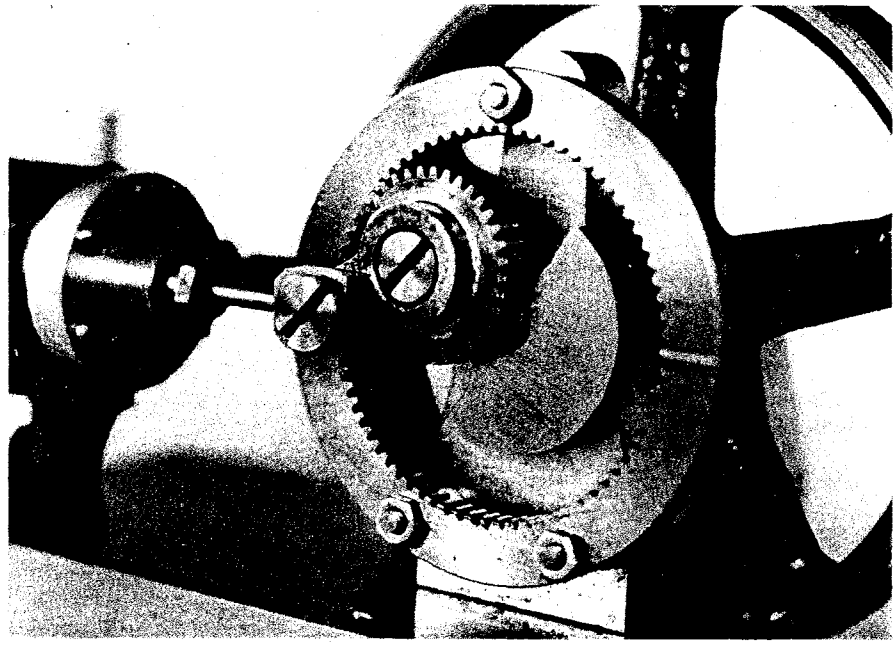
SPACERS
Brass or Aluminum
3 required

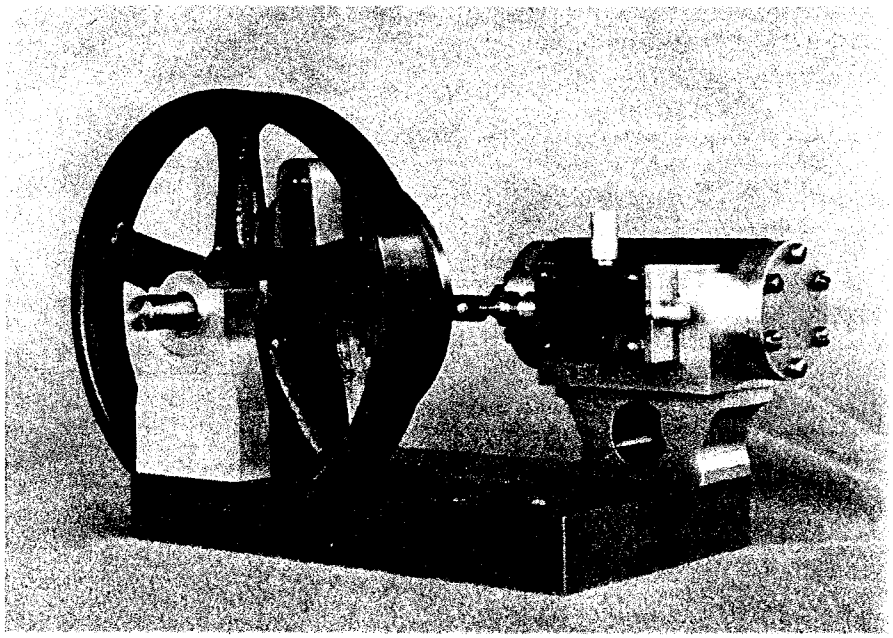


NUT
Brass


11/16
7/16
1/4
5/32
3/32
#2-56
1"
27/32
15/16
1"
15/32
3/4
#2-56
15/32
1/2 (c)(s)
1
2
3
4
5
6
drill 1/16
5/64
3/16
1/32
8° ref
Section A-A
drill #57
1/16
1/16
1/8
#5-40
#5-40
3/16 deep
5/16 rad
Section B-B
1 7/8
1 3/8
1/4
5/8
CYLINDER
Aluminum
LAGGING
Tin Plate
(s) smooth
(c) close fit
(f) flat
(p) press fit or "loctite"
(b) braze or solder
1/8
3/8
(b)
9/64
5/16
3/16
#3-48
5/32
2 13/16
(c)(s) 3/32
3/16 (s)(c)
PISTON ROD
Brass
3/32
1/32
15/16
drill #43
1/2
3/4
OUTBOARD HEAD
Aluminum
15/16
drill #43
3/4
3/32
1/32
3/16
drill #41
drill #21, depth 1/4
tap 3/16-40
1/2
5/16
INBOARD HEAD
Aluminum
#3-48
(c)(s) 1/2
1/4
1/8
oil grooves
approximately
.010 wide x
.005 deep
(c)
3/32
PISTON
Brass
1/16
11/16
5/8
7/16
drill #43
COVER
Brass
3/16
7/8
3/16
11/16
#5-40
1/4
5/8
7/16
11/32
3/16
drill #43
17/32
drill #41
drill #21, 1/4 deep
tap 3/16-40
1/16 dia (c)
STEAM CHEST
Aluminum
11/16
drill #43
drill #57
9 holes
(s)(f)
5/8
7/16
1/16
1/16
.100
.100
7/
VALVE PLATE
Brass







reduce pounding at the Valve.

The **ECCENTRIC STRAP** is a machined bearing end soldered to flat stock. Solder a close-fitting pin in the other end.

The **PACKING** is 1/16" strands unraveled from braided asbestos graphite packing. Do not snug up the Packing Nuts too tight but turn them lightly with the fingers.

Chuck 5/8" diameter stock in the 4-jaw for the **ECCENTRIC**. Brighten up the O.D. and bore 1/4" for the shaft. Offset .050" and turn the 7/16" diameter. One method is to mount a square-ended bar in the tool post and bring it up against the stock. "Zero" the cross-slide collar. Turn the chuck so two jaws are horizontal. Ease off the vertical jaws slightly and back up the rear jaw about 1/16". Push the stock back to the rear jaw, using the front jaw. Advance the cross-slide .050" and ease the stock back against the bar, using the rear jaw. Snug up all jaws. Now, when the high spot just kisses the bar and then the chuck is rotated 180 degrees, a .100" diameter rod should just pass between the bar and the stock in the chuck.

The **FLYWHEEL** can be made from 1/2" flat stock. Lay out and drill twelve 1/8" and six 3/16" holes as shown. Chuck in the 4-jaw, gripping about 1/8" of the stock thickness. Center and turn the outside diameter 11/64" x 2-1/4", recess and bore for the shaft. Reverse and mount in a 3-jaw, gripping on the rim I.D., then finish the O.D. and the 2-1/4" recess. Apply layout dye to one entire web face and scribe lines tangent to the holes as shown. Saw and file spokes to shape.

The **LAGGING** shape is transferred from a heavy paper pattern made by the cut-and-try method.

The mounting holes in the **INTERNAL GEAR** are critical and must match the bracket holes. Misalignment here can cause binding. count the teeth very carefully so the two center lines can be accurately established. A small vise, square on all faces, a surface plate and height gauge are a big help here. The three holes may be enlarged slightly if needed to line up.

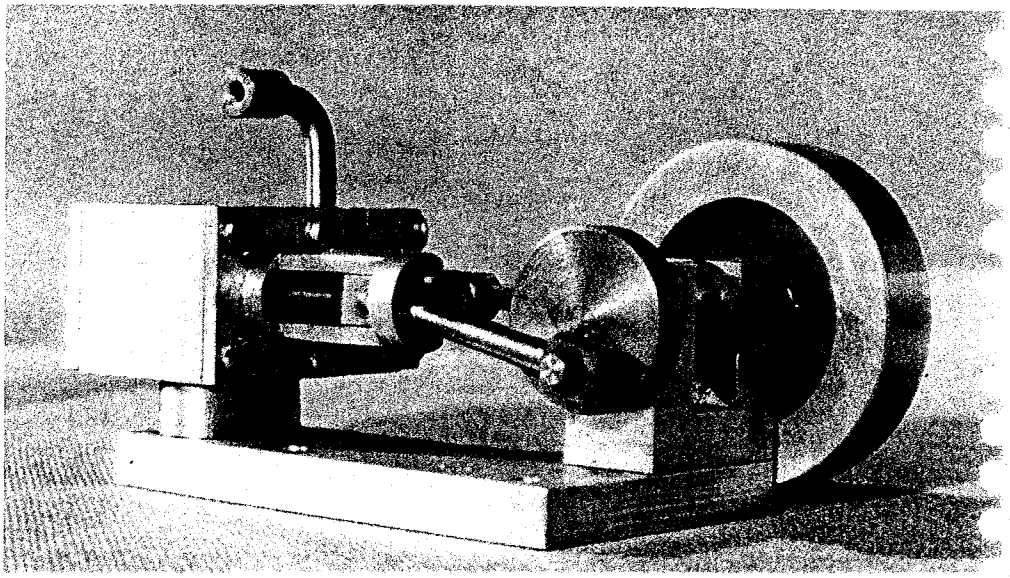
At the **FINAL ASSEMBLY**, turn the Crank to one dead-center position and tighten the Eccentric with its axis 90° from the centerline through the Crank. Temporarily hold the Steam Chest in place while adjusting the Valve to equally expose the Valve holes at each end of the stroke.

Oil all Bearings and sliding surfaces and load the gear teeth with light grease.

At first glance, it is a mystery why the rod travels in a straight line, making this engine fun to show off.

CHAPTER

6 Slider



This engine is more complicated than most designs in the Small Engine Series. There are more parts and some are quite small. The proportions are fair when compared with a large engine and the appearance is similar in spite of the bright block-like construction.

The **BASE**, **BEARING**, **SPACER** and **BUSHINGS** are plain straight layout and machining jobs and require no comment. The 3/16" steam connection is brass. The Bushings are set in the Bearing with Loctite and oil holes added.

Aluminum was used here for the **CYLINDER**, although any common metal will work. On an accurate and square 5/8" x 3/4" x 11/16" block, lay out the center for the 3/8" bore and center in a 4-jaw using a center test indicator. Bore and ream and break the sharp corners at each end. Next, lay out the two 3/64" recesses on the Valve Face and mill with a 1/16" end mill. Drill the two 1/16" steam passages at about 16 degrees as shown. Lay out and tap the two 2-56 holes that match the spacer. Later, use the cover and heads to locate and complete the drilling and tapping for the Steam Chest and Heads. Lay out and drill the 1/16" exhaust hole that the three #57 holes meet.

Make the two brass plates 1/16" x 5/8" x 11/16" for **COVER** and **VALVE PLATES**. Lay out and drill the Cover for four screws and use as a jig later to spot the Steam Chest, Valve Plate and Cylinder. It would be well to drill the Cover to tap-drill size and, after using as a jig, enlarge to the required size. Lay out and drill the nine #57 holes. This Valve Plate can now be used as a jig for the three center holes in the Cylinder that run into the 1/16" exhaust hole. Flatness and smoothness are important on the Valve side of the Valve Plate. On this model shown, the Cover was replaced by one of clear transparent plastic. It is good only on compressed air, but it adds interest and helps in setting the Valve.

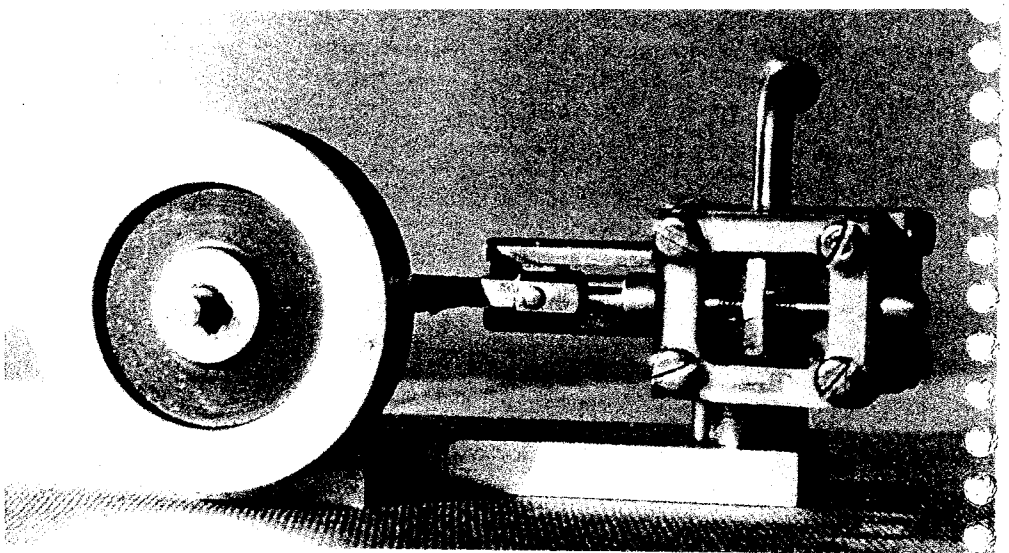
The **STEAM CHEST** was made out of aluminum on the model shown. Brass would be a bit more durable. Square up a block 7/32" x 5/8" x 1" and lay out the centers for the Valve Rod bosses. Note that they are not in the center of the 7/32" height. Prickpunch and center in the 4-jaw using a center test indicator. Turn the 1/8" projection and make the .086" and 1/16" holes for the Valve Rod. Reverse, center and turn the blind end. Use the Cover as a jig for the four holes. Enlarge them with a #43 drill. Lay out four 3/16" holes for producing the 3/32" radius inside and mill or file to 1/8" wall all around. Then drill and tap the 5-40 steam connection.

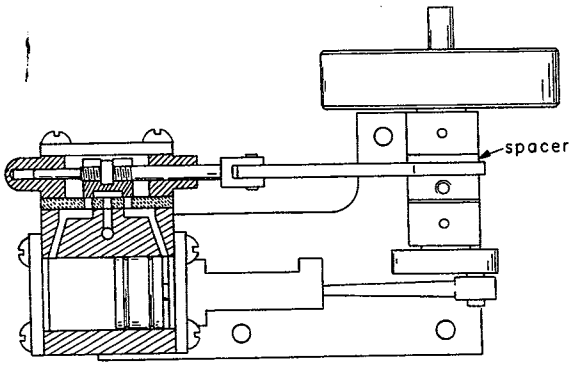
For the **HEADS**, square up the end of a 5/8" x 5/8" bar (aluminum was used on this model) about 2-1/8" long. Center in the 4-jaw with about 1-1/2" projecting from the jaw. Turn to 11/32" diameter back 23/32". Bore 5/8" deep to a flat bottom and ream 1/4". Use a center drill to start the 3/32" Rod hole and finish to a 3/32" close fit for the Piston Rod. Part off at about 27/32". Make the plain Cylinder Head from the piece remaining in the chuck. Mill or file to the **A** and **B** sections and then drill both Heads for screws. Wrap it in thin sheet copper to protect from jaw marks and chuck in the 4-jaw with enough clearance to use a junior indicator on the 11/32" diameter to center. If you have a 3-jaw accurate to .001", use it or a collet. Now turn to 13/16" long and turn a .370" x 1/32" dowel This .370" diameter permits moving the Head around to a spot where there is no Piston bind.

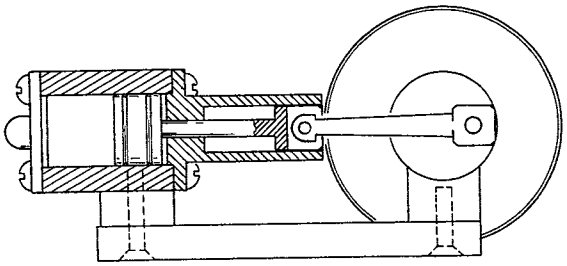
Make the **CRANKSHAFT** of steel, using press fit or Loctite at assembly.

When making the **PISTON**, use the Cylinder as a gauge. Concentricity is important here, so a close-fitting portion is unthreaded to help center the Rod.

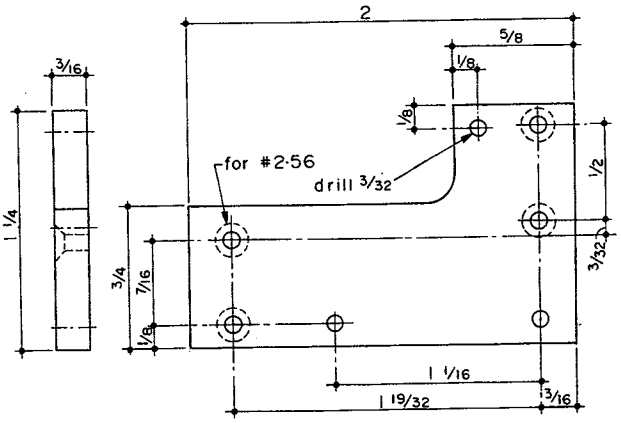
For the **ROD**, chuck a 9/32" or 5/16" rod in the 3-jaw with about 1-1/2" projecting from the jaws. Make a tiny center with a 3/64" center drill. Bring the tailstock up for support and turn to 1/4" diameter about 1-3/8" long, using the Head Guide as a gauge. Turn to 3/32" for about 1", again using the Head as a gauge. The extra



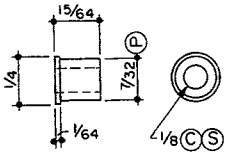




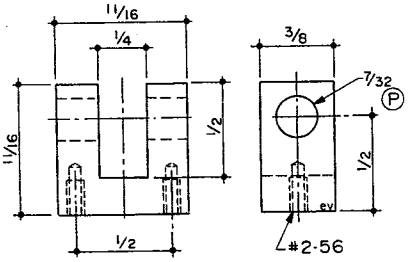
SLIDER



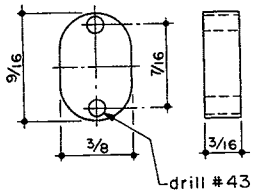
BASE
Aluminum



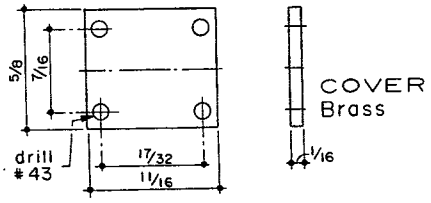
BUSHING
Brass
2 Required



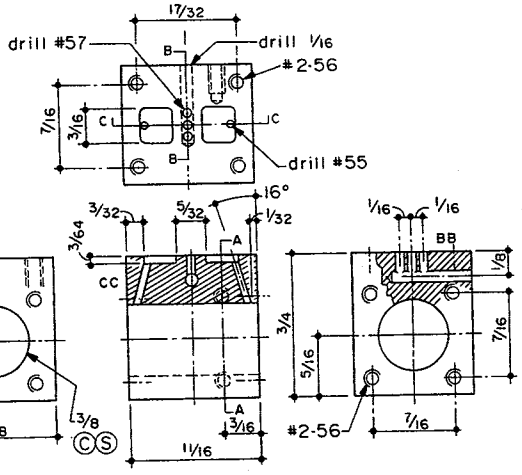
BEARING
Aluminum



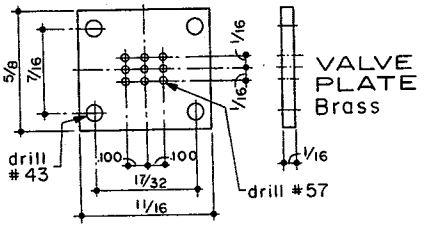
SPACER
Aluminum

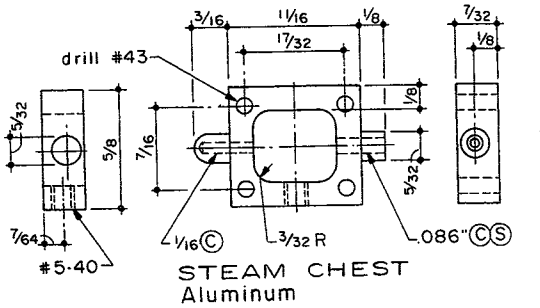


COVER
Brass

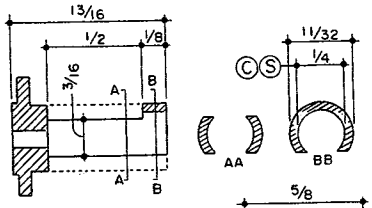


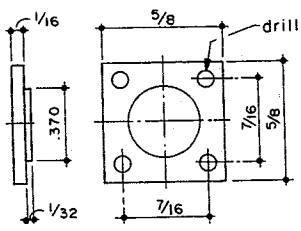
CYLINDER
Hard Aluminum



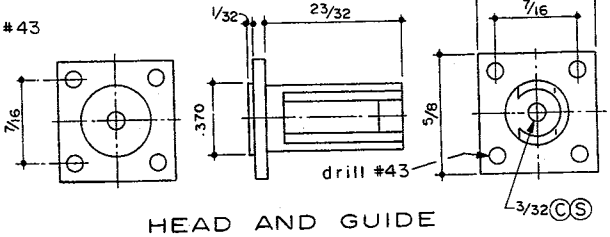


STEAM CHEST
Aluminum





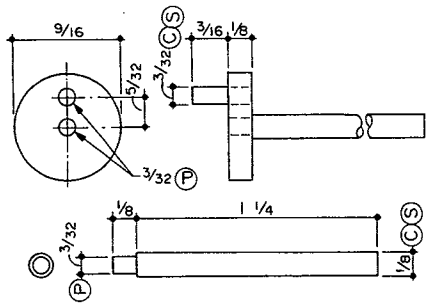
HEAD
Aluminum



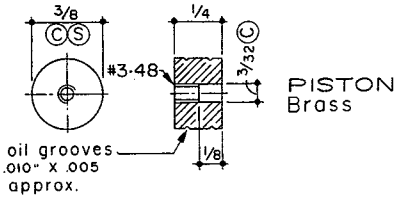
HEAD AND GUIDE
Hard Aluminum

length permits you to cut away the center hole later. Thread 3-48 up to 23/32" from the shoulder. The O.D. of a #3 screw is .099". This .094" diameter does not seriously affect the thread quality. Mount in the small V-groove in the milling vise and mill the two flats and the 3/32" slot. This can also be done in the 3-jaw mounted on the indexing fixture. Make the 1/16" pin hole squarely across the fork. If the Piston does not run tight on the Rod at the required length, some low-strength Loctite can be used. Cut off the excess Rod projecting through the Piston.

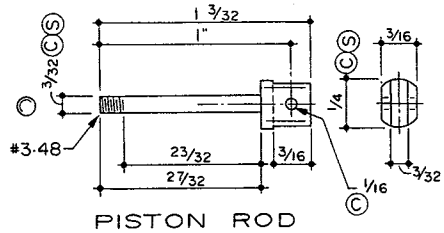
Start the **CONNECTING ROD** with about a 2" length of 1/8" x 1/4"



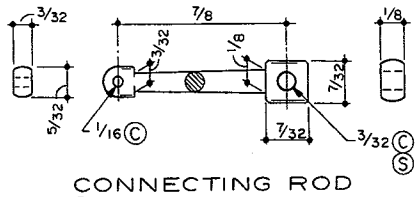
CRANKSHAFT
Steel



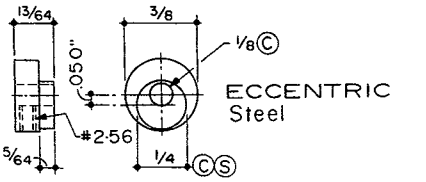
PISTON
Brass



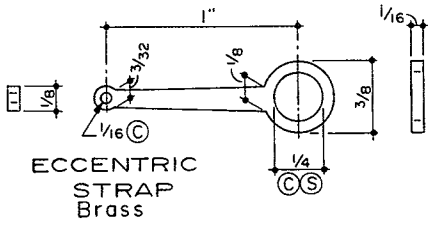
PISTON ROD
Brass



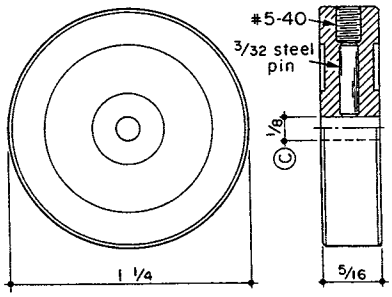
CONNECTING ROD
Brass



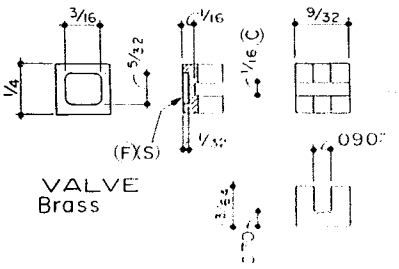
ECCENTRIC
Steel



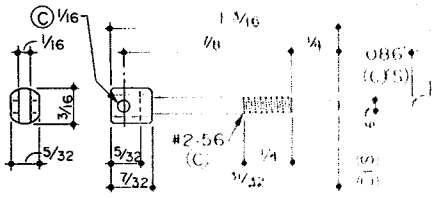
ECCENTRIC
STRAP
Brass



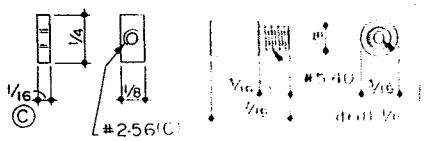
FLYWHEEL
Any Metal



VALVE
Brass



VALVE ROD
Brass



NUT
Brass

STEAM CHEST
Brass

brass and scribe the center on one end and prickpunch. Chuck it in the 4-jaw with about 1/4" projecting from the jaws. Center it with a center test indicator and make a tiny center with a 3/64" center drill. Loosen two adjacent jaws and project the stock out of the jaws about 1-3/8" against the tailstock center; retighten those two jaws. Then complete it, parting to the finished length. Lay out two holes 7/8" apart and make the 1/16" and 3/32" holes. Last, reduce the small end to 3/32" thick and round the end.

The **VALVE** is simply a 13/64" x 1/4" x 9/32" brass block with a 1/16" slot one way and a .090" slot the other way. A 1/16" end mill is used to make the 5/32" x 3/16" recess. The **ADJUSTING NUT** is a close fit in its slot and on the thread. The ideal condition is to have no shake between the Valve and the Valve Rod, with the Valve sliding just free on the Valve Plate.

The **VALVE ROD** is made of brass similar to the method for the Connecting Rod. Leave enough stock to cut away the tail center hole later. Here, the best bet is to use 3/32" and 1/16" rods that fit the Steam Chest with the right clearance and duplicate their diameters on the Valve Rod. When all the turning is done, cut the 1/16" end at 31/32" and thread 2-56 using a tailstock die holder. Part at 1-3/16" total length and mill the flats gripping on the .086" diameter in the small V-groove in the milling vise. Mill the slot and make the 1/16" hole squarely across the fork.

Make the **ECCENTRIC STRAP** out of 1/16" brass. It is purely a layout and sawing job with a jeweler's saw and filing to the line. Before sawing, make the 1/4" hole with progressive drill sizes until finally reaming it 1/4". Then make the 1/16" hole for the pin.

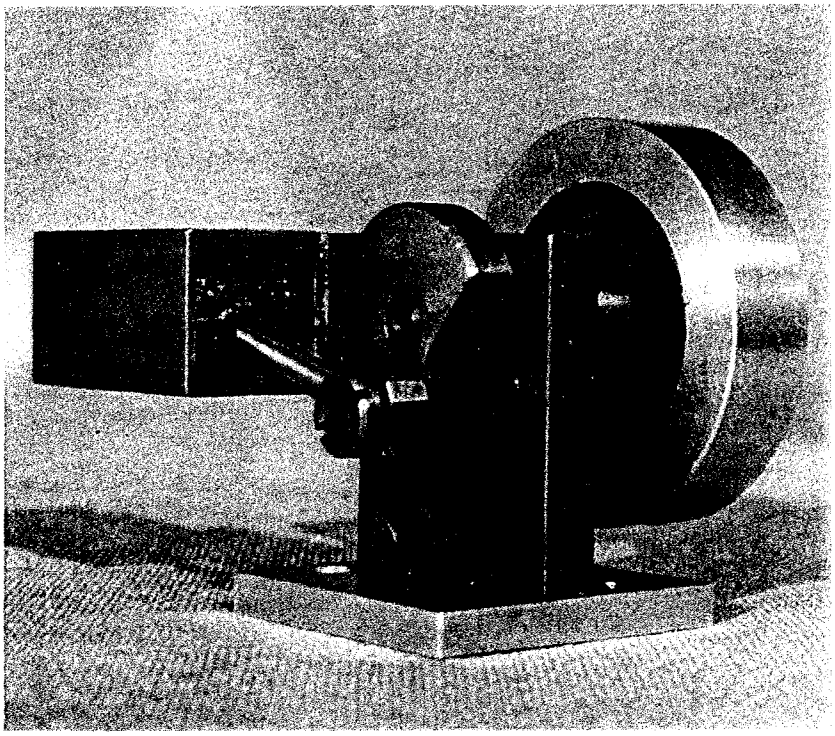
The best material for the **ECCENTRIC** is free-machining steel. Chuck a 3/8" diameter rod in the 4-jaw and center it with an indicator. Face the end and drill and ream the Shaft hole. Run the vertical flat end of a tool bit up against the O.D. of the stock. Set the crossfeed collar at zero. Loosen all the jaws slightly and, with one set of jaws horizontal, back up the rear jaw out 1/16". Force the work back with the front jaw. Run the cross slide in .050". Slowly feed the rear jaw back until the work touches the tool bit. Carefully snug up the other three jaws. Now, when the high spot just kisses the bit and the chuck is then rotated 180 degrees, a .100" diameter bar should just slip between. Turn the 1/4" diameter to a close fit in the Eccentric Strap.

If the holes are all the same size in the forks and eyes, the 1/16" cross pins should be just a shade shorter than the thickness across the fork. A very small prick punch mark on each side, at the rim of the hole, will retain the pins. On the model shown, a press fit was used in the eyes. This is no place for Loctite.

At **ASSEMBLY**, the Eccentric must be at 90 degrees from the Crank. With the engine bolted together, but with the Valve Cover removed, the extremes of the Valve travel should expose the Valve holes equally. The Valve Rod is given half-turns until the travel is equal, or very near so. With the Crank Pin on the vertical center line, the Cylinder should be getting full steam from one set of Valve holes.

CHAPTER

7 Square



This is a novelty engine. The "Cylinder" is 1/2" square brass tubing soldered to a brass frame. The Piston is a round brass tube placed crossways to take the oscillating motion from the Crank. You might say it is a round Piston in a square "Cylinder". The rest of the material is optional. The model as shown has a 1-1/4" aluminum flywheel but it would perform better with the weight of one made of steel.

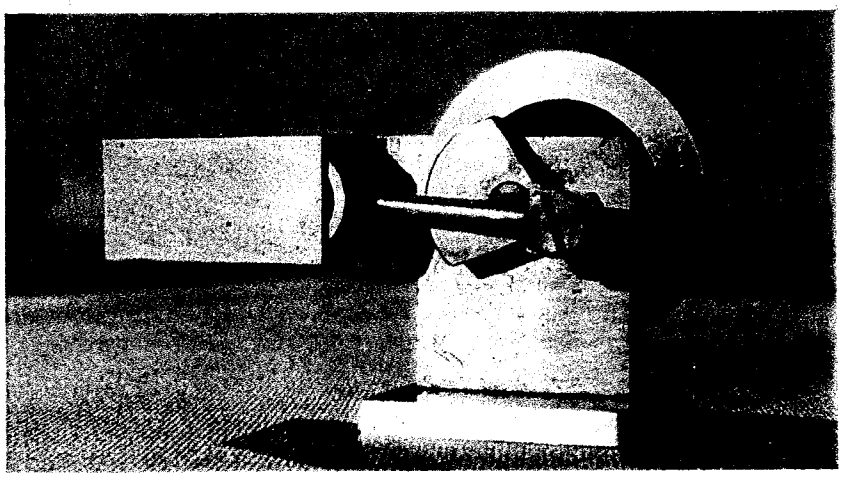
For the **CYLINDER**, select a straight and square piece of 1/2" brass tubing and cut a 15/16" length. This tubing is listed in Cole's Power Models' catalog. Use 1145° silver solder to hold the 1/16" end plate, and then lay out and drill the 1/16" steam passage.

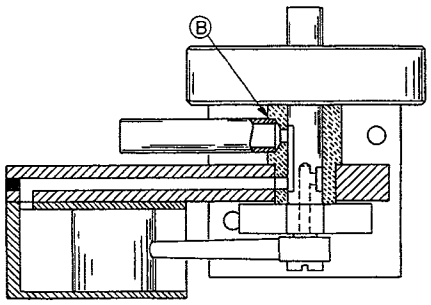
Make the **FRAME** of 3/16" brass complete as shown, except do not plug the 1/16" hole. File a piece of 1/16" aluminum wire to a free fit in the Cylinder and Frame holes. Bend it at a right angle about 1/4" from the end. Brighten the surfaces and apply flux to both the Cylinder and Frame. Melt 430° silver solder over the entire face of the Cylinder leaving only a thin coat. Insert the aluminum wire into the Cylinder with the bent end entering the steam passage and on into the Frame. Hold in position and apply heat with a torch, mostly to the Frame, until the solder melts and flows all around and the parts are tight together. Do not disturb this while cooling. The solder will not stick to the aluminum wire.

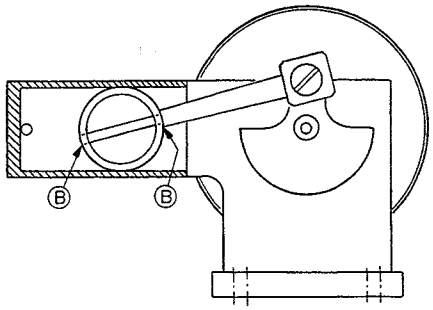
The **BEARING** is brass or bronze. Drill and counterdrill for the 3/4" piece of 3/16" tubing and solder. Set the Bearing in the Frame with Loctite. After curing, drill the steam passage and plug as shown. The plug can be a piece of brazing rod filed to enter about 1/16", set with Loctite, cured and dressed flush.

There is nothing special about the **PISTON** except the careful cut-and-try until the Piston is a close free fit in the Cylinder.

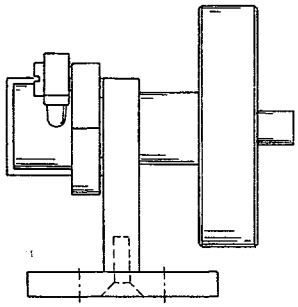
For the **ROD**, centerpunch the end of a 1/8" x 1/4" brass bar in the center of the end. Center in the 4-jaw with about 1/4" projecting, using a center test indicator. Drill a tiny center hole, using a 3/64" center drill. Loosen two adjacent jaws and extend the stock about 1-3/4". Hold the stock against the tailstock center and tighten those two jaws. The turning can now be completed. Start back far enough to be able to cut away the tailcenter hole. The taper is at about







SQUARE



1-1/4° off the lathe centerline. Bore the 1/8" crank pin hole and solder into the Piston making sure the Crankpin hole is parallel with the axis of the Piston. Make the shoulder screw of steel.

Make the **CRANKSHAFT** as shown. The important thing here is the accurate location and depth of the Valve flats, 180° apart, and the throw of the Crank set midway between the flats as shown in the assembly view. The Piston is halfway in its stroke and taking full steam.

The **FOOT** needs no mention.

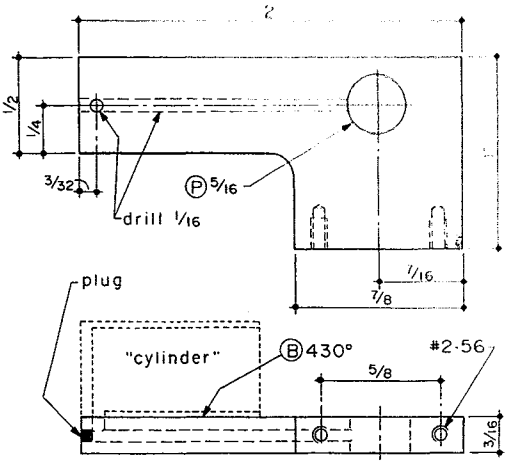
The **FLYWHEEL** is 1-1/4" diameter x 5/16" wide. The pressure of the setscrew is transmitted to the Shaft by a free-fitting pin in the tap-drill hole.

Assemble, lubricate and give it a trial run on 5 to 10 pounds of air.

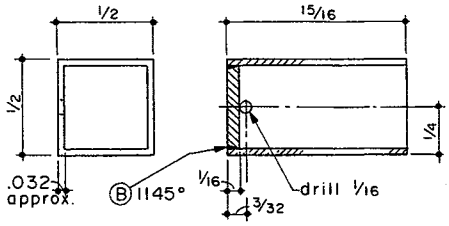
SAFETY FIRST

DO NOT USE

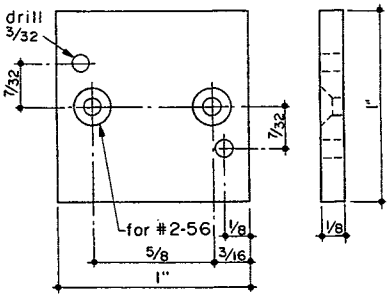
DULL TOOLS



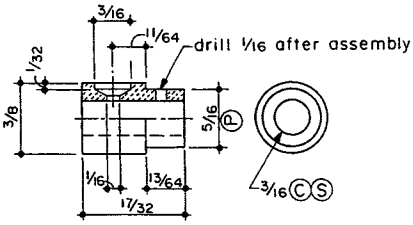
FRAME
Brass



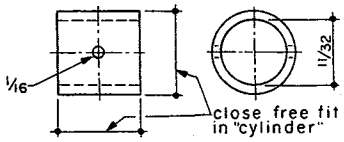
"CYLINDER"
Brass



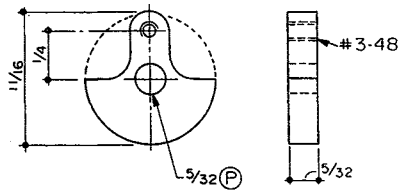
FOOT
Aluminum

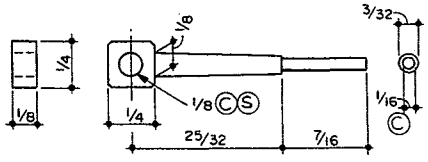


BEARING
Brass

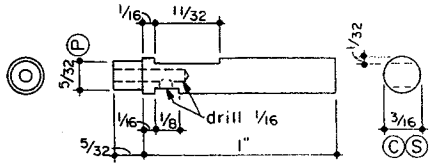


PISTON
Brass

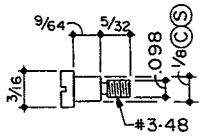




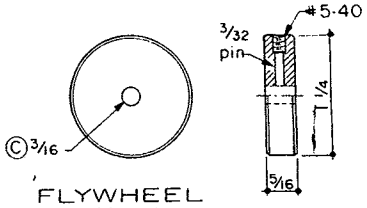
CONNECTING ROD
Brass



CRANKSHAFT
Steel



SCREW
Steel



FLYWHEEL
Any Metal

CHAPTER

8 Scotty

This is a simple Scotch Yoke Drive engine. It is another way of rotating a Shaft without rocking the Cylinder or using a Connecting Rod.

Make the **FRAME** complete as shown except do not plug the 1/16" hole. The **FOOT** needs no comment.

Make the **BEARING** of brass or bronze. Drill and counterdrill for the steam connection. Solder a 3/4" piece of 3/16" copper tubing into the Bearing as shown. Set the Bearing in the Frame with Loctite. Drill the 1/16" hole through the Bearing after curing and plug the hole in the Frame. Use a short bit of 1/16" wire filed to a slight taper to enter about 1/16" and set with Loctite. Cure and dress flush.

For the **CYLINDER**, lay out all the holes on a clean square block 5/8" x 11/16" x 1". The model shown has an aluminum Cylinder. Center it in the 4-jaw, using a center test indicator, to make the 3/8" bore. On the last cut before reaming, run the boring bar to the bottom and make an undercut for reamer runout. Do not leave a shoulder that the Piston might strike. Drill and tap the four bolt holes and drill the 1/16" port hole.

The **PISTON** and **ROD** need no comment. A brass Piston is used with a steel Rod. The Outbord Bearing is brass and, at assembly, is tightened in place when the Piston and Rod are free and easy moving.

Make the **YOKE** of steel. Square up a piece 5/16" x 7/16" x 3/4" and set up for milling the 3/16" slot. Lay out, drill and ream the 1/8" hole for the Rod. Lay out and center punch for the 2-56 setscrew. Chuck in the 4-jaw and turn to shape and drill and tap 2-56. The two small notches remove a condition where the exhaust is closed off for a moment each time the Yoke crosses the center.

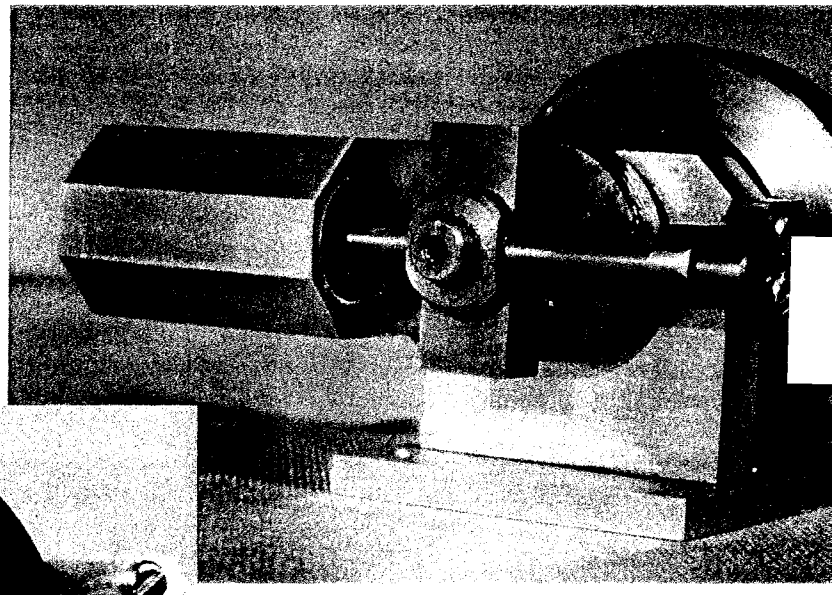
Make the 1/8" x 3/16" x 1/4" **SLIDING BLOCK** of brass or "oilite".

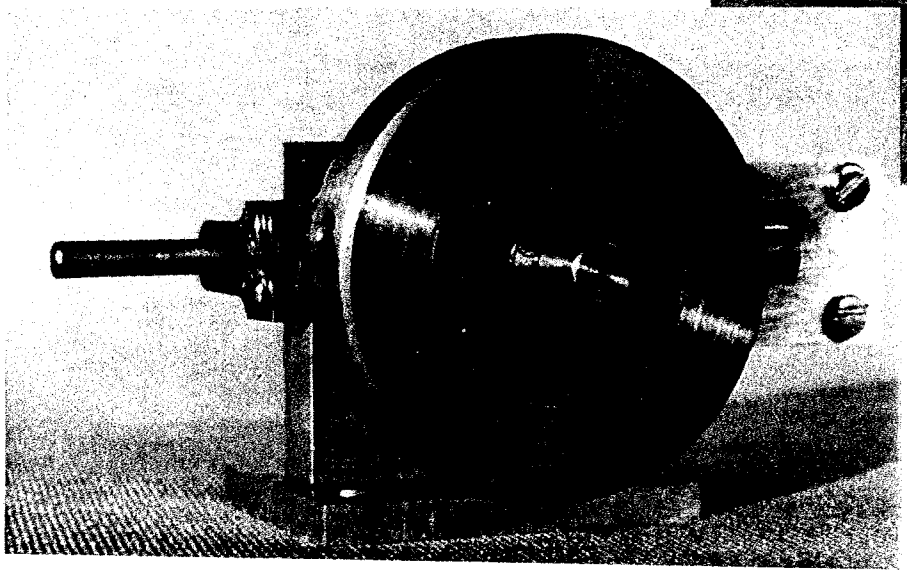
The **FLYWHEEL** is steel, 1-3/8" diameter x 5/16" wide, fitted with a setscrew. The setscrew pressure is transmitted to the Shaft by a loose pin in the tapdrill hole.

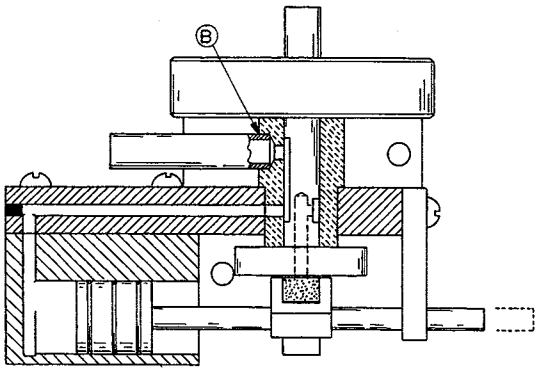
There is a bit of vibration in this engine since there is no counterbalance of any sort, so a solid mounting is called for. The Yoke should be close but free at the Crank Disk to reduce any rocking of the Yoke.

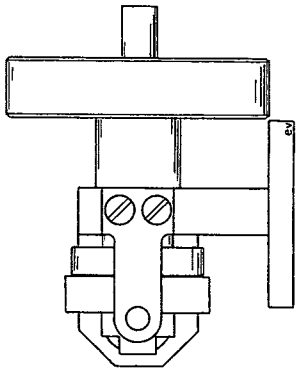
Make the **CRANKSHAFT** of steel. The important thing here is the accurate location and depth of the Valve flats 180° apart and the throw of the Crank set midway between the flats. In the assembled view, the Piston is at mid-stroke and taking full steam. Attach the Disk to the Shaft with Loctite.

When assembled and turning free, lubricate and give it a trial run on 5 to 10 pounds of air.

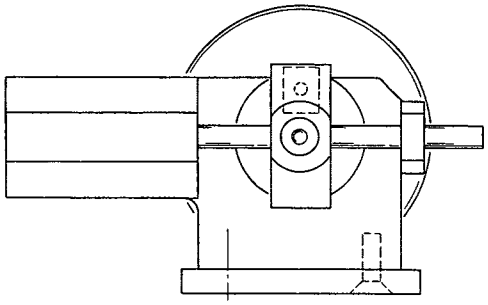


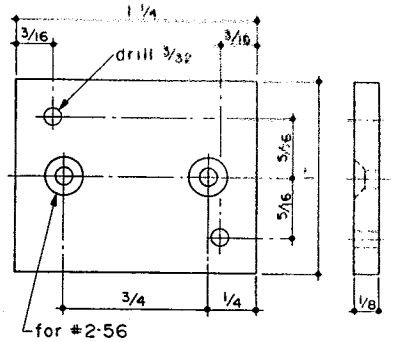




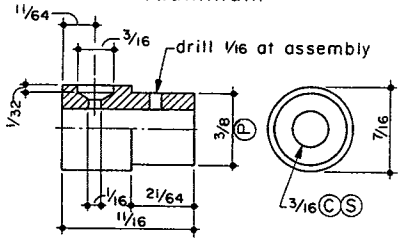


SCOTTY

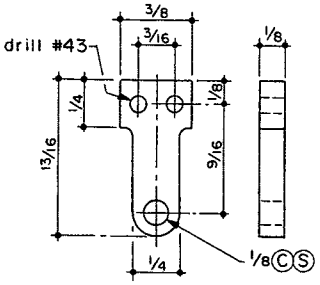




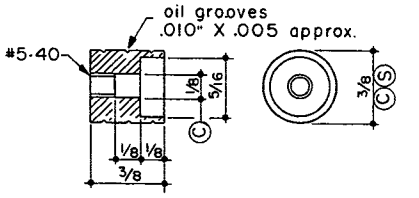
FOOT
Aluminum



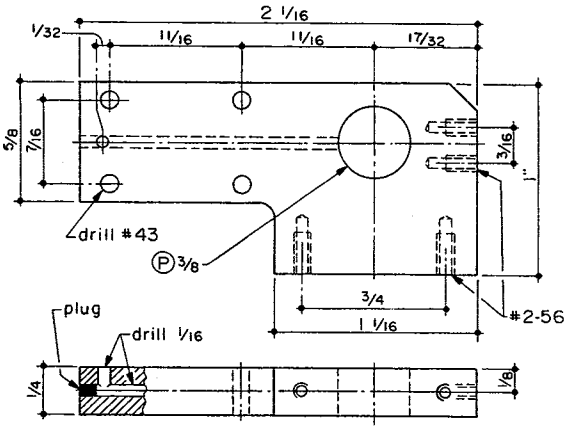
BEARING
Brass



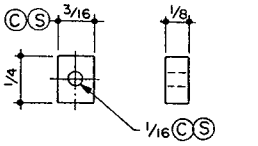
BRACKET
Brass



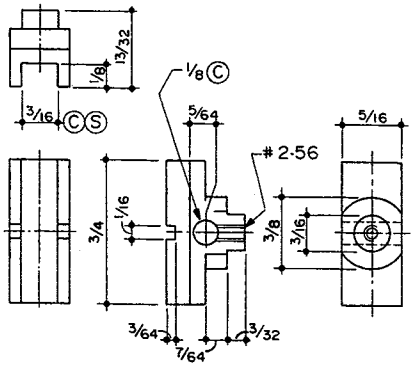
PISTON AND ROD
Brass



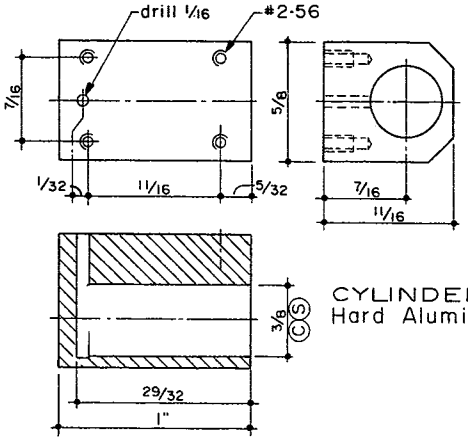
FRAME
Aluminum



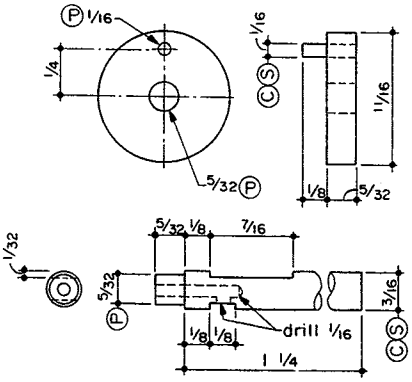
SLIDE BLOCK
Brass or "Oilite"



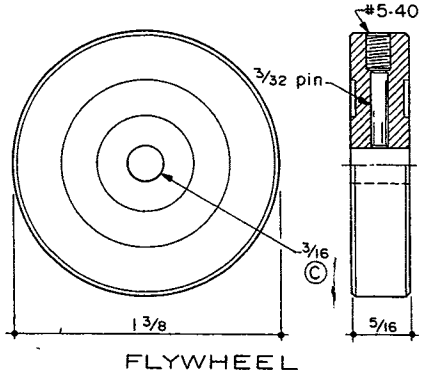
YOKE
Steel



CYLINDER
Hard Aluminum



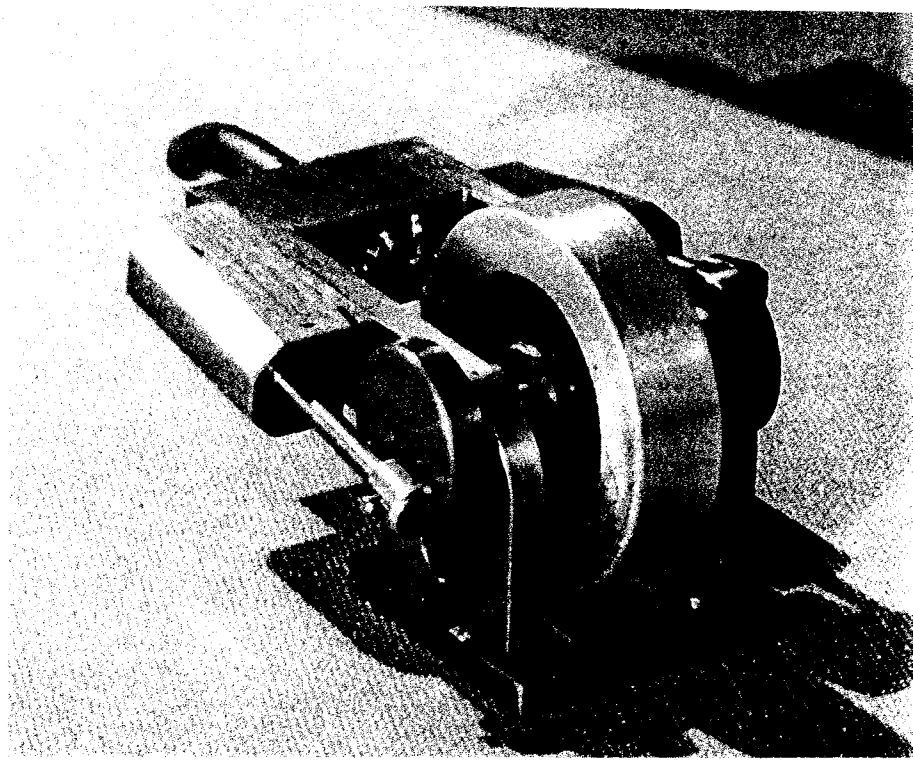
CRANKSHAFT
Steel



FLYWHEEL
Any Metal

CHAPTER

9 H Twin



This horizontal twin, in a way, suggests a miniature *Tangye*. It is mostly of brass because of the soldering.

Starting with the **FRAME**, make two side pieces about 1/16" oversize on all edges. Mill the top edges and the 7/8" ends true and square. Apply layout dye to one piece and lay out the rest of the Frame and the 2-56 screw at **X** and another at **Y**. Clamp the two pieces together with top and end in good alignment. Drill through at **X** and **Y** with a #50 drill. Tap one Frame 2-56. Enlarge the holes in the other Frame and countersink for the 2-56 x 1/4" flat head screws. Fasten the two pieces together and mill the rest of the outline squarely to the layout lines. Layout, drill and ream for the 1/4" O.D. bushings and for the 3/32" pivot holes. Lay out, drill and tap four 2-56 holes for the Foot. Separate the two pieces. Drill out the tapped holes at **X** in the one Frame and countersink for 2-56 flat head screws. Note — make right hand and left hand Frames when countersinking. Drill out the holes at **Y** to about 1/4". A clean drilled hole looks better than an unused bolt hole.

Make the **PORT BLOCK** and the **FOOT** of brass as shown. This calls for squareness and accuracy to preserve the Shaft alignment at assembly. Coat the ends of the port block and the bottoms of the side Frames with a light coat of solder. Coat the side Frames at the port block area and the Foot piece where it meets the side Frames with soldering flux. Assemble with 2-56 screws and insert close-fitting pins across through the 3/32" and 1/4" holes to help keep the Shaft alignment. Apply heat at each joint and tighten the screws when the solder melts. If you have the right amount of solder, a neat tiny fillet will be formed in the corners.

Make the **DRILL JIG** and **LOCATING PIN** of steel. Insert the Locating Pin. Insert a 3/32" x 1-1/8" rod in the pivot holes and the 3/32" jig hole. Holding the jig edge **Z** against the 1/8" Locating Pin, drill the #57 starter hole in the Frame. Turn the jig over to make the other port hole. Do the same on the opposite side of the Frame. Note — on the upper hole, drill halfway from each side. Do not drill all the way through from one side. The exhaust holes are 5/16" deep from each side. Apply layout dye to the port end of the assembly and to the bottom of the port area. Pick up and transfer the upper hole centerline to the end and then locate the 3/16" steam connection; drill and tap. Transfer the lower hole centerline to the bottom of the block. Locate and drill two 1/16" exhaust holes.

Make two **CYLINDERS** from clean and accurate 3/8" x 3/8" x 13/16" brass blocks. Lay out the center of the 1/4" bore offset as shown and prick punch. Do the same for the 3/32" Pivot Shaft. Chuck in the 4-jaw and center for the 1/4" bore, using a center test indicator. Square up the bottom with a boring bar. On the last boring, cut before reaming, make an undercut at the bottom for reamer runout. Do not leave a shoulder for the Piston to strike. Chuck again, this time for the pivot valve face. Add a small bit of metal under the jaw at the bore-end of the Cylinder. Check for squareness in the chuck. Face, undercut and drill for the 3/32" pivot pin.

Make the two brass **PIVOT PINS** 17/32" long. Drill the cross holes for the spring retaining pin. Make a close free-fitting aluminum pin to enter the 1/4" bore of the Cylinder. Apply a thin coat of flux to the end of the 3/32" pin and the pivot hole. Cut about 1/32" or less piece of 1/16" low-temperature silver solder and lay it up against the Shaft and apply heat with a propane torch. Heat the entire Cylinder until the solder melts and flows down around the shaft. Using too much solder will leave a mound that will prevent the Cylinder from seating. The solder will not stick to the aluminum.

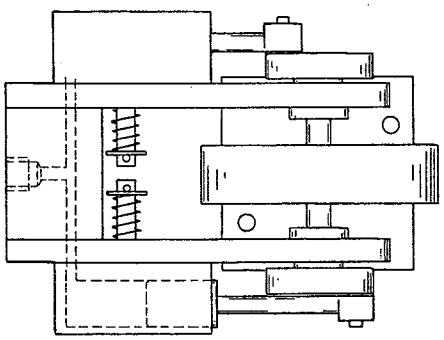
For the **PISTON** and **ROD**, chuck a piece of 5/16" rod in the 3-jaw with about 1-5/8" projecting. Centerdrill for the tailstock center. Start the cuts far enough in that the end with center can be cut away later. Use the Cylinder as a gauge for a close fit. Keep each Piston with its own Cylinder. Make parting cuts to length. Mill the crank end to 9/64" and make the 1/16" pin hole. Insert a Piston into its own Cylinder. Place the drill jig over the 3/32" pivot and run a close-fitting 1/16" pin through the jig and the eye in the Rod. Drill the #57 port hole in the Cylinder.

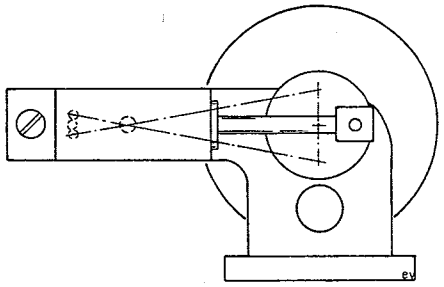
Make the **SHAFT** and **CRANK DISKS** as shown. Set the 1/16" crank pins with Loctite.

The **SPRINGS** on this model are about the dimensions shown. They came from the odds-and-ends drawer and seem just right for this job.

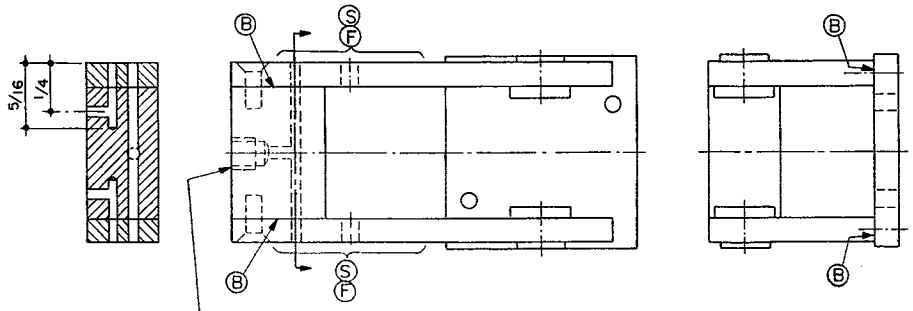
The **FLYWHEEL** is simply 1-1/4" O.D. x 5/16" wide fitted with a setscrew. The pressure of the screw is transmitted to the Shaft by a loose pin in the tapdrill hole.

This is a pretty well balanced engine and it runs fine on as little as 5 to 10 pounds of air.

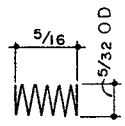




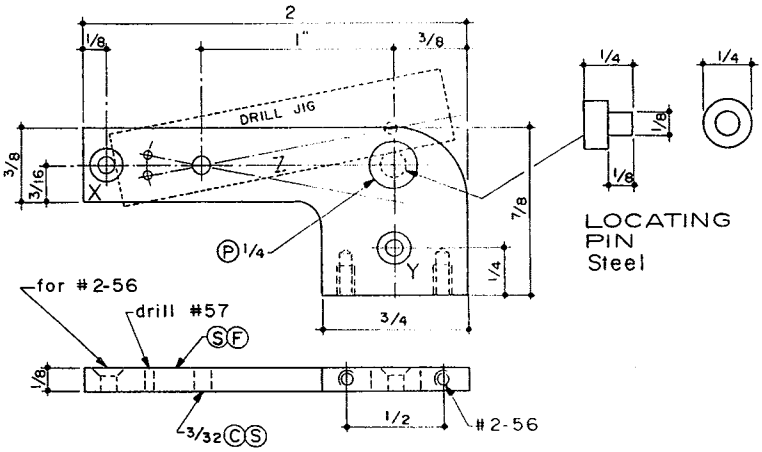
H TWIN



FRAME ASSEMBLY
see text

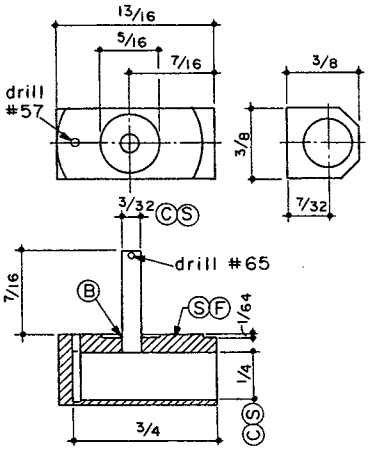


SPRING
Steel
.020" WIRE
2 Required

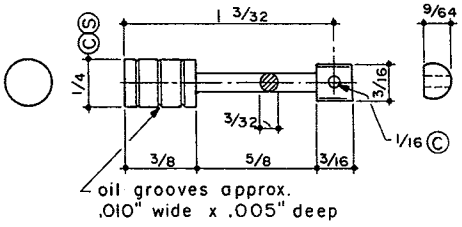


LOCATING
PIN
Steel

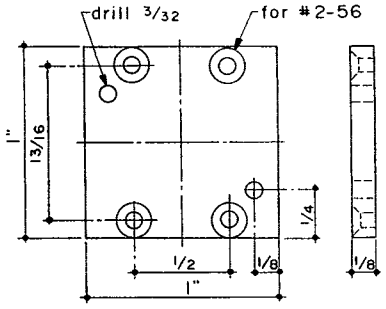
FRAME
Brass, 2 Required
1: RH and 1: LH see text



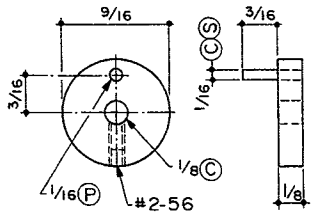
CYLINDER
Brass
2 Required



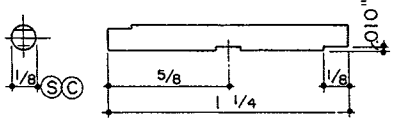
PISTON AND ROD
Brass
2 Required



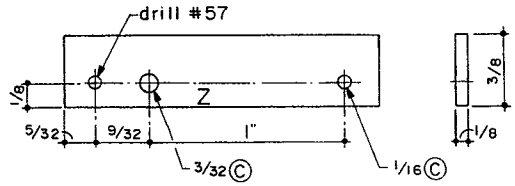
FOOT
Brass



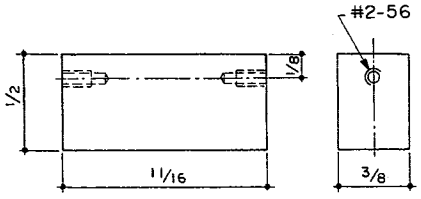
CRANK
Brass
2 Required



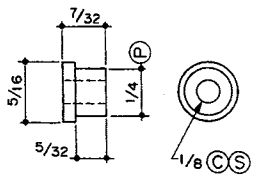
CRANKSHAFT
Brass



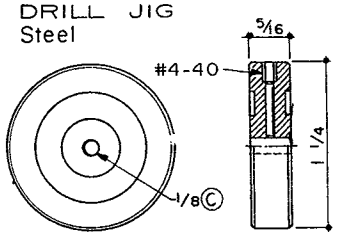
DRILL JIG
Steel



PORT BLOCK
Brass



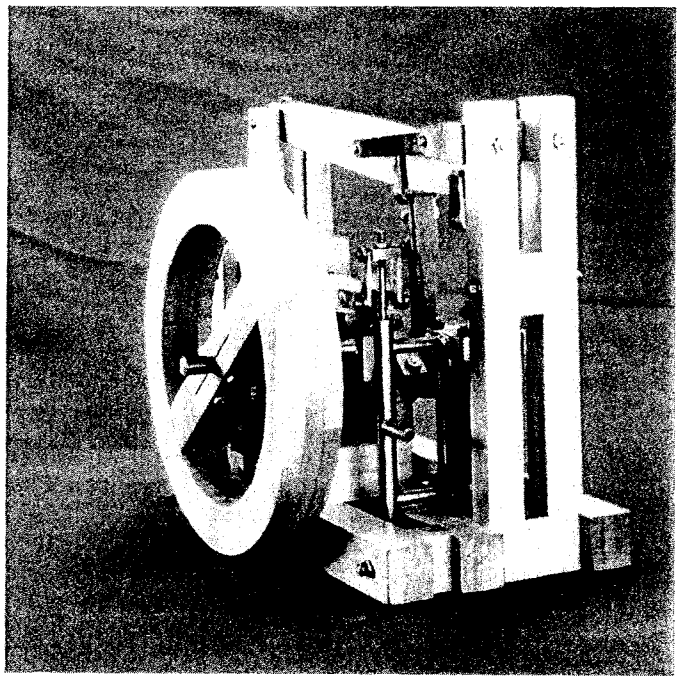
BEARING
Brass
2 Required

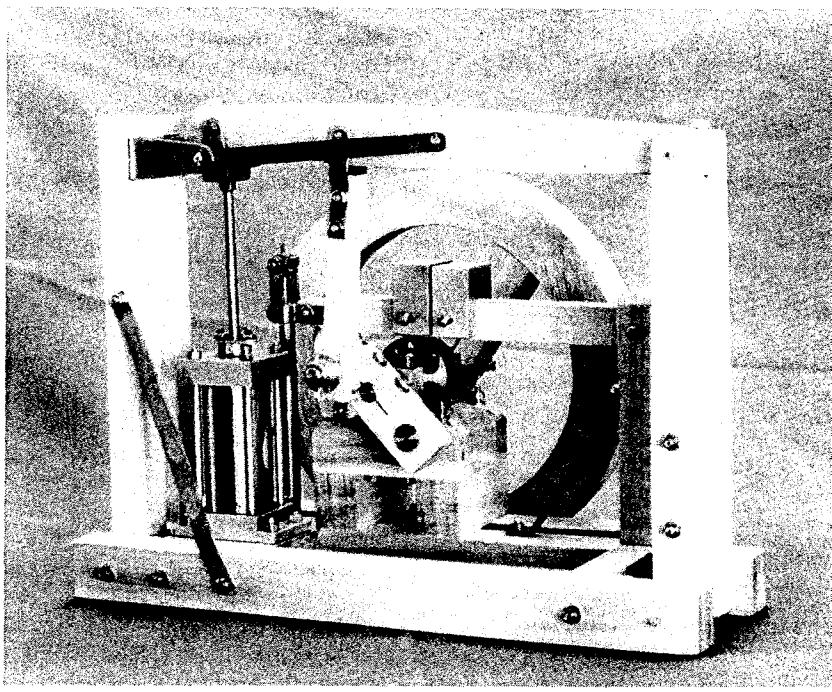


FLYWHEEL
Brass

CHAPTER

10 Wooden Grasshopper Engine





This is a project for the wood and metal worker — a grasshopper type which turned out quite well.

The cylinder and valving are a near duplicate of the Wood Beam Engine. The parts made of wood are a bit different. There is no metal hub in the flywheel and metal pieces were inserted to increase the weight as noted by Ralph Weidman in his model. The crank is wood with a metal pellet added as a counterweight. The frame uses a simple construction, no mortise and tenons. The builder can use his own ideas. Wood cannot be worked as precise as metal, so warpage, a tiny slip when gluing, etc., may require a bit of shimming and filing at assembly to get satisfactory alignments. It is a fun engine to build, not difficult, and it is a good conversation piece to show off at the club meetings.

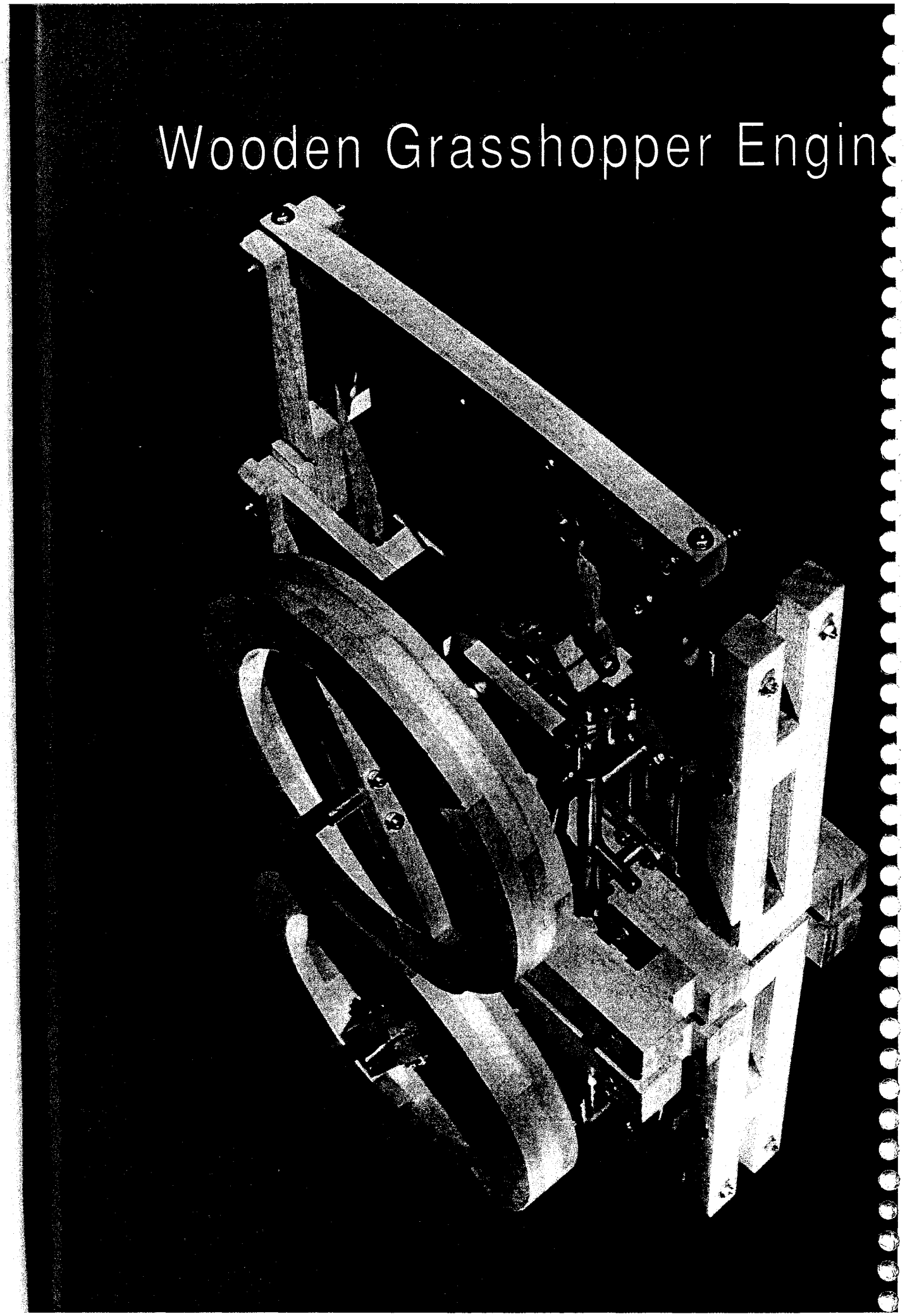
Select hard maple or any dense hardwood for the **FRAME**. The wood in the model shown is a Central American wood quite like maple. When making the wood pieces, try for all the accuracy you can get. Make all the notches and inserts close so, at final gluing, it will be square and well aligned. Drill the holes in the two outside timbers and clamp to the next piece so you can use it as a jig for spotting the tiebolt holes. Do this on all the related pieces. When all the holes are made in these frame pieces, enlarge, if necessary, all the holes in the inbetween pieces .008" to .015" so the long tiebolts will enter easily. Make all the holes in the Column, Pivot and Bearing Support before gluing. It will be difficult, if not impossible, after assembly. The tiebolts help the clamps when gluing.

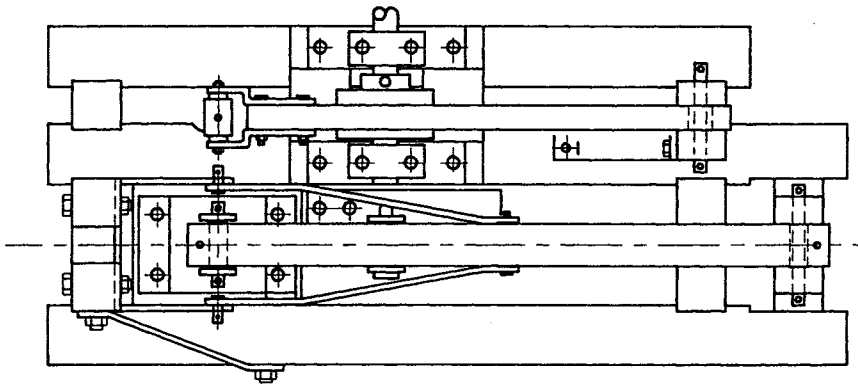
If the **BUSHINGS** in the **BEAMS** are not a snug fit, set them with epoxy glue.

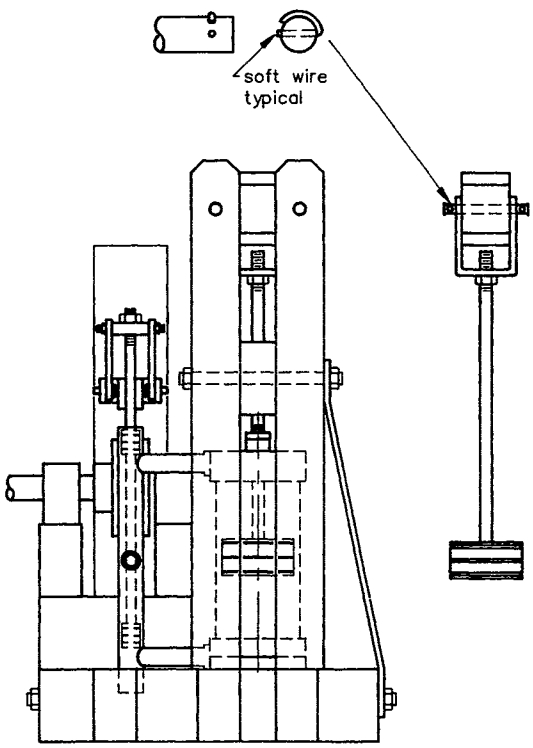
The **FLYWHEEL** is made of 1/4" layers built up in hex form and the inside diameters very carefully jigsawed so all three rings match.

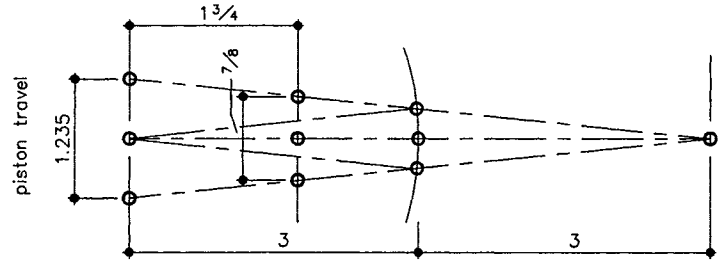
Make the **SPOKE-HUB** a close fit in the center ring. File the 1-7/8" radius to match the inside diameter of the outer rings. The Spoke is centered in the middle ring and a prick punch mark for the Shaft centered off the 3-3/4" ID of the Ring. With care, the punch mark should center in the middle of the Spoke, as well. Drill four holes for #2-56 bolts in the Spoke before gluing. The 1/4" Shaft bore is done later. The three layers with the Spoke in place sho be assembled with small clamps check for fit and alignment. T tongues on the ends of the Spoke h alignment and hold the rings in pl while the inside diameters of the ri are matched.

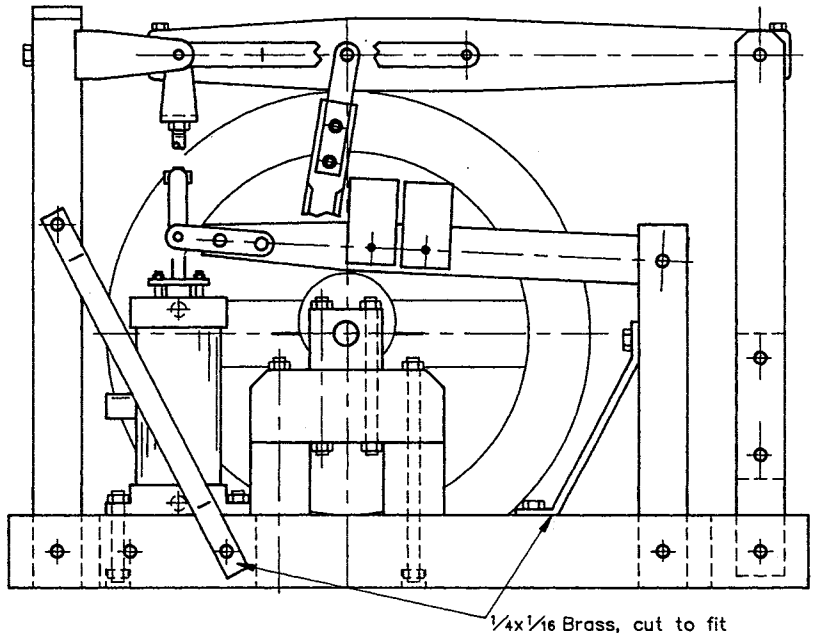
Wooden Grasshopper Engin

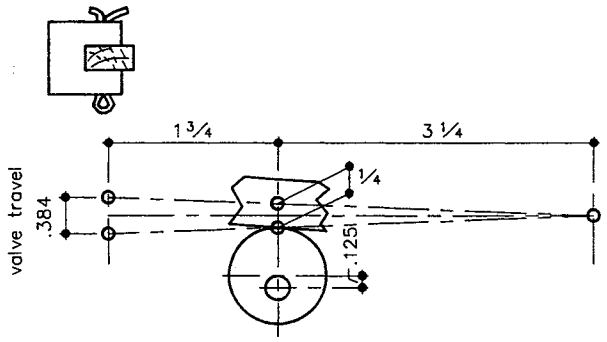


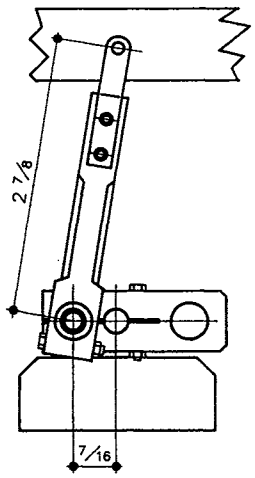


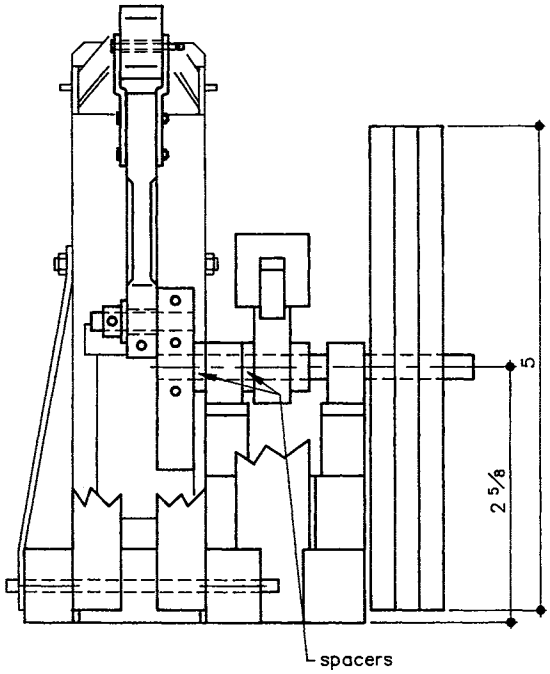

soft wire
typical


1 3/4
7/8
piston travel
1.235
3
3


1/4x1/16 Brass, cut to fit

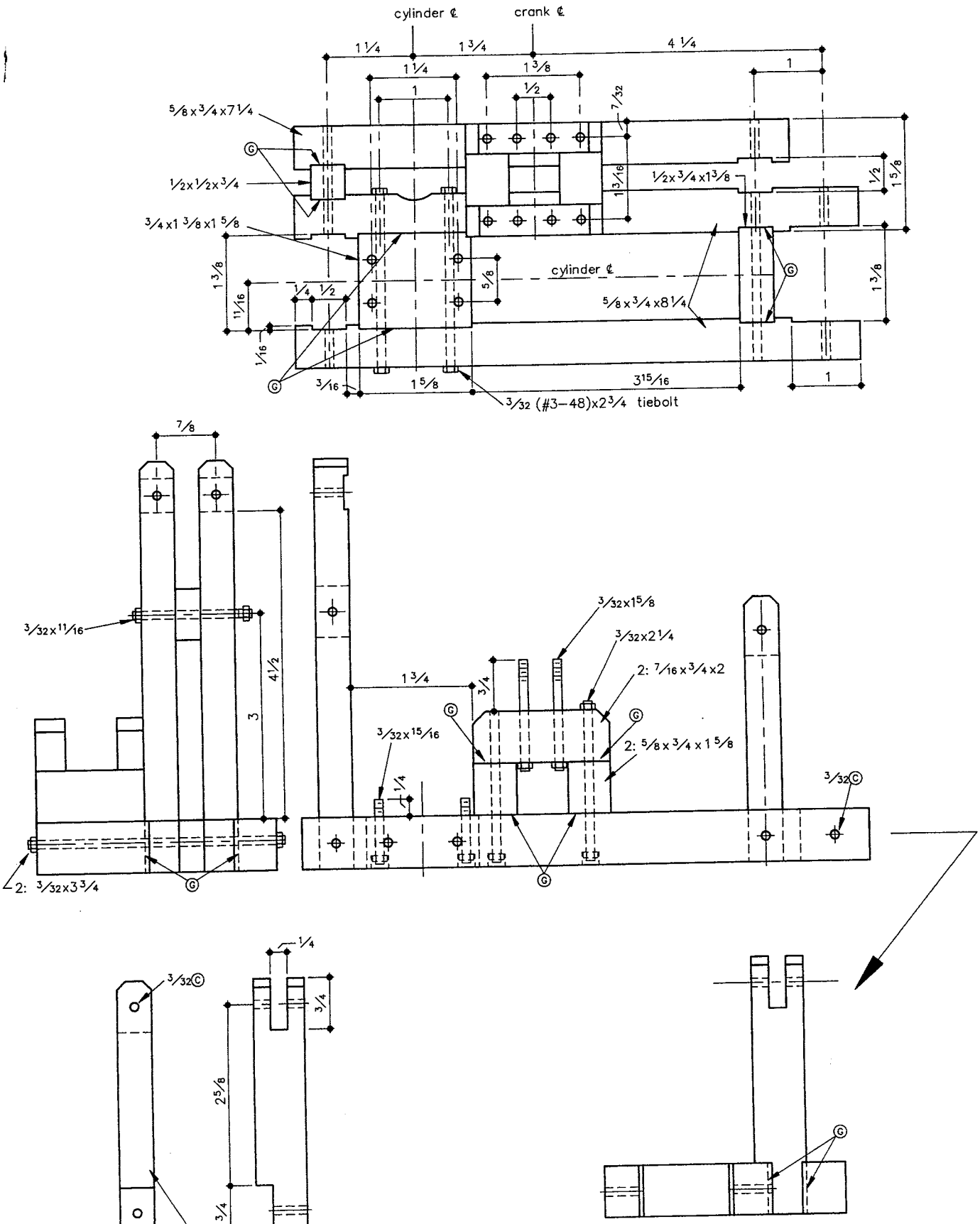






Drill two small holes in the waste area for small brads that will prevent sliding when gluing and clamping. DON'T FORGET THE STEEL WEIGHTS. When the glue has set, jigsaw the outside diameter a bit oversize. Chuck the Wheel, gripping the rim I.D. in your metal-working lathe 4-jaw and center the prick punch mark with a center test indicator. If all is well, the rim I.D. will run quite true and be satisfactory. Carefully turn the O.D. with a keen tool bit. Drill the 1/4" shaft hole. Take back to the jigsaw and add the slot at the center. When all the wood parts are glued and sanded, they can be given a fine spray coat of varnish.

At this point you are finished with the wood work section of this engine and can now get into the metal work that gets the engine running.

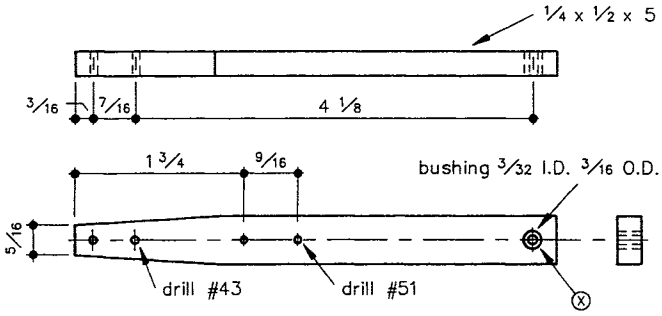


VALVE ARM PIVOT

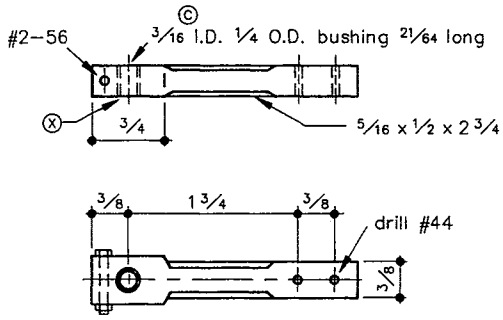
Wood

BASE

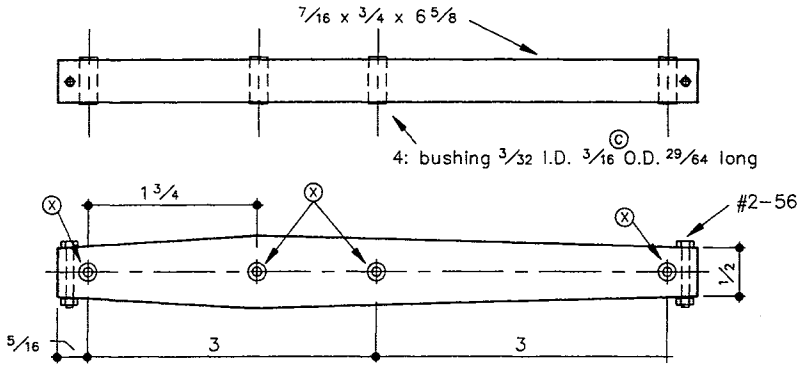
All parts – Wood
All bolts – Brass 3/32 dia., thread #3–48



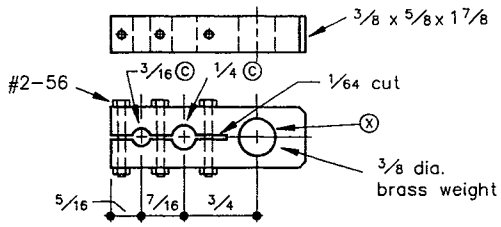
VALVE BEAM
Wood



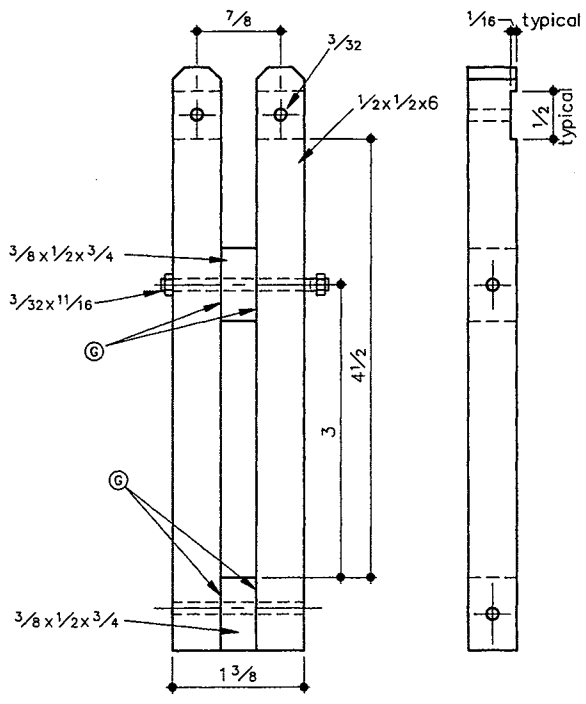
CONNECTING ROD
Wood



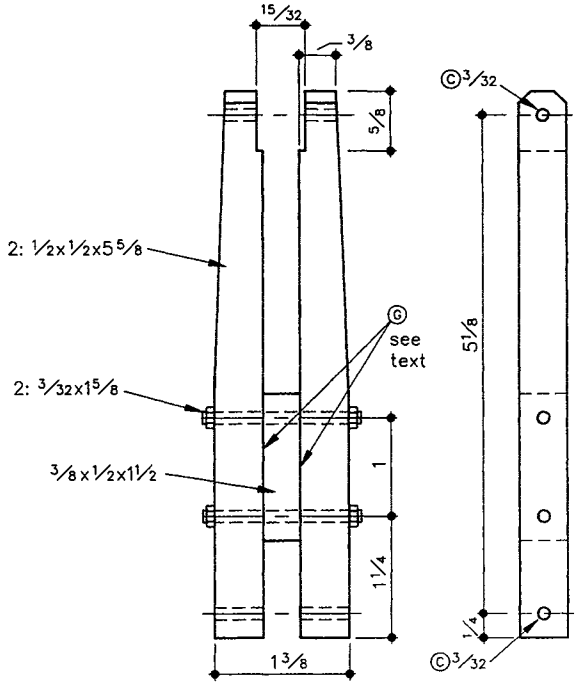
BEAM
Wood



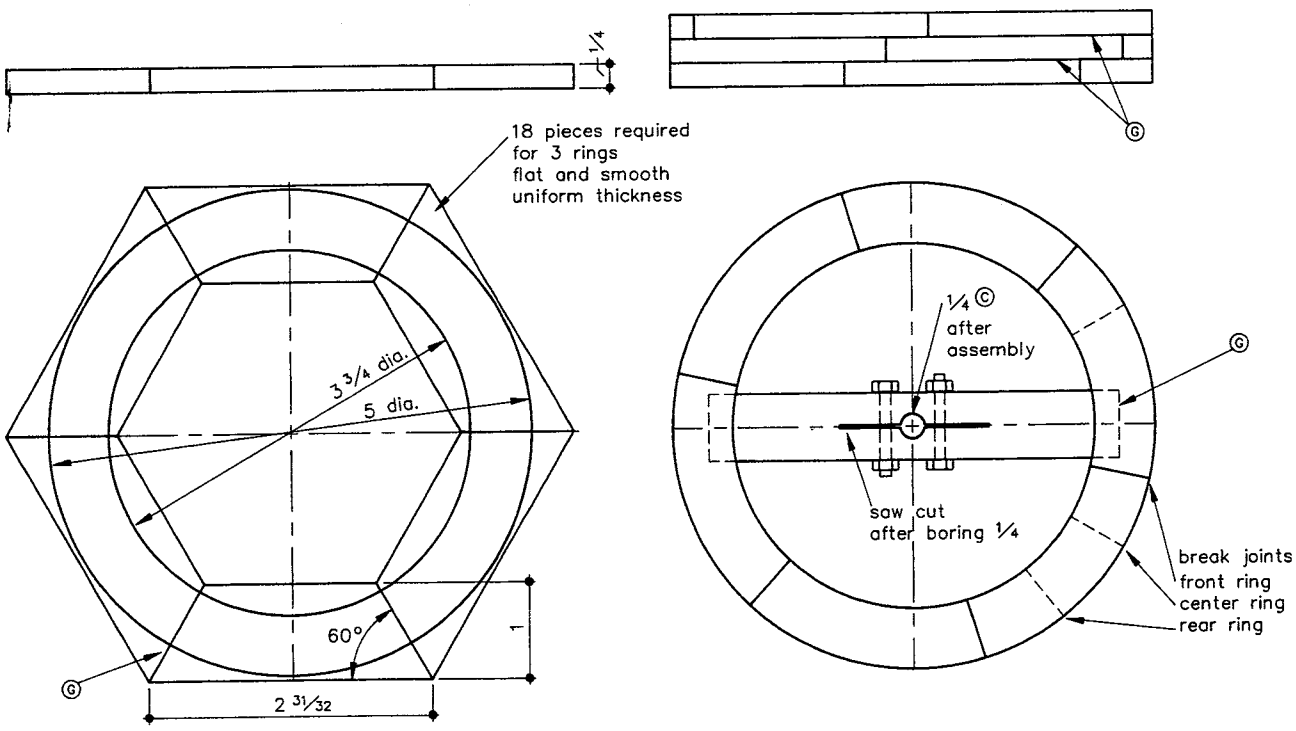
CRANK
Wood

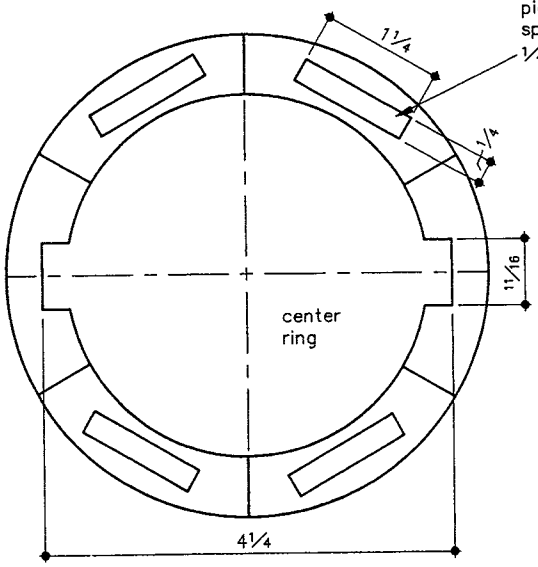


COLUMN
Wood



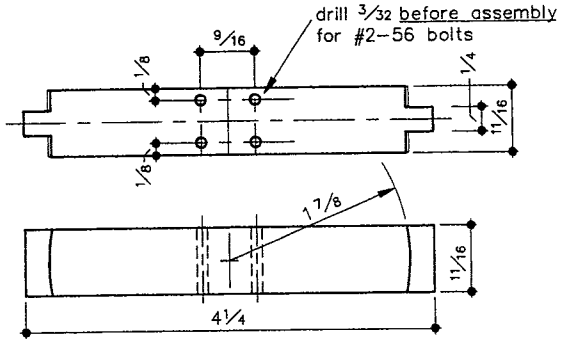
LEG
Wood



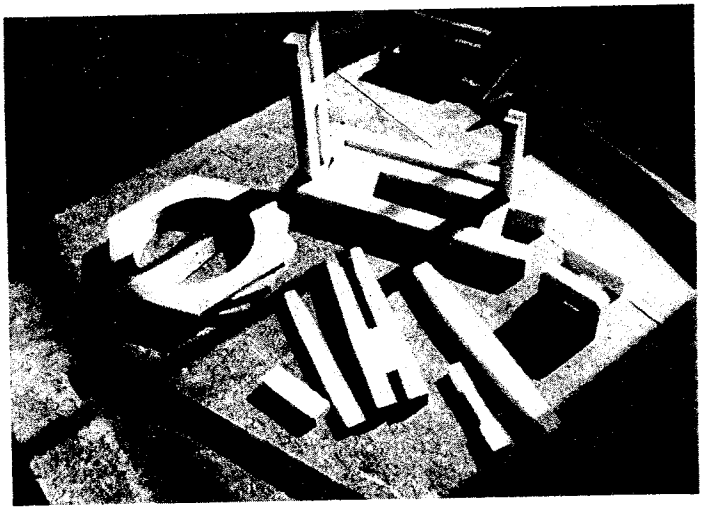


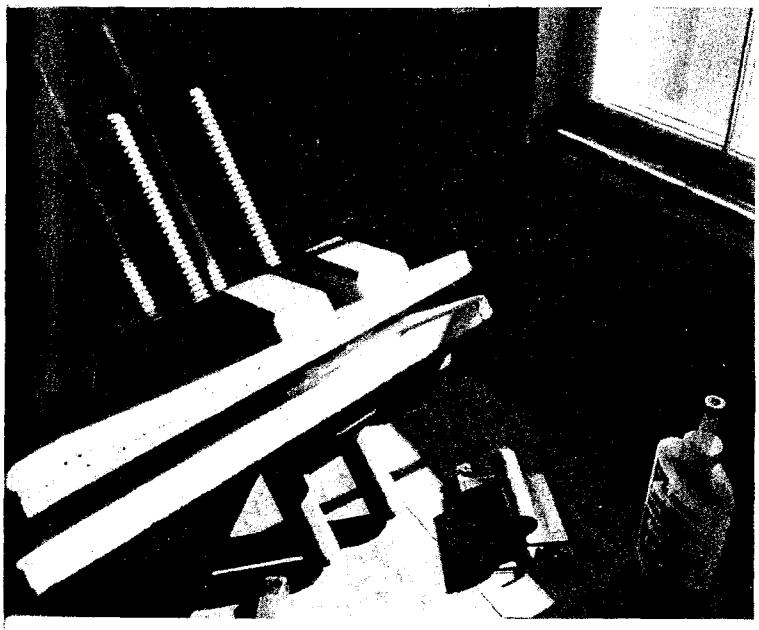
FLYWHEEL
Hard Maple or equivalent
1 Required

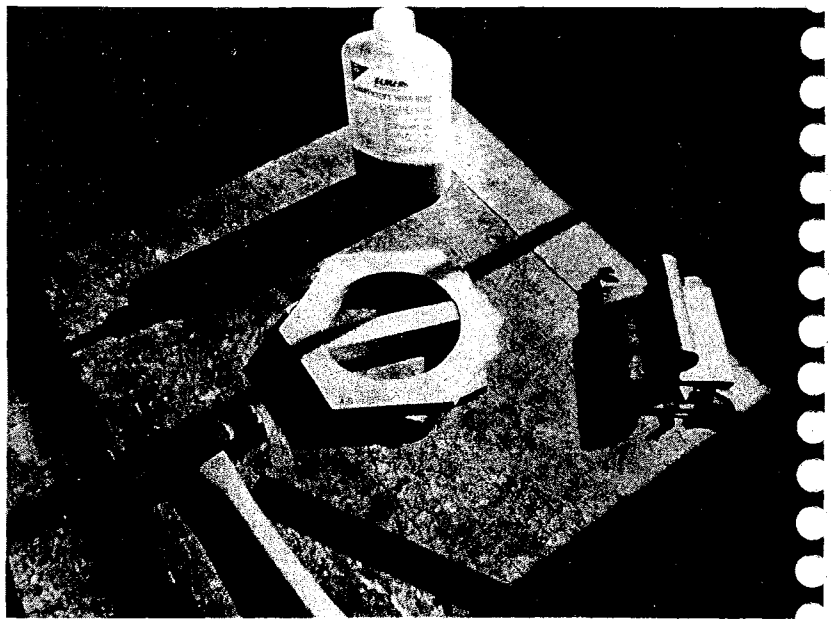
The sub-assemblies of the Wooden Grasshopper are pictured above, while the wooden parts of this engine are shown below.



HUB



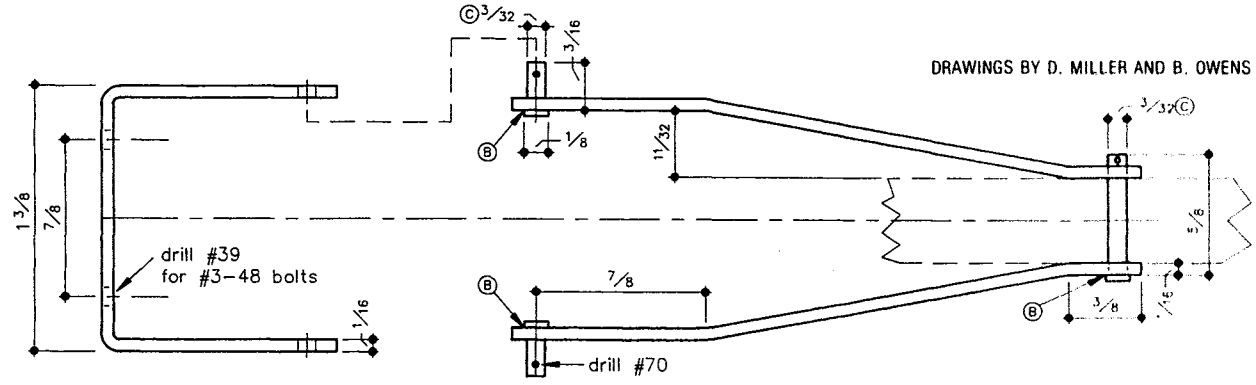


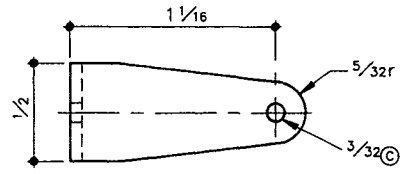


Above left. The flywheel rings are held in clamps while the glue sets. **Above right.** The flywheel is shown ready to be jigsawed and turned. The bench shown here was used in a Grand Rapids, Michigan, furniture factory 60 to 75 years ago. The hammer was used by my grandfather, a ship's carpenter, about 125 years ago.

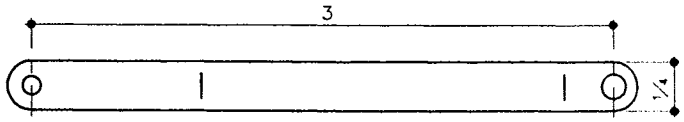
At this point, we begin the metal working section of this project. Basically, this portion is straightforward machine practice with only a few pointers to be offered to, hopefully, make your work easier.

Spot the setscrew in the **ECCENTRIC** on the centerline through the Shaft and offset. The Allen wrench in the setscrew helps in timing the engine. At assembly, with the **CRANK** at midstroke, the setscrew

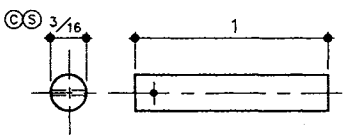




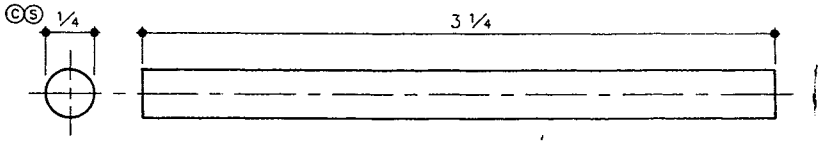
LINK FORK
Brass



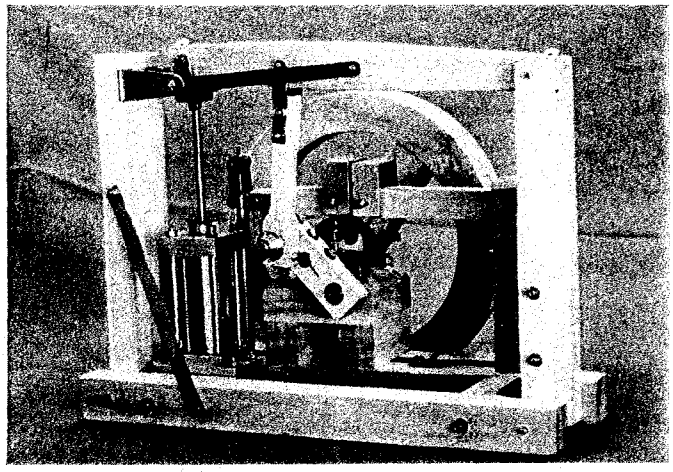
BEAM LINKS
Brass



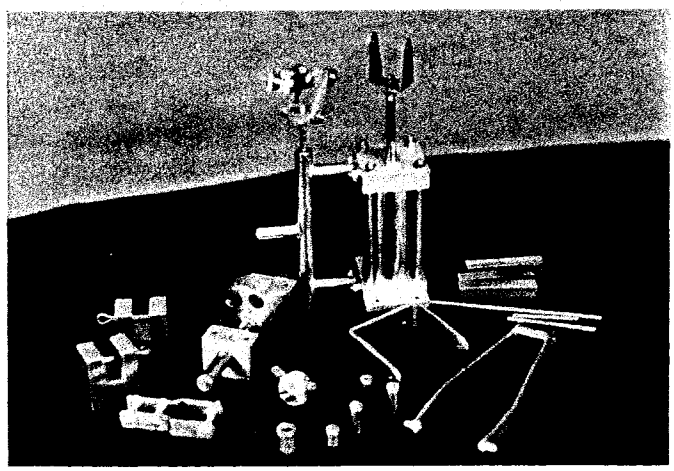
CRANK PIN
Steel



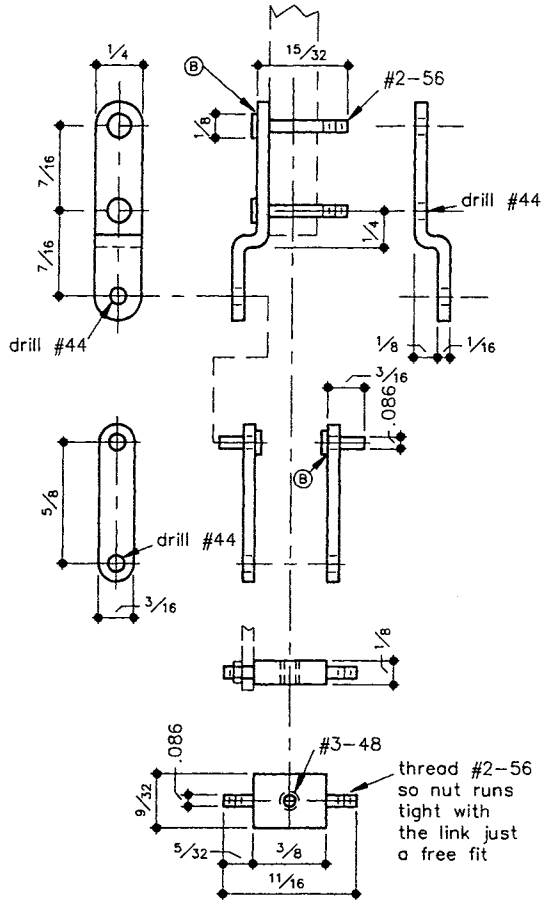
CRANK SHAFT
Steel



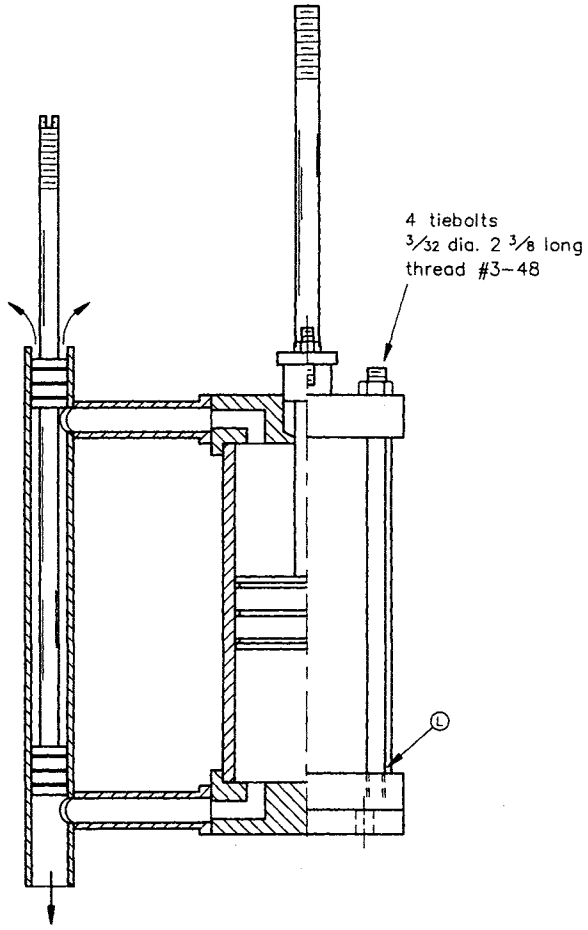
Side view of the Wooden Grasshopper Engine



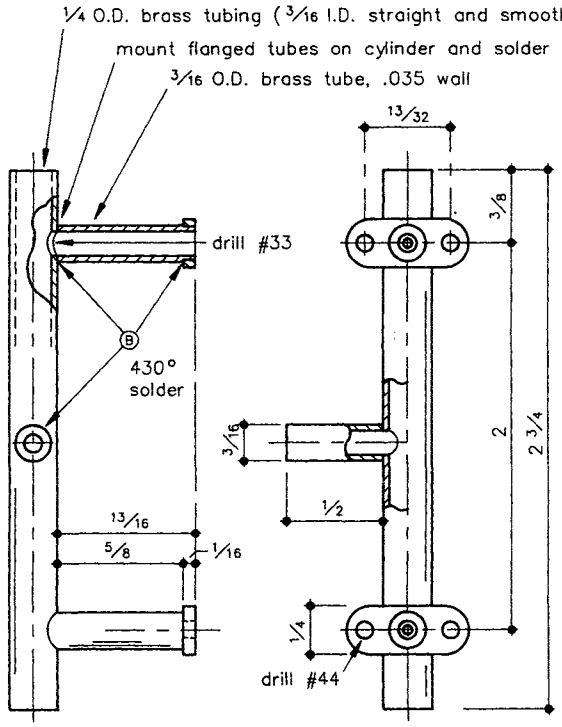
The metal parts for the Wooden Grasshopper Engine



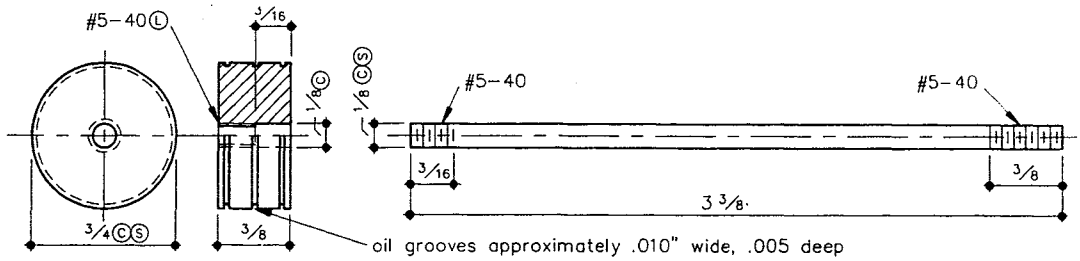
VALVE LINKAGE
Brass



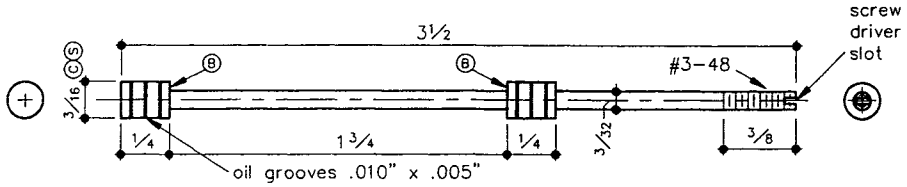
VALVE & CYLINDER ASSEMBLY



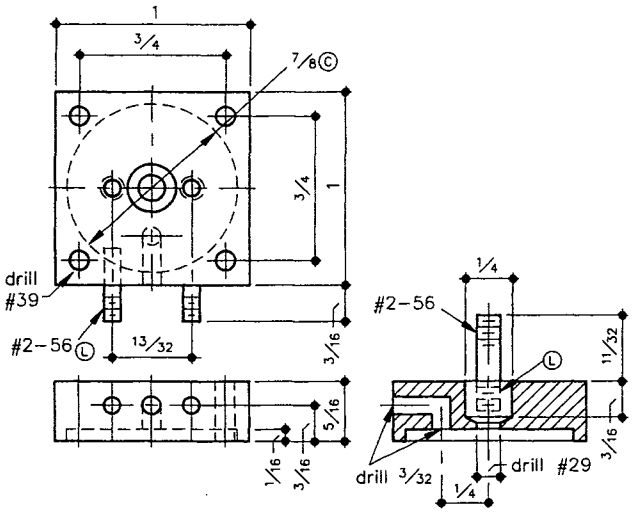
VALVE HOUSING ASSEMBLY
All Brass



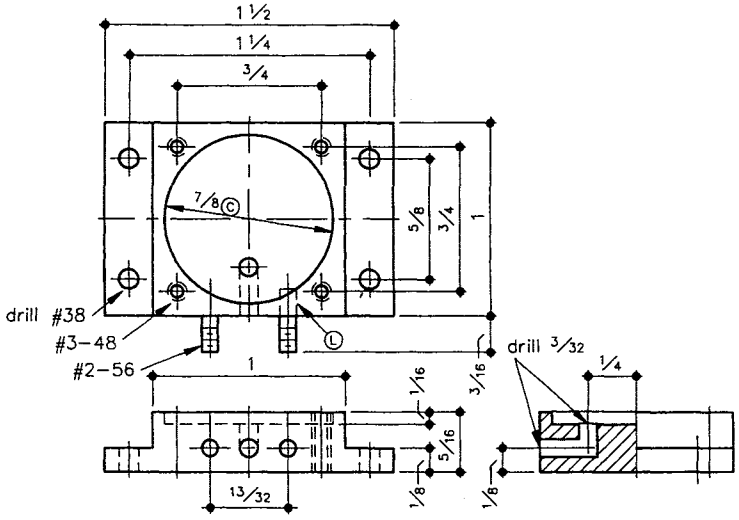
PISTON AND ROD
Brass



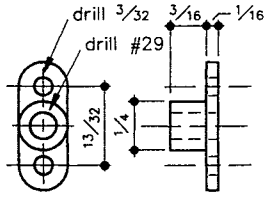
VALVE
Brass



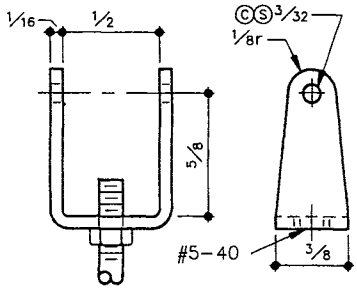
CYLINDER HEAD
Brass



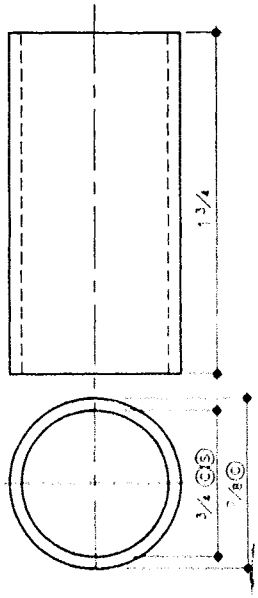
CYLINDER BASE
Brass



GLAND
Brass

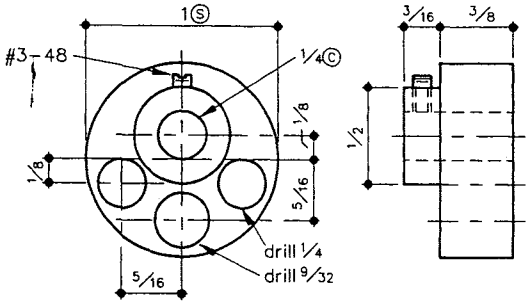


PISTON ROD CLEVIS
Brass

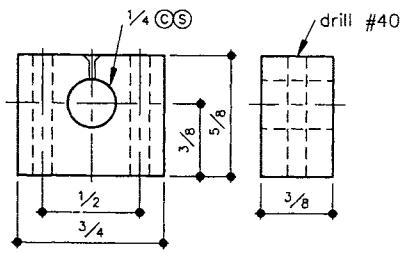


CYLINDER
Brass

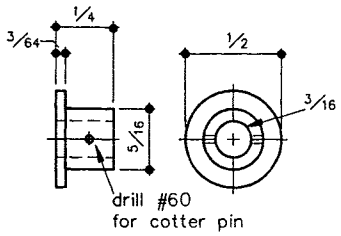
Ⓒ	close fit
Ⓢ	smooth
Ⓑ	braze or solder
Ⓛ	set with "loctite"
Ⓧ	epoxy glue
Ⓖ	wood glue



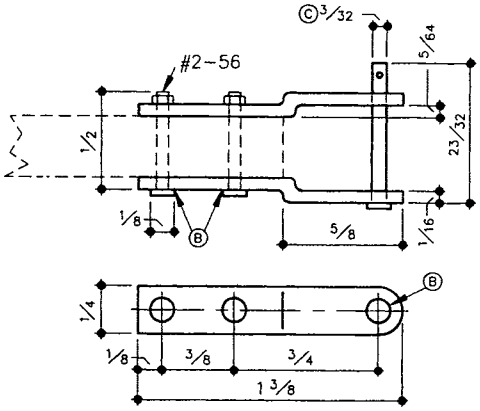
ECCENTRIC
Steel



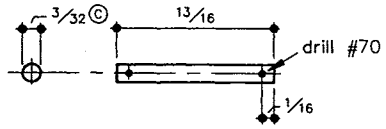
CRANK SHAFT BEARING
Brass
2 Required



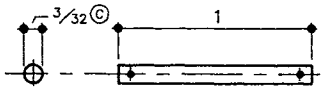
COLLAR
Brass



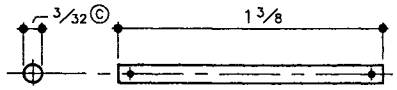
CONNECTING ROD, CLEVIS
Brass



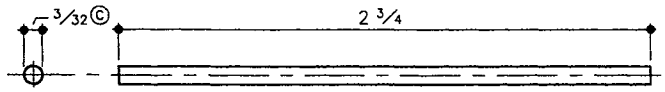
Piston Rod



Valve Beam

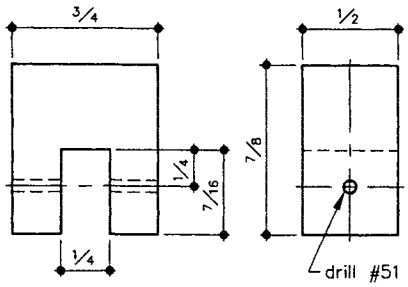


Upper Leg

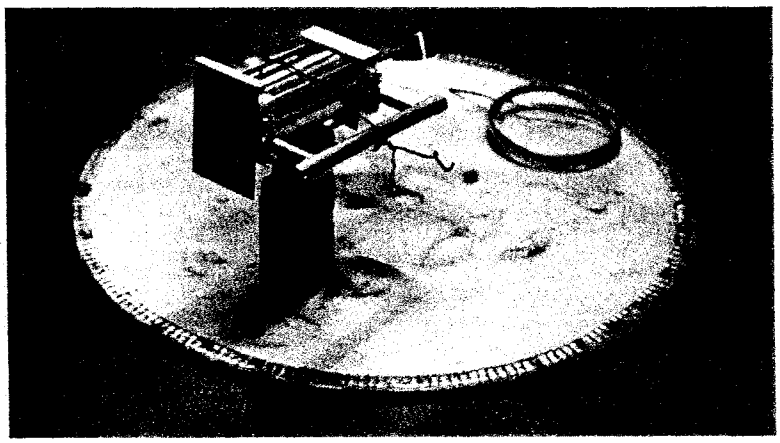


Lower Leg

PINS
Brass



WEIGHT
Steel
2 Required



Soldering the valve tube to the cross tubes.

should be on the vertical centerline. If the **CRANK ARM** does not grip the smooth shaft tight enough, a bit of epoxy glue can be used or a light, fine knurl added to the Shaft for a more positive drive.

The **CYLINDER** and **PISTON** are straight machine work and pretty well covered by the drawings. Use your favorite Packing.

The **VALVE ASSEMBLY** is mostly tubing. The flanges are soldered to the Cross Tubes and mounted on the Cylinder. The Valve ends of the Cross Tubes are filed to fit around the Valve Tube. The Valve Tube is held against the Cross Tubes by soft wire while soldering. Drill through the Cross Tubes into the Valve Tube and remove the burrs inside. Make sure the Valve slides smoothly and not too sloppy in the Valve Tube. A three-cornered scraper made from a small file is handy for this job.

The 1/2" long **STEAM INTAKE TUBE** is made with the end fitted around the Valve Tube. Clamp together and solder. If there is a threat that the heat will soften the soldered joints already made, dip pipe cleaners in water and wind around the Valve Tube each side of the intake near the Cross Tubes. They will absorb the heat. Drill through and remove burrs. The importnt area to keep in fine condition is at the Cross Tubes where the Valves operate.

This engine will run on very low air pressure. The slot in the end of the Valve Stem will help you fine-tune the engine using a jewelers screw driver. Until the Valve is centered, the Piston will tend to go to one end and stay there. Adjust until you get a nice even sound at each end of a stroke.

Try to run as slow as possible. A large engine of this sort would hardly run 25 rpm.

CHAPTER

11 Radial Engine

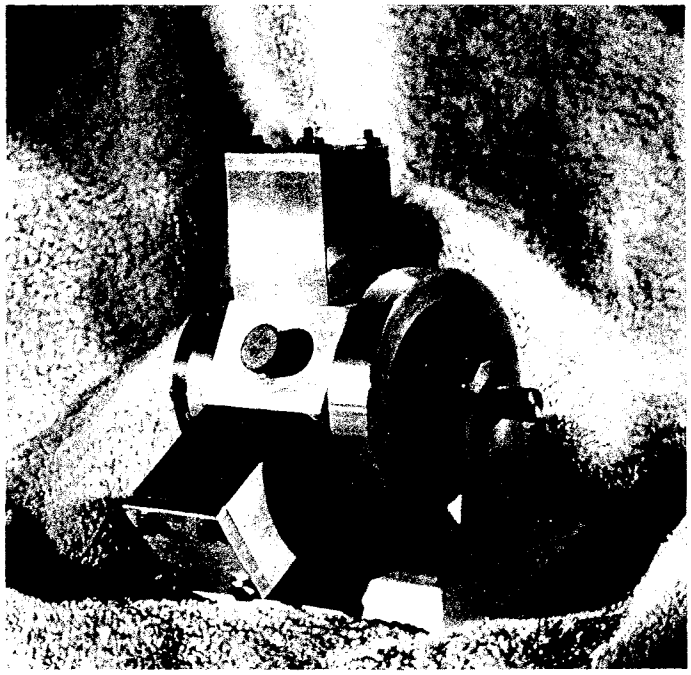
This is a simplified radial engine using a disk valve driven by an offset pin in the hub of the crank mechanism. It is interesting to build and run; and with three impulses per revolution, it has quite a bit of power. The optional Bearing Bushing is "Oilite." Use any material you may have in your odds-and-ends department as the kind of material is not critical.

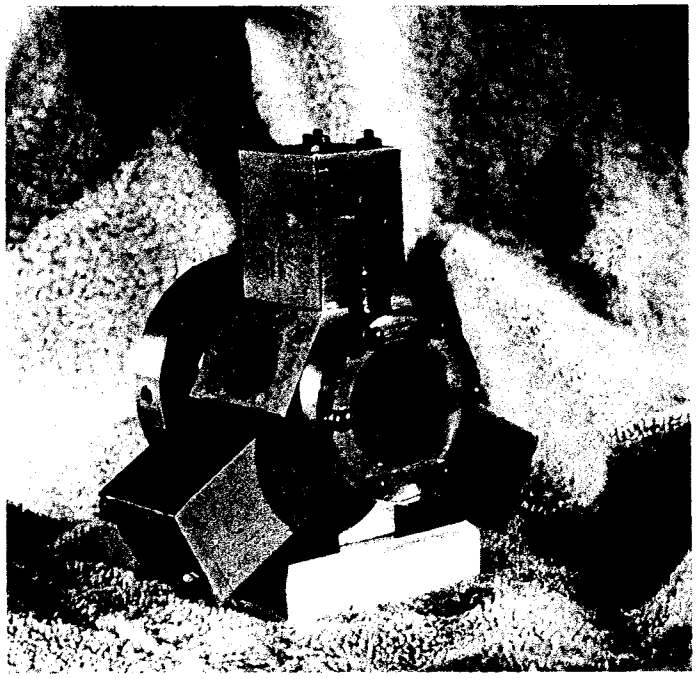
The Base is detailed to show four anchor holes, a decision made after the engine was assembled. Since most of the parts involve common machining practice, only the parts that need an extra word will be mentioned.

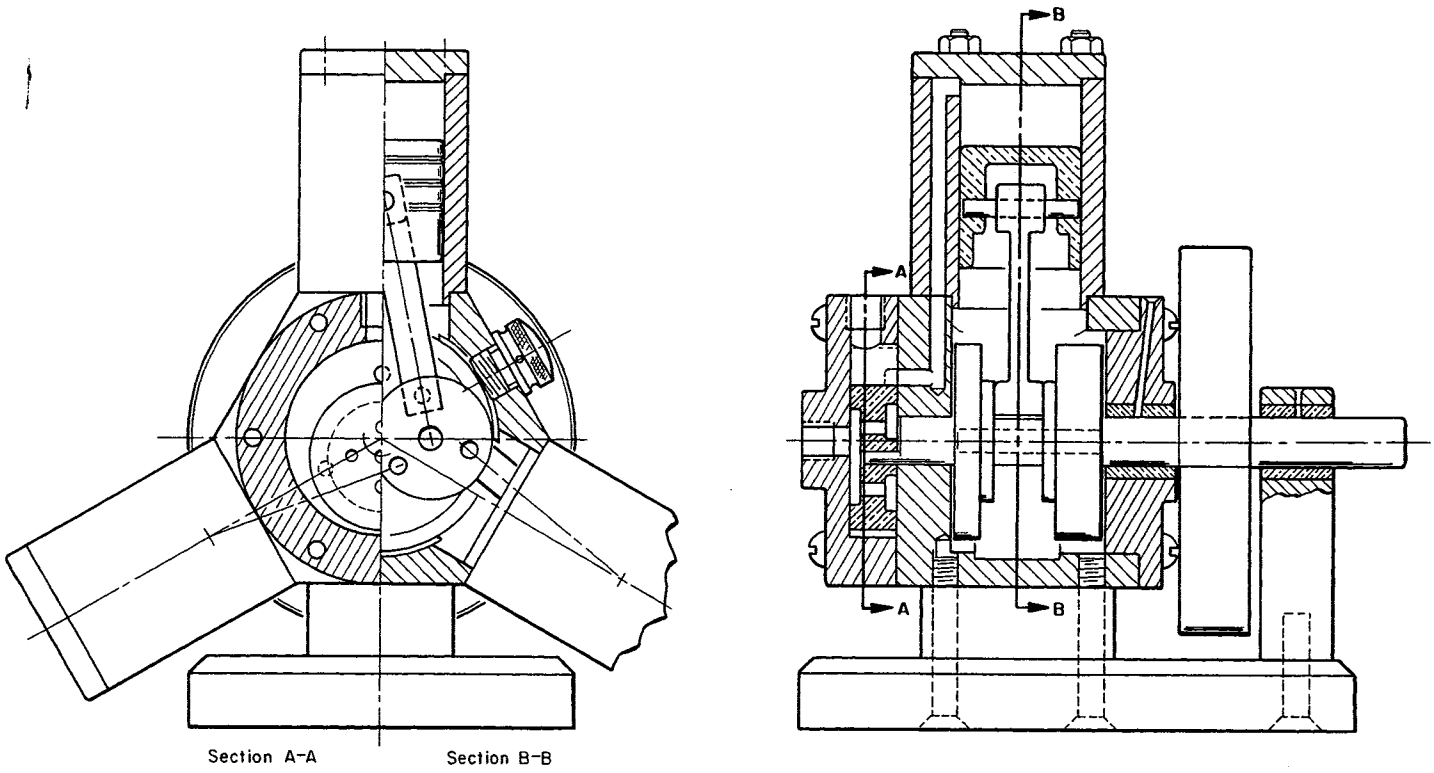
Make the **CRANKCASE COVER** with 6 accurately located #50 (.070") drilled holes on a 1-5/16" bolt circle and 1-5/32" dowel. NOTE: These are tap drill size for use on a jig on the crankcase. Enlarge later as needed.

Make the **VALVE HOUSING**, again drilling #50 for use as a jig. Take care to make the face and inside backwall parallel and smooth. This has to be just barely a free fit on the valve to make it as steam-tight as possible. Drill #23 (.154") through the backwall for later tapping the 3/16-40 MTP exhaust connection.

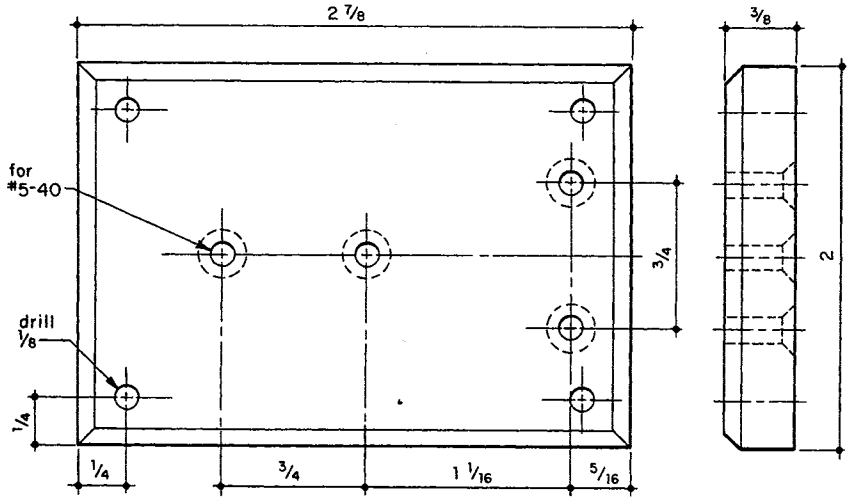
The **CRANKCASE** starts out as 1-3/4" round stock. First, chuck a 1-5/16" length in the three-jaw. Face the end and bore 1-5/32", 31/32" deep to a close fit on the Crankcase Cover. Bore and ream the 1/4" hole in the backwall. Since this is a very compact engine, a 1/32" x 7/16" undercut in the bore helps to provide clearance for the Connecting Rod Assembly. Use the Crankcase Cover as a jig and drill six #50 holes. Reverse in the lathe and turn the back face. At final assembly, this face must be smooth and flat. Make a turning fixture for mounting on an angle-plate mounted on the lathe faceplate. The location of the .065" pin and the diameter of the 1-5/16" pilot are important since this is the indexing means for turning the faces of the hexagon and making the three holes for the Cylinders. Center the jig squarely on the angle plate and spot the Crankcase on the lathe centerline. Index and machine the six faces. Prick punch the center for one Cylinder Mounting Hole; and using a center test indicator tunk the angle plate around until centered. Bore the three Cylinder Holes. Use the Cylinders as jigs to make the four Stud Holes for each Cylinder and the three 5/64" Steam Passages. Also, use the Cylinder to drill the three Cylinder Heads. Mark all these parts so they can be assembled in the spot where they were drilled. Use layout dye and transfer the center lines of the 5/64" Steam Holes around onto the back of the Crankcase. Using a "morphy" caliper, mark the



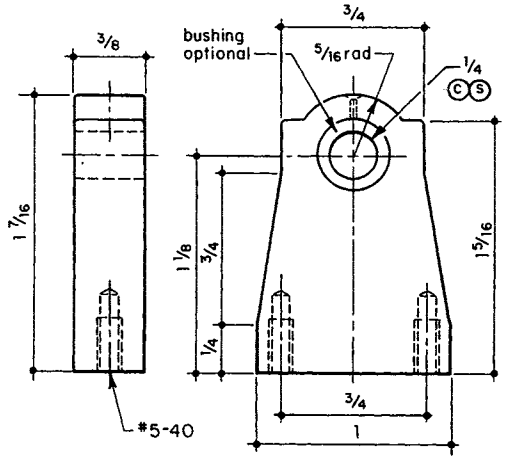




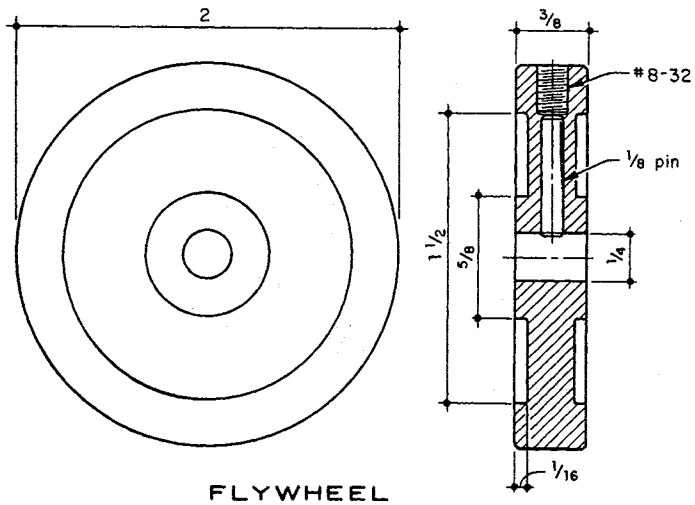
RADIAL ENGINE



BASE

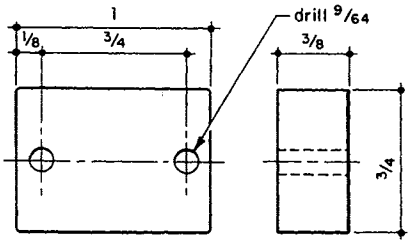


BEARING

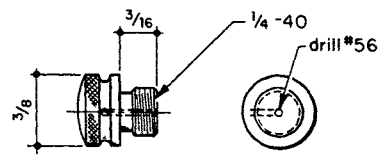


FLYWHEEL

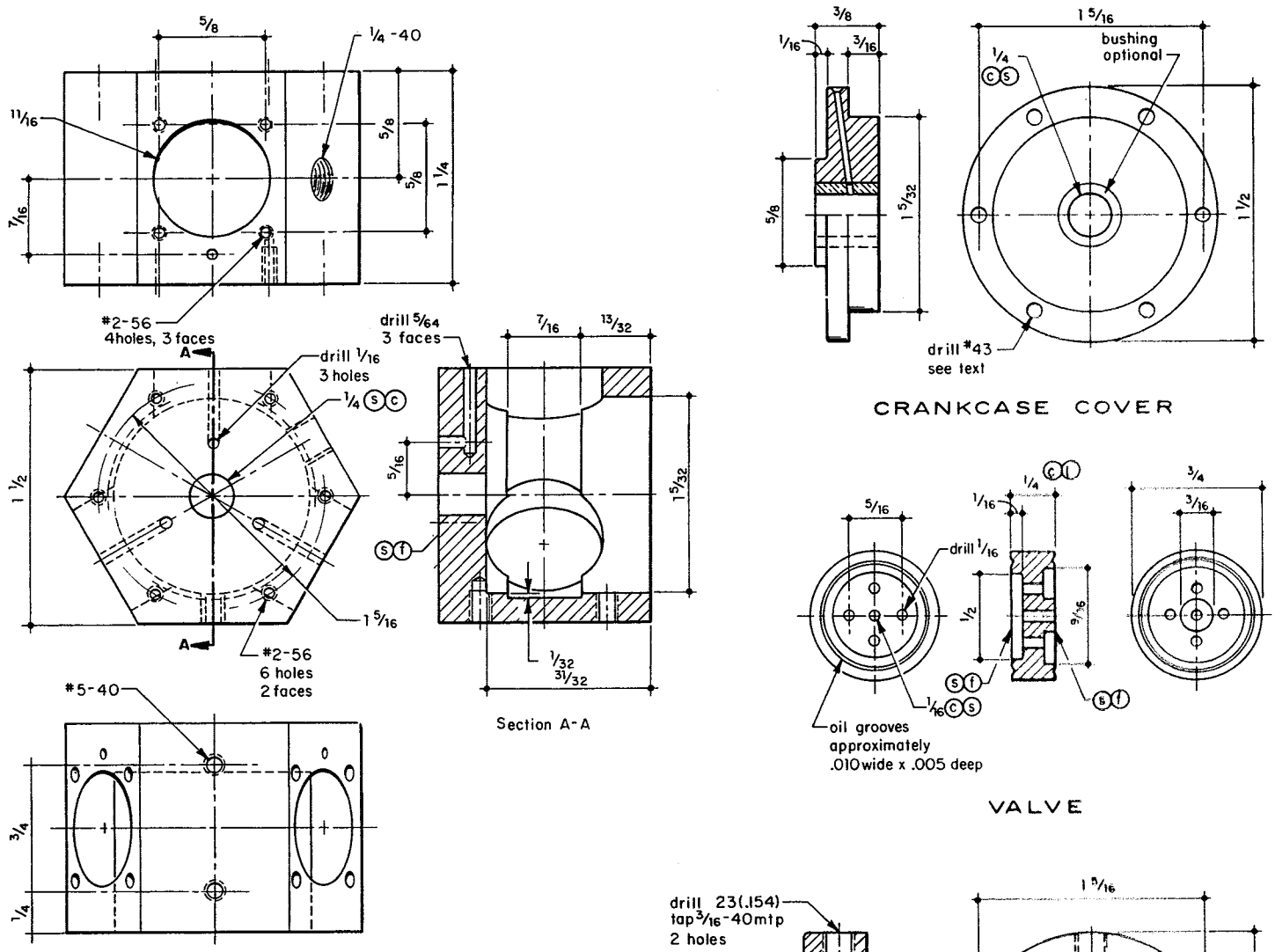
(s)	smooth
(c)	close fit
(f)	flat
(b)	braze or solder
(p)	press fit or "loctite"
(l)	parallel

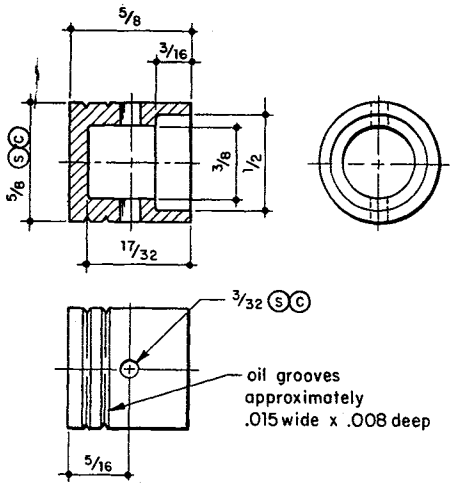


ENGINE FOOT

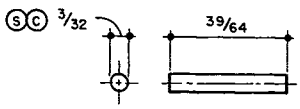


VENT PLUG

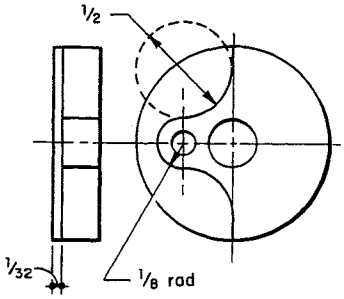

5/8
1/4 -40
11/16
5/8
5/8
1 1/4
7/16
#2-56
4holes, 3 faces
drill 5/64
3 faces
7/16
13/32
A
drill 1/16
3 holes
1/4 S C
1 1/2
5/16
1 5/32
S f
1 5/16
A
#2-56
6 holes
2 faces
1/32
31/32
Section A-A
#5-40
3/4
1/4
CRANKCASE
3/8
1/16
3/16
1 5/16
bushing
optional
1/4
C S
5/8
1 5/32
1 1/2
drill #43
see text
CRANKCASE COVER
5/16
1/4
C L
1/16
drill 1/16
3/4
3/16
1/2
9/16
S f
1/16 C S
S f
oil grooves
approximately
.010 wide x .005 deep
VALVE
drill 23(.154)
tap 3/16-40 mtp
2 holes
1 5/16
1/2
1
1 1/2
1/4
.154
S f L
drill #43
1/4 C
3/8
1/2
LOCATING PIN
VALVE HOUSING
drill #43
5/8
7/16
5/8
1
1/32
1/8
5/8
7/8
CYLINDER HEAD
B
drill #43
1
5/8 S C
B
drill 5/64
3/32
11/16
3/32
1/16
1 3/16
Section B-B
5/8
7/16
5/8
7/16
CYLINDER
3 Required

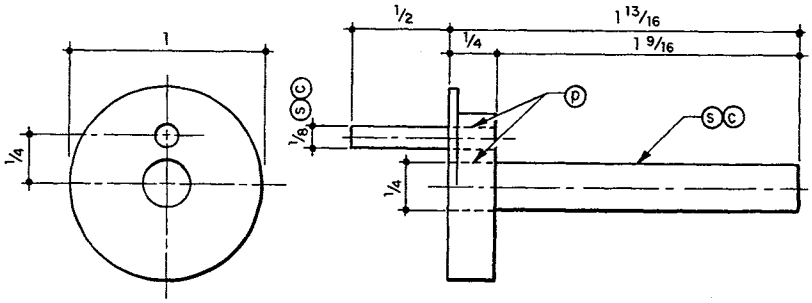


PISTON
3 Required

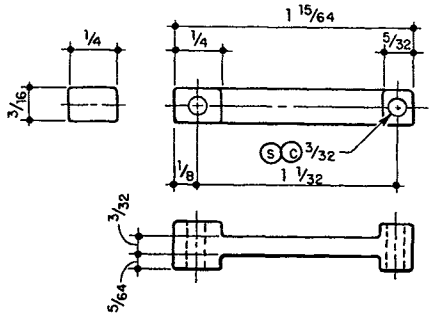


WRIST PIN
3 Required

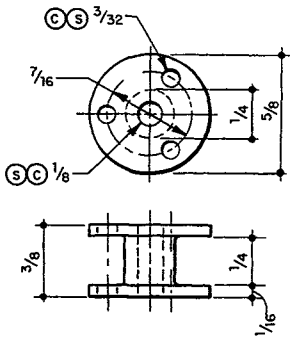




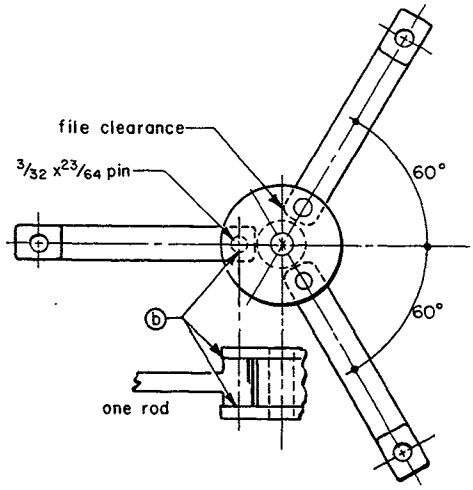
CRANKSHAFT



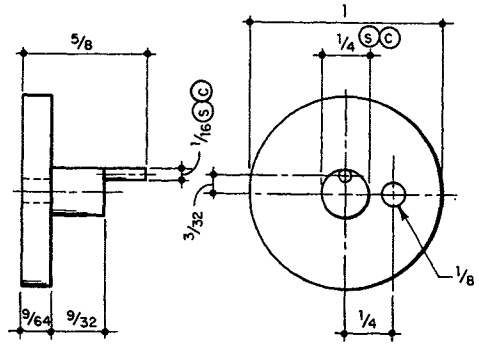
CONNECTING ROD
3 Required



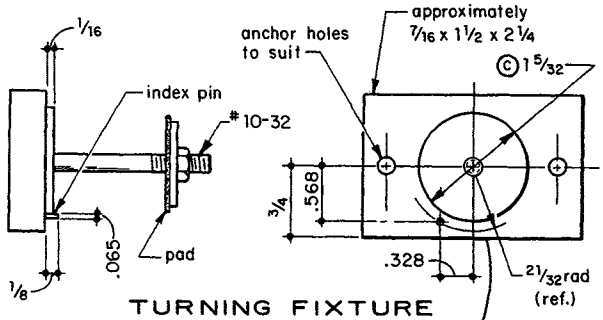
CONNECTING
ROD HUB



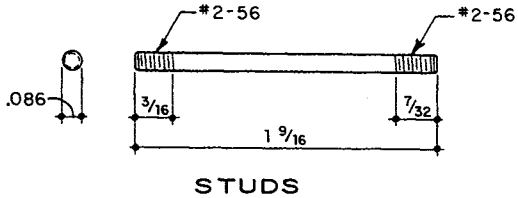
CONNECTING ROD ASSEMBLY



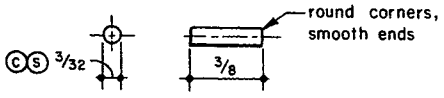
VALVE CRANK



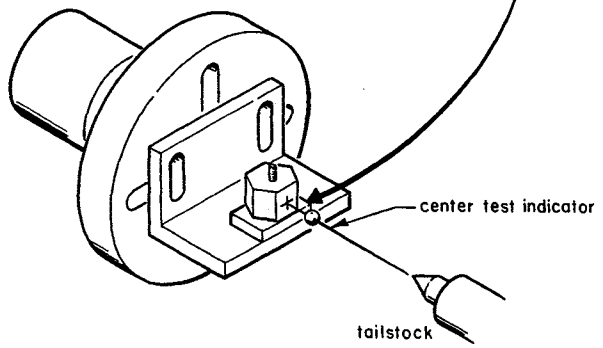
TURNING FIXTURE



STUDS
12 Required



HUB PIN
2 Required



centers of the 1/16" holes, 3/16" from the 1/4" hole, thus 5/16" from the center. Now carefully drill the 1/16" holes into the 5/64" holes. Make a Stepped Pin .154" and 1/4" diameter to locate the Valve Housing on the Crankcase. Spot so as to locate the holes on the centerlines through the hexagonal points. Tap-drill #50 for 2-56 thread.

The **VALVE CRANK** is a turning job. Turn the 1/4" diameter 31/64" long, then make a parting cut 5/32" from the face (to later clean up to 9/64") down to a diameter of 1/4". Offset 3/32" and turn the 1/16" diameter projection. Chuck on the 1/4" diameter, using a bit of thin copper to avoid chuck marks, and bring the Disk to 9/64" thickness.

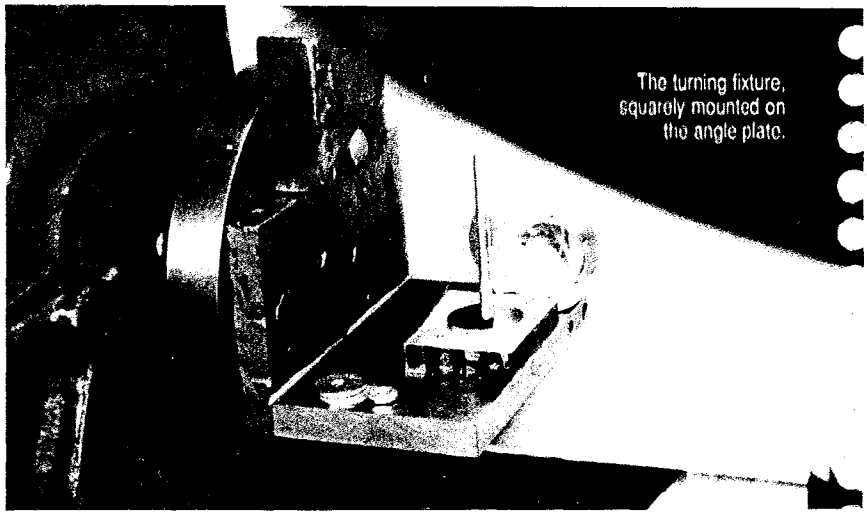
The **VALVE** is also a simple turning job, but flatness and parallelism are important. Turn the outside, face, and recess 9/16" x 3/16" x 1/16", adding the oil groove. Make an accurate 1/16" center hole. Make a rough parting cut at 17/64" down to about 3/16" diameter. With a keen parting tool, make a fine cleanup cut to bring the thickness to 1/4". This is to guarantee the two faces are parallel. Part off without touching this surface. Rechuck and cut away the 1/2" x 1/16" metal without touching the finished 1/4" rim. Add the oil groove. At assembly, using a very fine emery on a flat surface, lap this Disk or the Disk Housing or both until the Disk is just barely free in the Housing when assembled. Another important point on this Valve is to accurately hold the O.D. and the 9/16" diameters. This rim slides across the 1/16" ports, exposing them to steam and exhaust at the right amount and moment in each revolution. This Valve can be assembled with a thin coat of Moly Lube to fill the surface pores and prolong its sealing life.

The **CRANKSHAFT** is more or less simple, except the entire 1" diameter face is required to retain the two loose pins in the Connecting Rod Hub. It is hard to balance this engine so all the counterbalance possible is used. The milling cut shown is one way. Another way is to drill blind holes to remove metal. Even then, it will not be entirely free of vibration. So, mount the engine solidly. (If you care to try it, the Crankcase Cover can be made perhaps 1/8" shorter and the Crank Disk 1/8" thicker. There is also a possibility to remove some weight from the Pistons and Connecting Rods.)

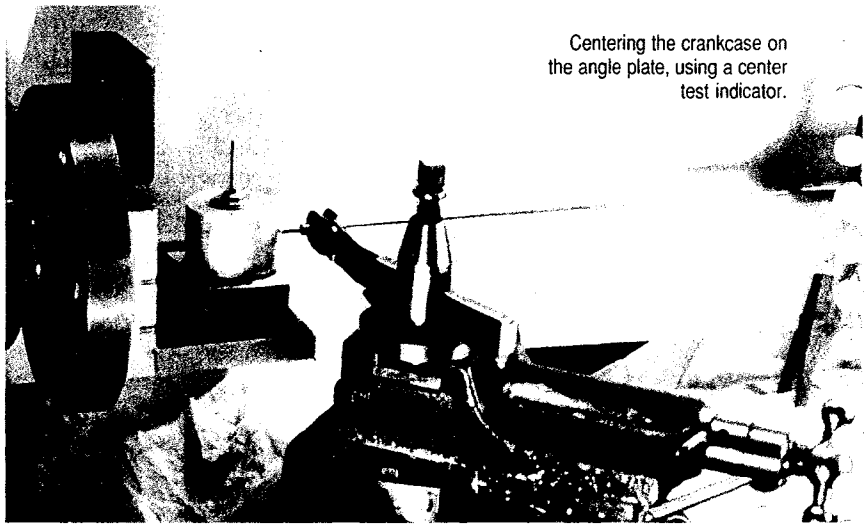
The **CONNECTING RODS** are all alike except one is soldered into the hub permanently. Try to make the Rod centerline pass through the hub centerline. A brass Pin is used in this Rod for easy soldering. The other two pins are bits of drill rod with polished ends to reduce scoring in between the Crank Disks.

The **WRIST PINS** are drill rod, a bit shorter than the Piston diameter. A tiny bit of **PISTON** metal is flowed over the ends of the Pins to keep them centered to avoid scoring the Cylinder Walls. A prick punch mark at the rim of the hole will form a tiny burr over the end of the Pin.

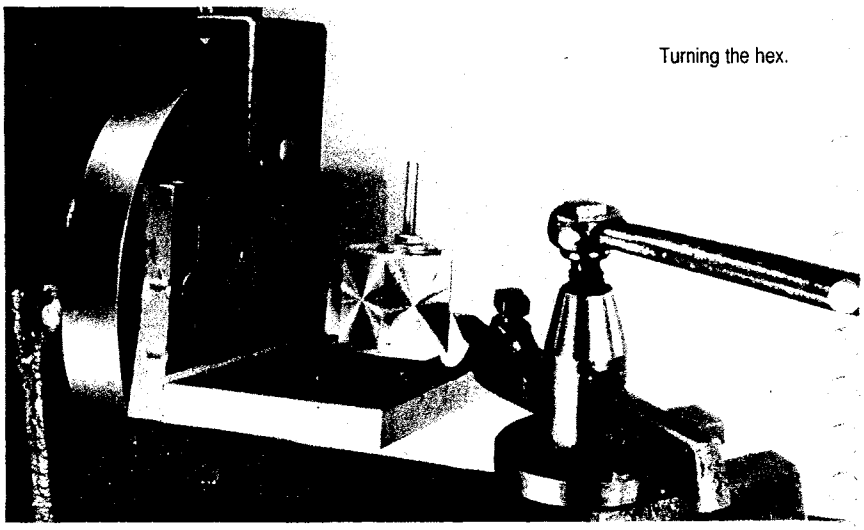
This Radial Engine should provide you with many hours of enjoyment in both the building and operation.



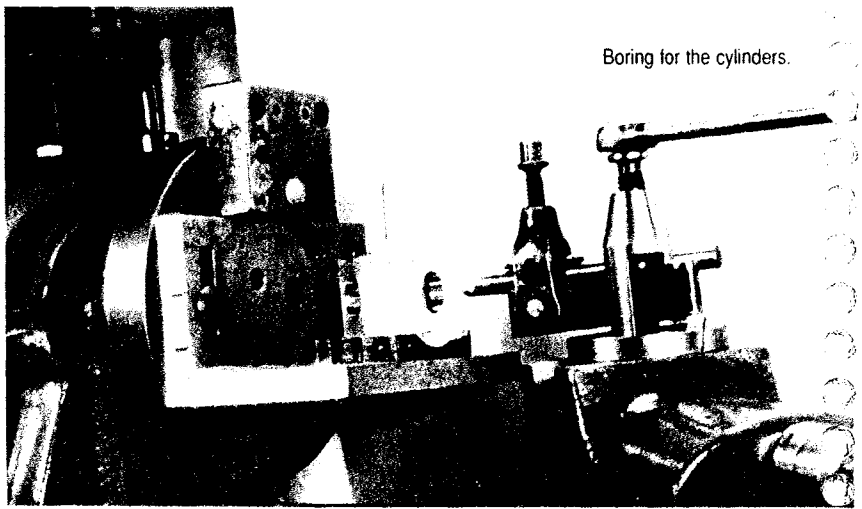
The turning fixture, squarely mounted on the angle plate.



Centering the crankcase on the angle plate, using a center test indicator.



Turning the hex.



Boring for the cylinders.

CHAPTER

12 Turbine and Centrifugal Pump

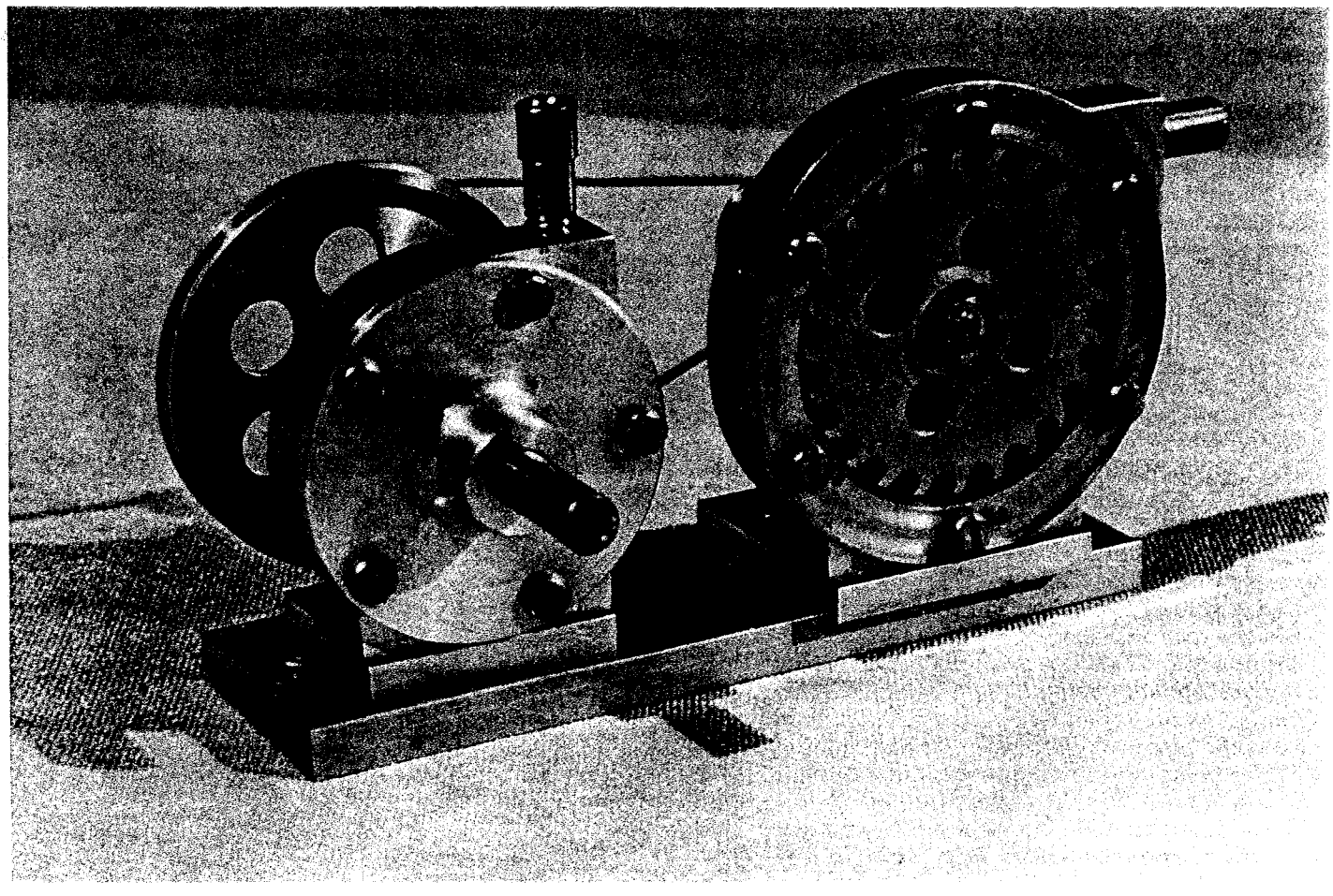
Turbine and centrifugal pump designs are quite deep subjects and will not be covered here. These are simplified designs based on dead reckoning and a smattering of experience, and will probably make experienced turbine and centrifugal pump engineers cringe. However, they do work and they show the principles.

The **COVER** is 1/16" clear plastic, although any 1/32" metal will do. You may use any convenient material you may have for this model.

Start the **HOUSING** with an accurate 1/4" x 1-5/8" x 1-5/8" block and lay out the outline, foot holes, cover screw holes and the steam connection. Drill the #60 nozzle before boring the 1-1/4" x 7/32" chamber. Complete all the tapped holes. Saw and file to the outline at the 13/16" radius. This is a place where Bob Maynard's filing machine would be a most handy tool for this job.

The **ROTOR** shown is the fourth one tried in this design and worked the best. It is simple and not difficult to make. Try for uniformity and balance, as this will spin up in the thousands of revolutions per minute. Start with a 1-1/4" diameter x 3/16" disk. Chuck in a 3-jaw, gripping about 1/16" of the width. Next, turn to 1-7/32" diameter and face true with a skin cut. Drill the center hole in stages with the final pass a #34 drill. While in the lathe, scribe the 35/64" and 9/32" radius circles. Reverse in the chuck, true up and face to about .164" thick and turn the O.D. to match the first cut. If you have an indexing fixture, proceed to drill the twenty-four 3/32" holes and four 3/16" holes. A dividing head is great for this type of drilling. If not available, pace off 24 spaces and drill in the drill press. Do the same for the four holes. Chuck a piece of 1/4" diameter steel in the 3-jaw with about 1/2" projecting. Turn to .112" diameter for about 3/8" for a close fit in the Rotor and thread #4-40 for 1/4". You now have a stub arbor for dressing down the Rotor to 5/32" thick and 1-3/16" diameter. This operation must be done slowly and carefully with a finely-honed tool bit. Remove it from the arbor and insert the Turbine Shaft. Then lay an accurate 1/4" strip of metal on the Rotor against the 1/8" diameter Shaft and scribe lines tangent to each hole as shown. File each opening to this line.

As with all models in this series, the steam connections are for 3/16" plastic tubing. Your first test will be most interesting as you begin running it it on pressures all the way from 10 to 60 psi. A pulley or collar should be used in order to keep the



Rotor centered in the Housing.

This **PUMP** is very simple. The material can be anything you may have on hand. If you pump water, it is well to use material thatwill not rust.

For the **HOUSING**, make the layout on an accurate block 3/8" x 1-1/4" x 1-1/4". Saw and file to the 1-1/4" diameter. Here, again, a filing machine is handy. Mount in the 4-jaw and bore the 29/32" x 7/32" opening and 1/4" center hole. Reverse it in the chuck and turn to 9/32" thick down to 3/8" diameter. Drill and tap foot holes and the discharge hole. Later use the head as a jig.

Next, make the **OUTER BEARING, BEARING and WASHER** with 5/16-40 threads as shown, although you can adapt to 32 threads. The 40 series of thread is a big help in making tiny model parts. Set the Bearing in the Housing with Loctite. The packing is 1/16" strands unraveled from braided graphited asbestos packing. The Spring has a wide range and should be a cut-and-try operation from your odds-and-ends box.

The **HEAD, SHAFT, PIPE CONNECTION** and **FOOT** need no comment.

The **IMPELLOR** is a tiny part that may try your patience. The one shown in the assembly requires careful layout and filing. A filing machine is great here, too, although it is possible to do the job by hand. Two alternates are shown which can be straight milling cuts.

To make the curved bladed Impellor shown, start with an accurate 7/8" diameter x 1/8" disk. Scribe the exact center and prickpunch. Set the dividers at 21/64" and scribe a circle. Without changing the setting, pace off six points on the circle and prickpunch. Scribe the 7/32" circle. Draw three centerlines through the six points. Drill the six 1/8" holes. Using the intersection of the three centerlines and the 21/32" circle as centers, scribe tangents to each hole as shown. Chuck in the 3-jaw and bore 3/32" and turn the 7/32" and 7/16" diameters 1/16" deep. Round the 7/32" hub for an easier flow of the liquid to the vanes. Use a jewelers saw and file to the curves as shown. Attach to the Shaft with a press fit or Loctite.

Assemble and give a test run at a fairly fast speed. A Centrifugal Pump requires flooding or priming to start pumping. If your Pump is above the supply level, a foot valve will be needed to retain a prime.

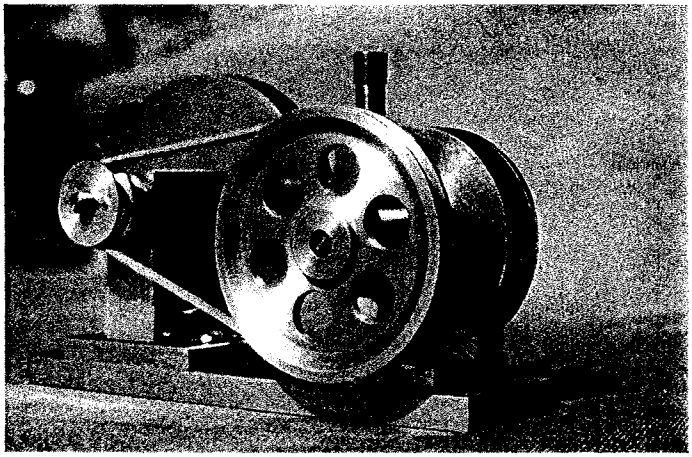
A pulley or collar should be used to keep the Impellor centered in the Housing.

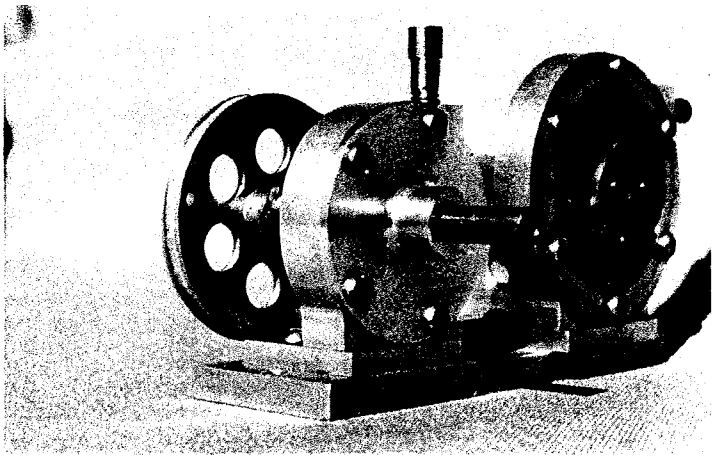
The Centrifugal Pump is mounted on a Base driven by the Turbine.

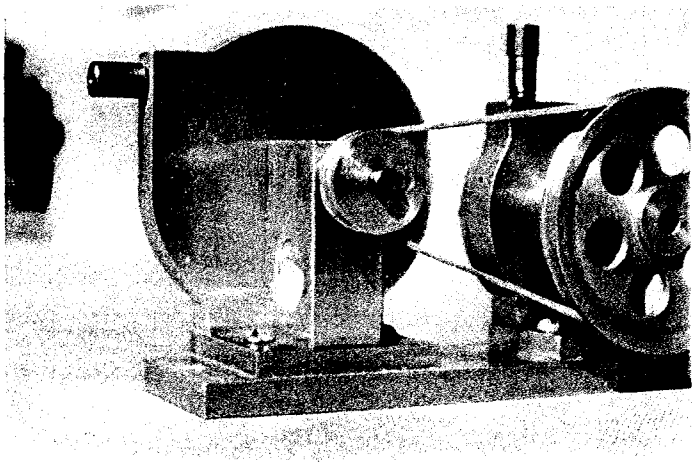
A common rubber band of about 1/16" square (cross section) runs in the V-pulleys. Try several to get one that will drive the Pump freely without too much pressure on the Bearings. The Turbine doesn't have much power until it is running at a fairly high speed.

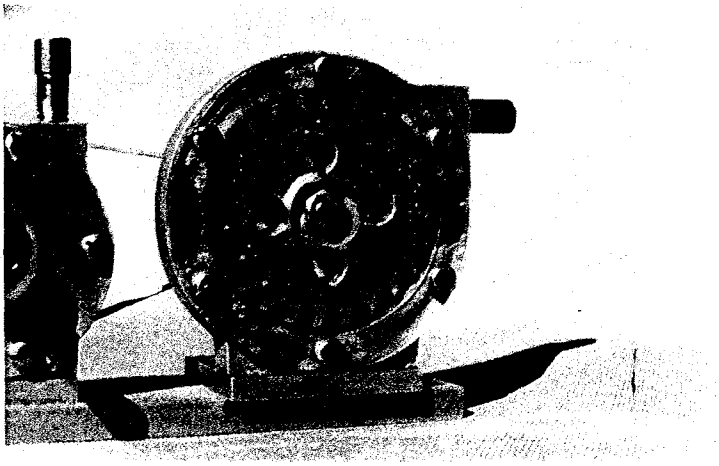
The parts shown require little comment. You may have Erector pulleys or such that can beadapted. The **BASE** and **PULLEYS** are aluminum, though any odds and ends can be used. It is well to consider rusting when selecting material if water is to be used. This model was tested on water and then drained to prevent rust on the Shaft. It should have been made of stainless steel. Pumping light oil will lube the Inner Bearing. It showed a nice stream at high speed with the turbine running on about 60 psi air.

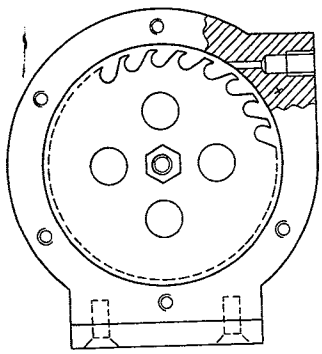
This is a cute little unit and it is fun to run and show off.

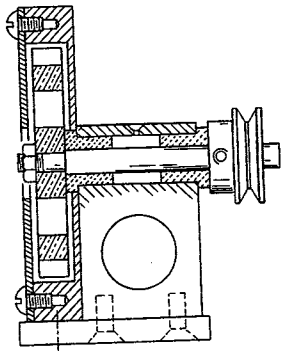




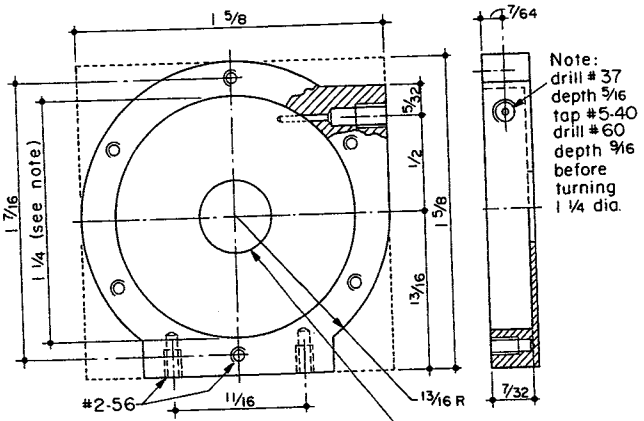


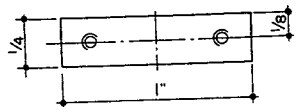




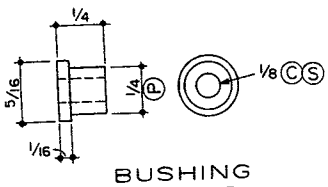


TURBINE

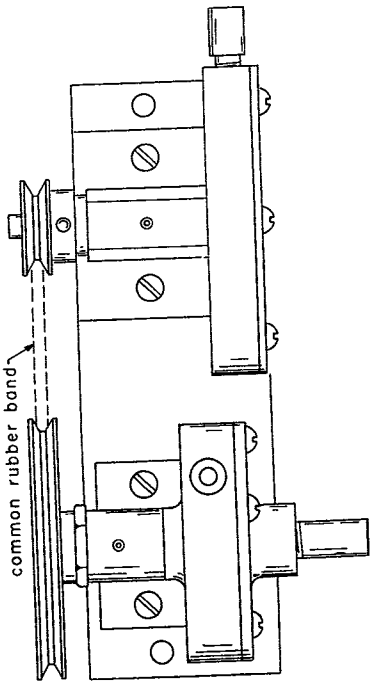


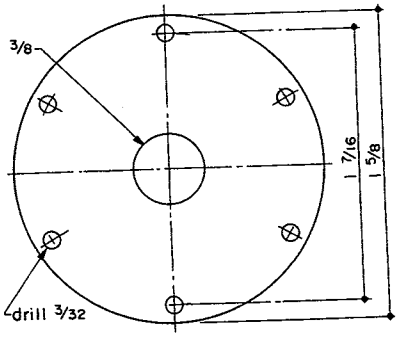


HOUSING
Aluminum

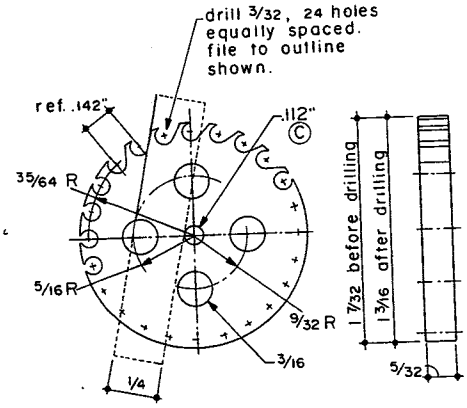


BUSHING
"Oilite" or Bronze
2 Required

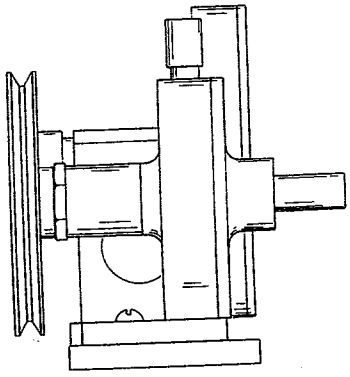




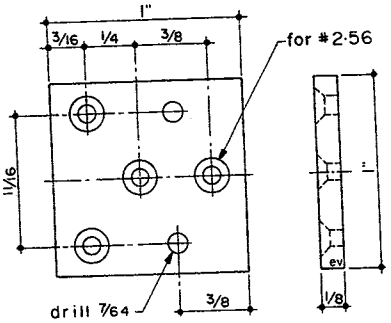
COVER
1/32" Brass



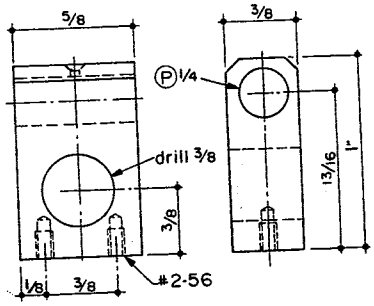
ROTOR
Aluminum



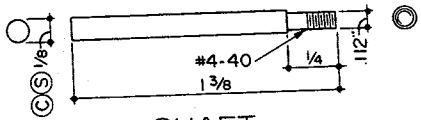
TURBINE AND
CENTRIFUGAL PUMP



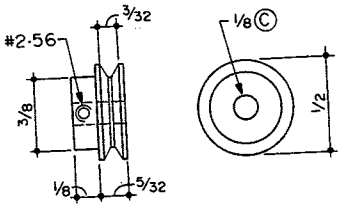
FOOT
Any Metal



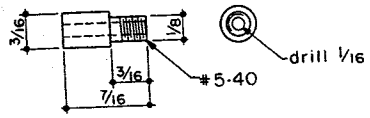
BEARING
Aluminum



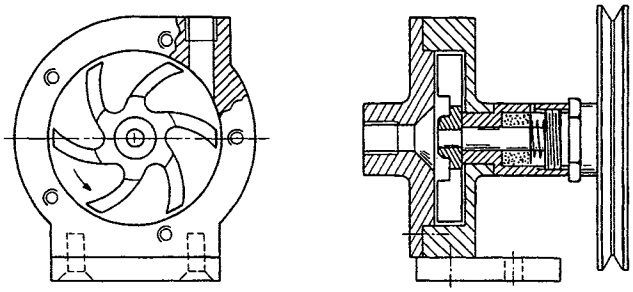
SHAFT
Stainless Steel



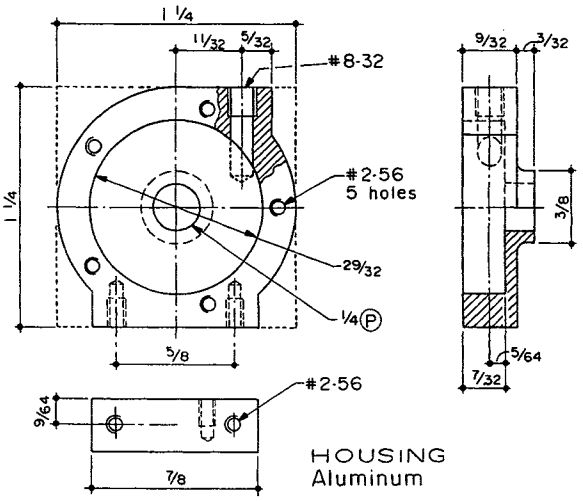
PULLEY
Aluminum



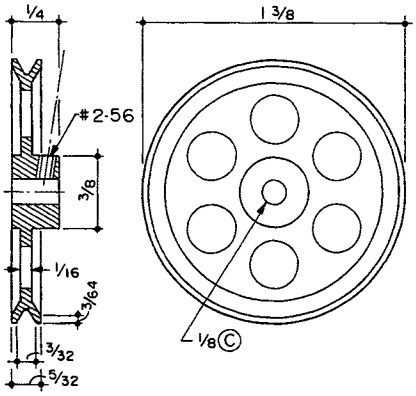
STEAM CON.
Brass



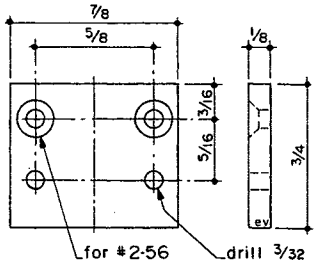
CENTRIFUGAL PUMP



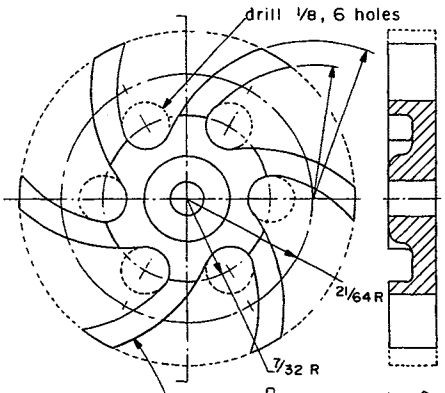
HOUSING
Aluminum

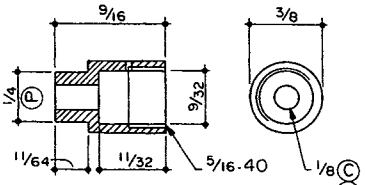


PULLEY
Aluminum

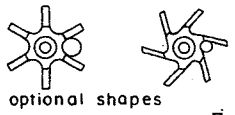


FOOT
Any Metal

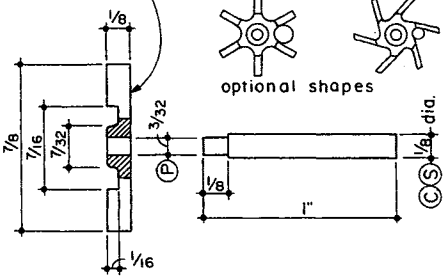




BEARING
Brass

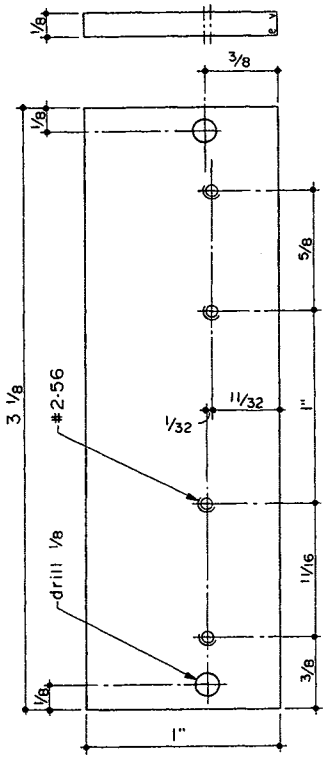


optional shapes

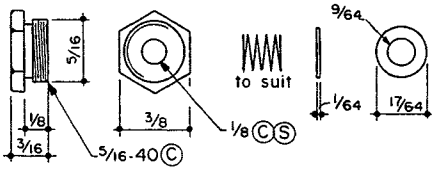


IMPELLER
Brass

SHAFT
St. Steel

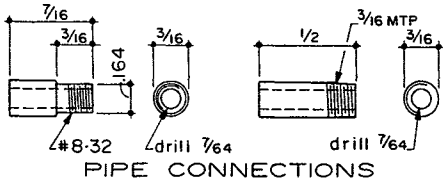


BASE
Any Metal

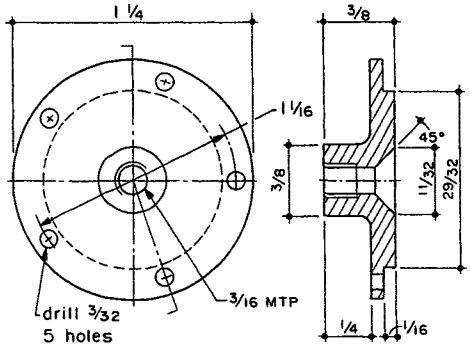


BEARING
Brass

SPRING WASHER
St. Steel Brass

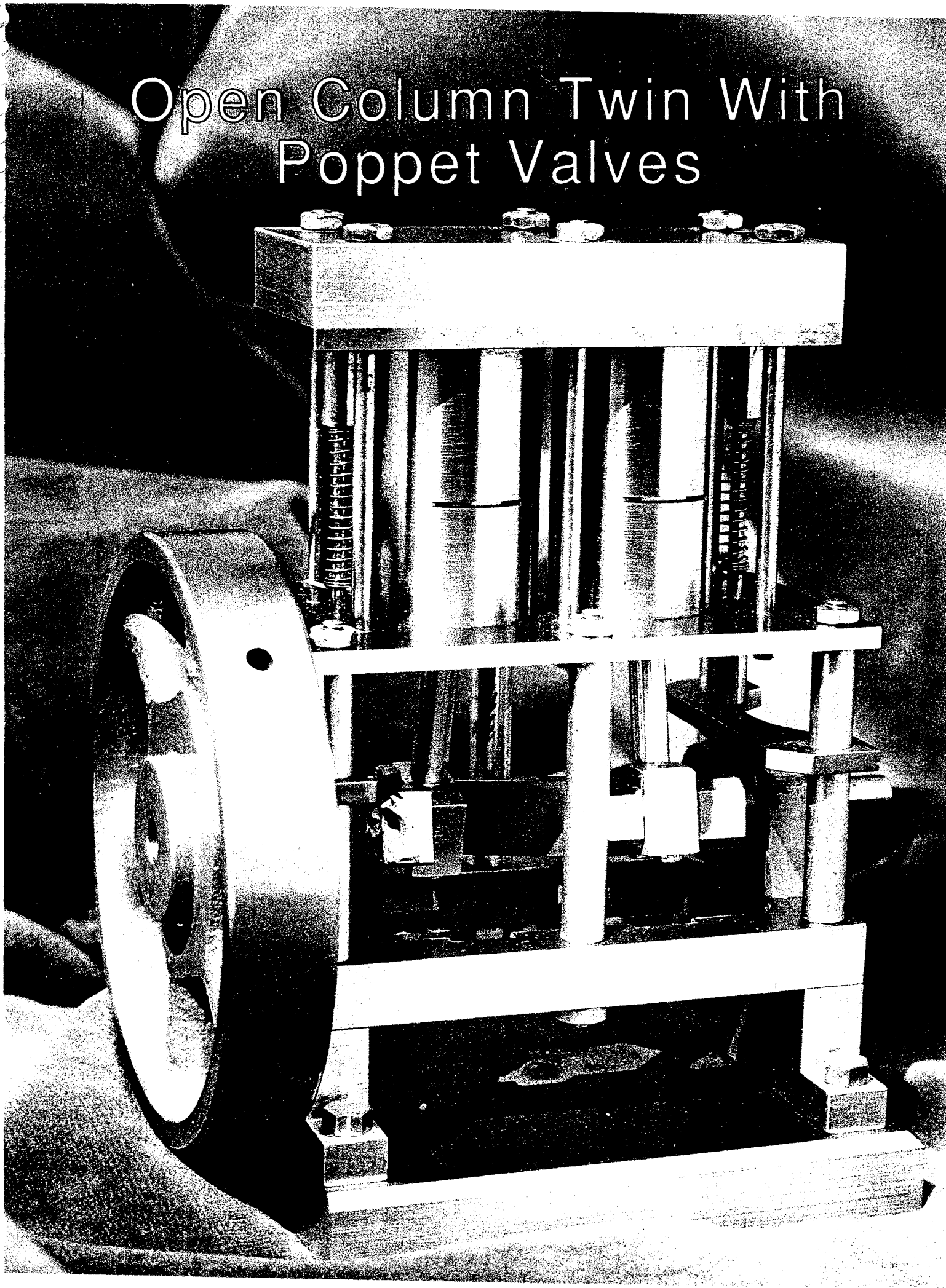


PIPE CONNECTIONS
Brass



HEAD
Aluminum

Open Column Twin With Poppet Valves



CHAPTER

13 Open Column Twin With Poppet Valves

A while back, Mr. D. A. Drayson of Westmont, Illinois, sent us a copy of a page from *The Boy Mechanic* Magazine published in 1913, thinking that it would be a good subject for some of our model makers. It showed a two-cylinder poppet valve engine made from odds and ends. The article states that the engine was made with simple tools, " ... the pistons were done in a machine shop for a small sum." On the basis of the 1-1/2" tubing used for the cylinders, the original was about 8" high with a heavy 4-1/2" flywheel "borrowed from another model." On the engine shown here, 1" O.D. tubing is used for the Cylinders. The Flywheel is 3-1/2" in diameter.

The original design showed solid valve rods. Adjustable Rods are used here and they turned out to be handy in making the rise the same for both Valves. When setting the Cams, the position was set so the top of thePiston was just ready to exhaust when the Valve tripped. Then, one-half turn around, the Valve STARTS to open just a degree or two after dead center. If the Valve Stem is "long," it rides the Cam longer and rises higher and opens early. If the Valve starts to open before top dead center (TDC), the stem can be shortened about .010" for a trial and, perhaps, bring the START after TDC. This changes the amount of flow, so this procedure can go only so far and then the flow is restricted and it is then necessary to cut the notch on the Cam back, say .025" for a trial. This shortens the time the Valve is open. This timing will take time and patience and you will disassemble several times.

This engine idles nicely on 5 to 10 psi air but, at 40 psi, the Valves were noisy because the Springs were set a bit tight. The Spring setting is a bit of dead reckoning. If you think the Spring pressure is low, drill a second set of holes in the Valve Stems. These Springs were picked out of about eight salvaged from ball point pens. One pair was about 1" long and the other 1-3/16". Either length is acceptable.

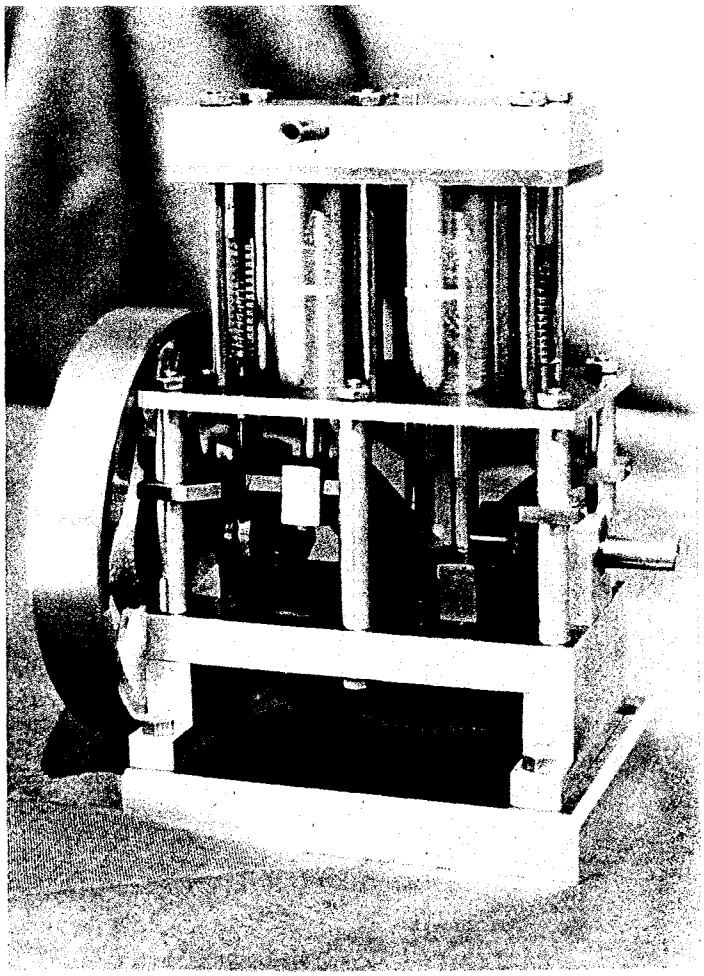
There is no provision for controlling the exhaust; it just escapes free out of the una-flow ports. The Valves showed slight leakage and were lapped in. Thin, approxiately .008" thick, Gaskets were added at the top end of the Cylinders. The 7/32" diameter Valve Seat that projects through the middle Valve Plate had a few thou clearance and was sealed with Permatex. So you have lots of fun, "fiddling', fussin' filin' and fittin'!"

The **SUB-BASE** is not detailed. It can be most any form or material you wish. Its weight helps reduce vibration.

The **FEET, COLUMNS, TIE RODS** and **BASE** need no special attention.

The **TABLE** is a careful layout job. Chuck this part into a 4-jaw or clamp it to a faceplate to turn the Cylinder recess. Center with a center-test indicator. Make these recesses the same depth.

The **LOWER VALVE PLATE** is brass for easy soldering at the valve seats. Turn the Cylinder recesses as mentioned for the Table.



The **MIDDLE** and **TOP VALVE PLATES** are straight milling and drilling jobs. The Base, Table and three Valve Plates must match each other for a good, square assembly. Upon assembly, solder or Loctite the Tie Rods into the Lower Valve Plate. Tighten the Tie Rods onto the three Valve Plates before tightening the table-end of the Rods to avoid leakage between the Plates.

The **BEARINGS** can be brass, bronze or bushed aluminum. The Bushings on the engine shown are "Oilite." Often, on a set of Bearings like this, the Shaft will bind when the Bearings are tightened down to the Base. To reduce this condition, insert a straight, close-fitting 1/4" rod through the two Bearings and grasp all three with the Bearings about 3" apart. Lightly draw the mounting surfaces across a large fine file. The first pass will show the high spots. Do this until the entire mounting surface bears on a flat surface. This can also be done on emery cloth on a surface plate or plate glass.

The **VALVE GUIDE** is brass or bronze and, again, the holes must match the related Columns and Valve Stems.

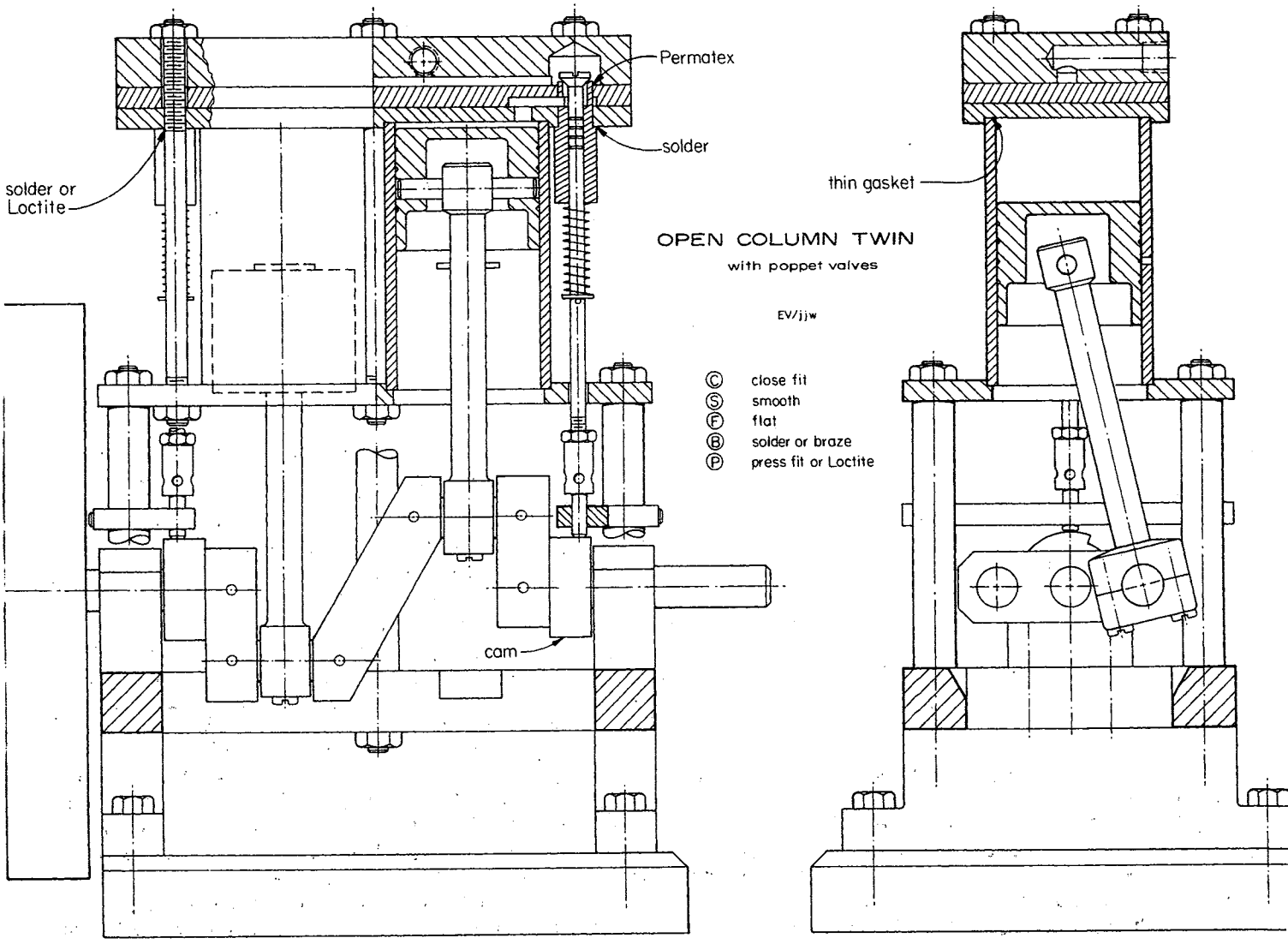
The **CRANKSHAFT** is machine steel and drill rod, asembled with Loctite and Spring Pins. Make the center throw 51/64" wide and cut away the corners after reaming the holes. At assembly, set a slide calipers to 2-5/64" and lock. Set a rule depth gauge at 1-11/32" and an inside calipers at 21/64". Assemble the entire Crankshaft loosely. Apply Loctite at joints **A** and **B** only and set aside to cure on a flat surface. When cured, slide the pieces apart enough to apply Loctite to all the remaining joints and slide back together, using the calipers to space the parts. When cured, add the Spring Pins and mill away the sections as shown.

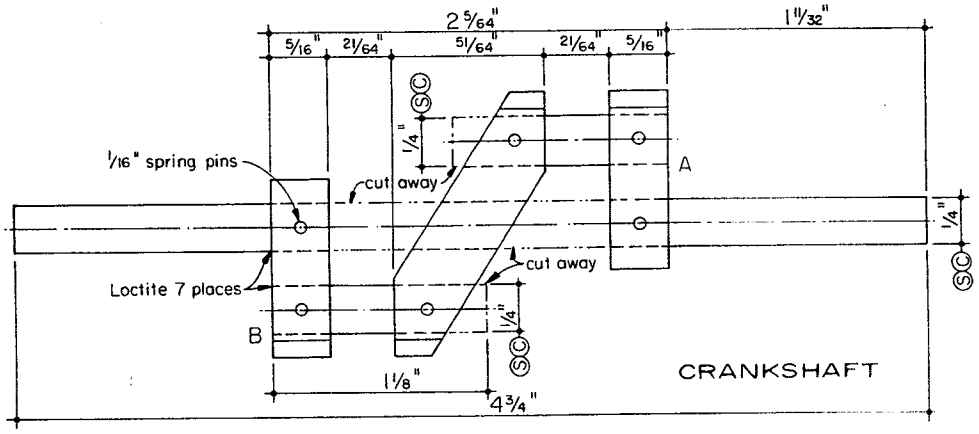
The **CYLINDERS** were made of steel on the model shown. Brass would have been preferred, but none was in the "odds and ends department." Common galvanized pipe was used. Ordinarily, iron pipe is tough to cut and get a fine finish but this time it was not bad. Make the two Cylinders the same length so the Table and Valve Plate will be parallel. When everything from the Table on down is done, assemble and insert the Pistons and Cylinders. Hold the Cylinders in place while measuring from the top of the Cylinder down to the top of the Piston in its lowest position. Use this dimension as the bottom edge of the una-flow port.

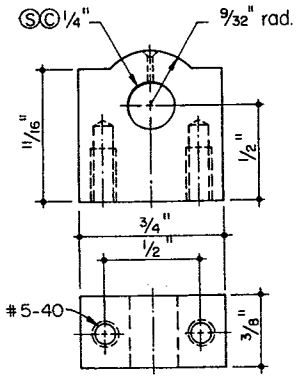
The **PISTONS** are plain turning and drilling jobs. If the 7/8" bores in the Cylinders were not reamed, they should be fine-turned as near alike as possible. Fit the Pistons to the Cylinders, mark them and keep each with its own.

The **CONNECTING RODS** start out as two accurate aluminum or brass bars 5/16" x 19/32" x 2-1/2". Lay out and TAP-drill for the two screws. Squarely cut a 7/32" piece off the end with a slitting saw in the mill. Tap the Rod and drill the Cap #43. Assemble and dress the four sides flush and neat. Lay out a centerline the full length of the 19/32" face of each piece. Carry this centerline around onto the end and prick punch the exact center. Prick punch the point on the centerline at the Cap joint. From this point, lay out the Wrist Pin center. Squarely drill and ream the 1/4" and 1/8" holes. Chuck in a 4-jaw with about 1/4" projecting and center with a center-test indicator. Make the center hole with a tiny center drill. Mark two adjacent jaws with chalk. Loosen these two jaws and move the piece out with about 2-1/8" projecting. Hold the piece against the tailstock center while tightening the two chalked jaws. Complete the turning and dress to 2-5/32" from the joint.

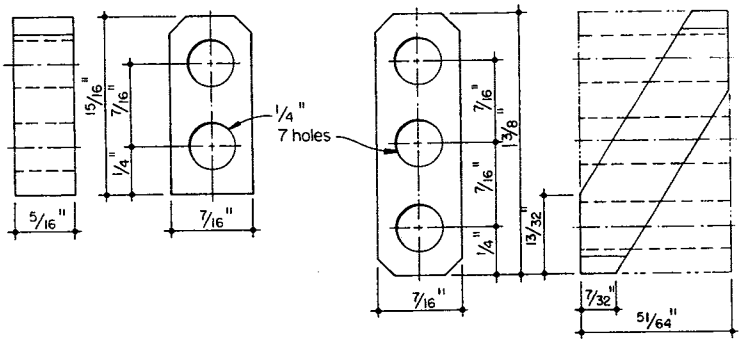
The **WRIST PIN** is simple drill rod. At assembly, a slight prick punch mark will flow some Piston metal over the ends of the Pin to keep it in





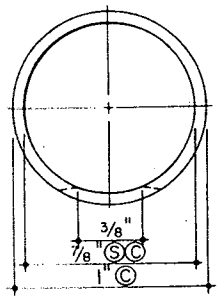


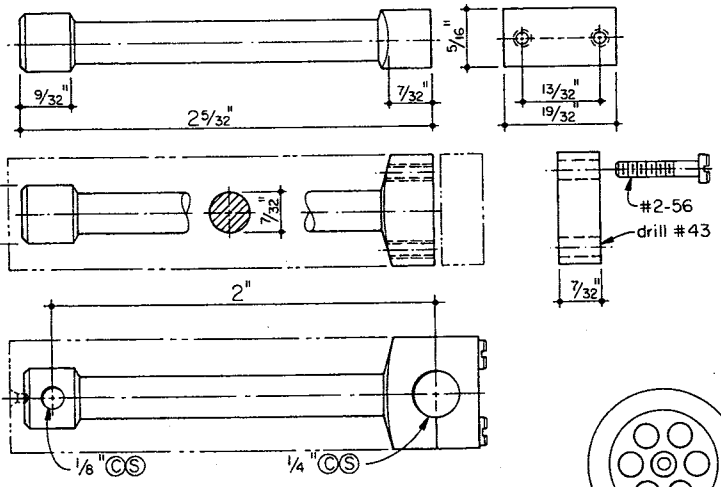
BEARING
2 Required



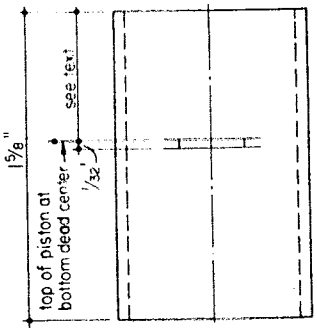
END THROW
2 Required

CENTER THROW

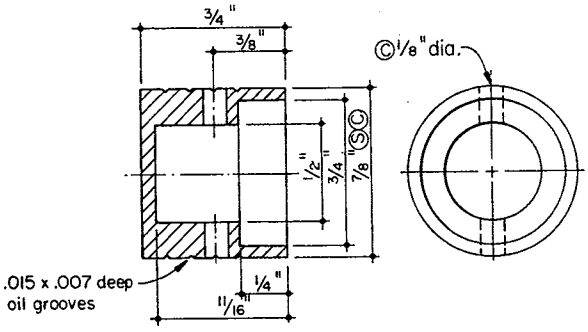




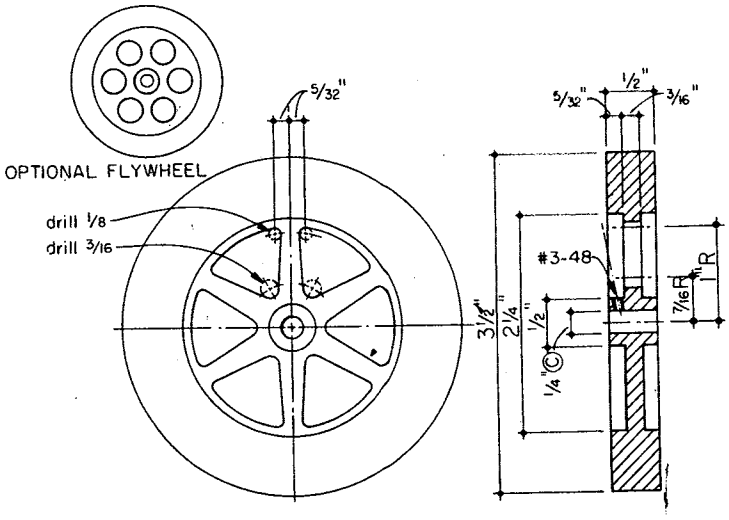
CONNECTING ROD
2 Required



CYLINDER
2 Required

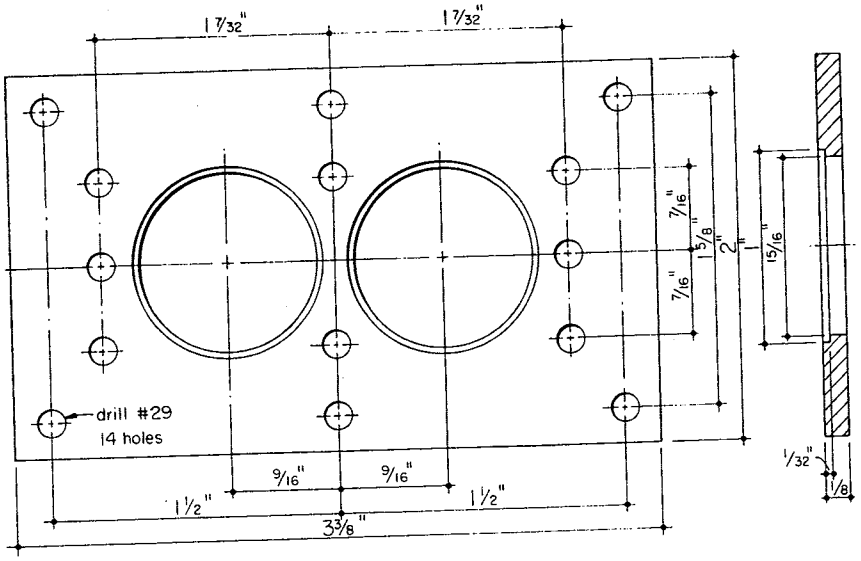


PISTON
2 Required

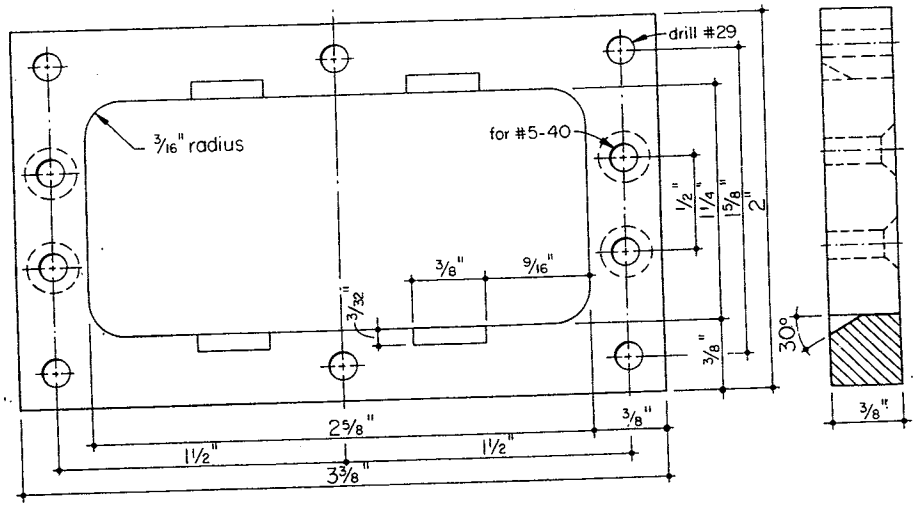


FLYWHEEL

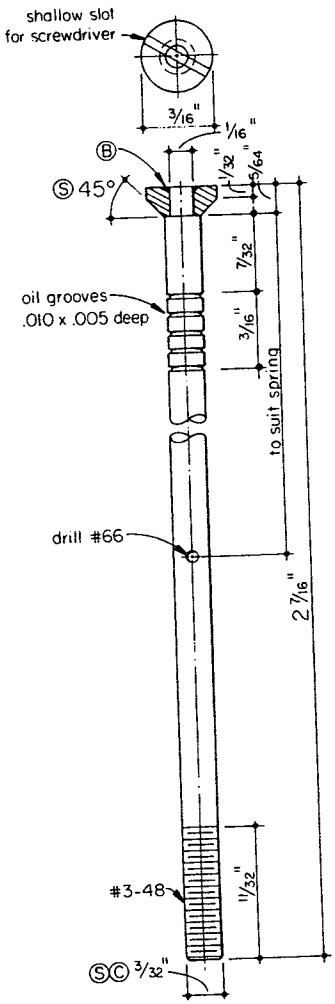
EV/jjw



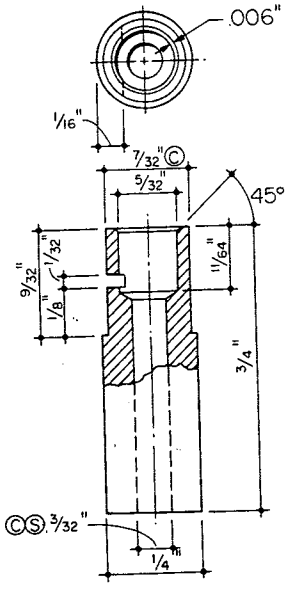
TABLE



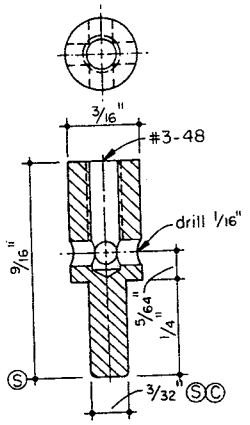
BASE



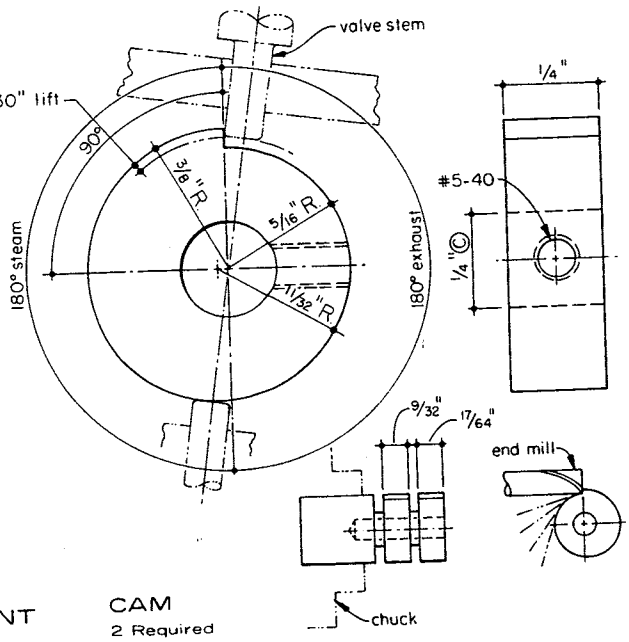
VALVE
2 Required



VALVE SEAT
2 Required

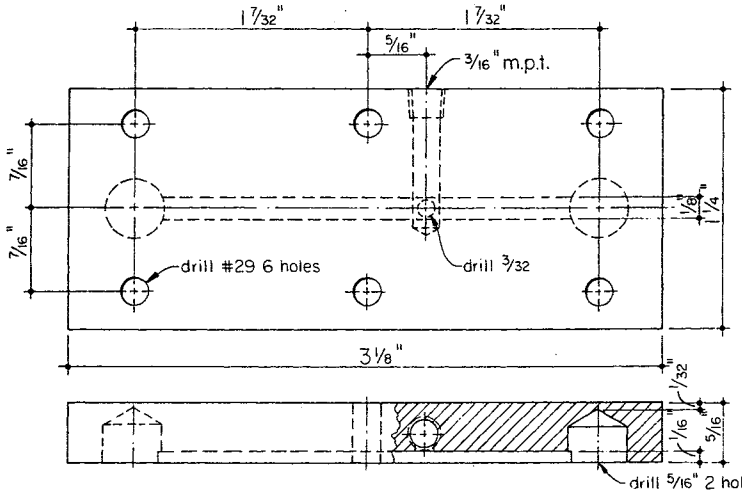


VALVE ADJUSTMENT
2 Required

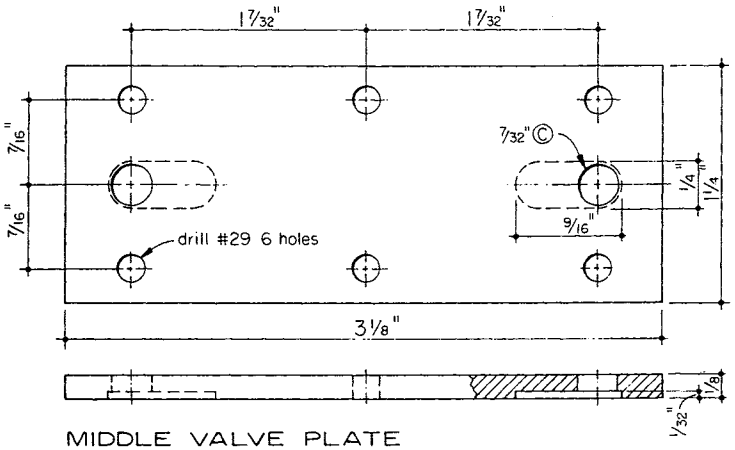


CAM
2 Required

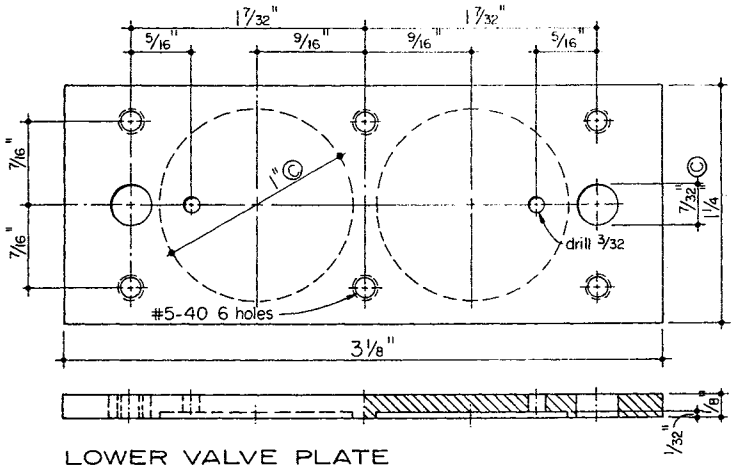
EV/jjw



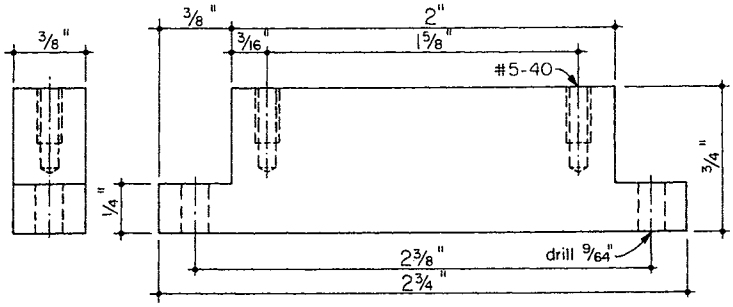
UPPER VALVE PLATE



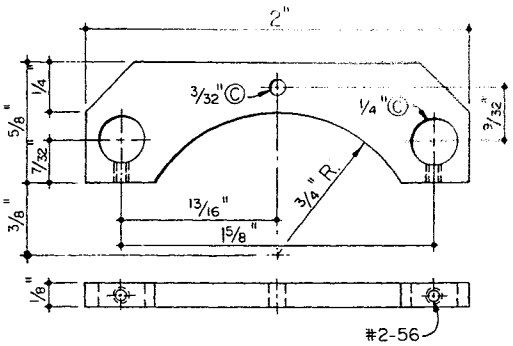
MIDDLE VALVE PLATE



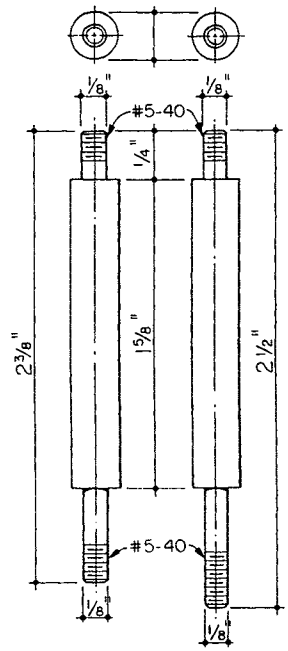
LOWER VALVE PLATE



FOOT
2 Required

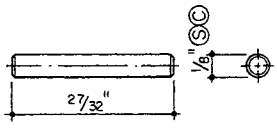


VALVE GUIDE
2 Required

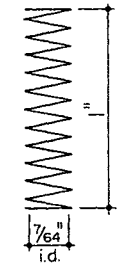


2 Req'd. 4 Req'd.

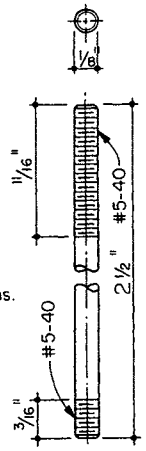
COLUMNS



WRIST PIN
2 Required



VALVE SPRING
2 Required



TIE ROD
6 Required

EV/jjw

place. Dress off any raised metal on the piston surface with an oil stone.

For the **CAMS**, chuck a piece of 3/4" diameter cold finish steel about 1-1/2" long in the 4-jaw with about 7/8" projecting and center with an indicator. File lightly and polish the 3/4" diameter. Face the end and make a light center prick with a sharp tailstock center. Remove the chuck from the lathe and take to the bench and coat the end of the stock (still in the chuck) with layout dye. Carefully pick up the prick mark and make a better center with a prick punch. Scribe a 5/16" arc. Return the chuck to the lathe and bore and ream for 1/4" shaft. Make a parting cut about 17/64" from the end and another about 9/32" from the first, down to a neck diameter of about 3/8". Remove from the chuck and mount in the 3-jaw chuck on an indexing fixture. Mount a 1/4" end mill and spot at the lines for the notch as shown on the drawing. Use an indexing plate with about 36 divisions and mill successive cuts at each division. When you reach the point just before the curve starts to rise, back off at each cut so you do not lose the layout line. Remove from the mill and spot the set screws about 90° from the notch where the follower never touches. Saw the Cams off the stock and face off the three faces to 1/4" thickness on a stub arbor in the lathe. Anchor these two Cams on a 1/2" length of close-fitting 1/4" rod, notches even and holding with the set screws. Use a filing machine and dress to the line. Be sure of a good polished surface from the setscrew around to the notch. Do this with emery cloth on a flat plate. If you do not have indexing and filing equipment, complete one Cam by carefully hand-filing to the line. Use the 1/4" rod, 1/2" long, and place the layout side of this Cam against the other blank and scribe round it. Then file that Cam to the line. Mount the two together on the stub Shaft with the two layout faces outward. Line up the notches and carefully dress and polish to the lines. If this engine has a hard-working future, case harden and polish these Cams.

The same could be said about the **VALVE ADJUSTMENT**. This piece is brass on the model shown and is a lathe job calling for fair concentricity. The cross holes make it a bit easier to tighten the lock nuts.

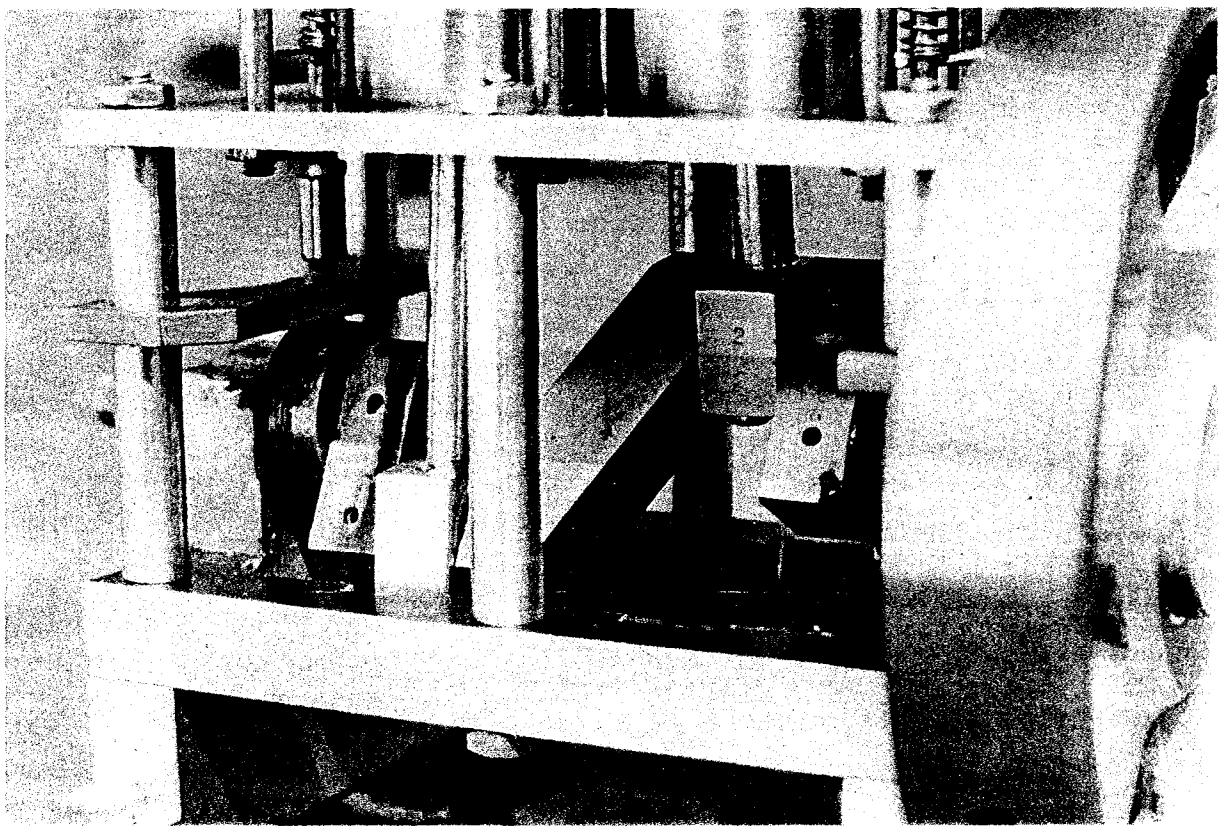
The **VALVE SEAT** is a turning, soldered with 430° solder into the lower Valve Plate. Alignment with the Valve Guide is important for free movement.

The **VALVES** are brass rod, close-fitting in the guides with a soldered-on head. Silver solder was used since it was thought that soft solder might not take the pounding. After brazing, the rod was carefully chucked, centered and turned so the tapered valve surface would be concentric with the valve rod.

At assembly, apply a dab of soft grease to the Cams and lower Valve Guide. Cut out an arrow from colored adhesive tape and locate on the table to show the direction of rotation. The Cams and Valve Stems can be damaged if a vigorous boost is made in the wrong direction. A hard bump on the Cams can change the timing.

The **FLYWHEEL** on the model shown is a cast iron gear with the teeth turned off. It had a 3/4" bore which was plugged and rebored to 1/4". It is a bit clumsy, but the engine needs a fairly heavy wheel. A Flywheel can be made from 1/2" flat stock. Lay out and drill the twelve 1/8" holes and six 3/16" holes as shown. Chuck in a 4-jaw, gripping about 1/8" of the stock thickness. Turn the O.D., recess 2-1/4" x 5/32" and shaft bore. Reverse in a 3-jaw chuck, gripping on the rim I.D. and finish the O.D. and second 2-1/4" recess. Remove from the chuck and apply layout dye to one entire web face. Scribe lines tangent to the holes a shown and saw and file the spokes to shape.

You now have another fine example of the Steam Era to add to yoiur collection.



CHAPTER

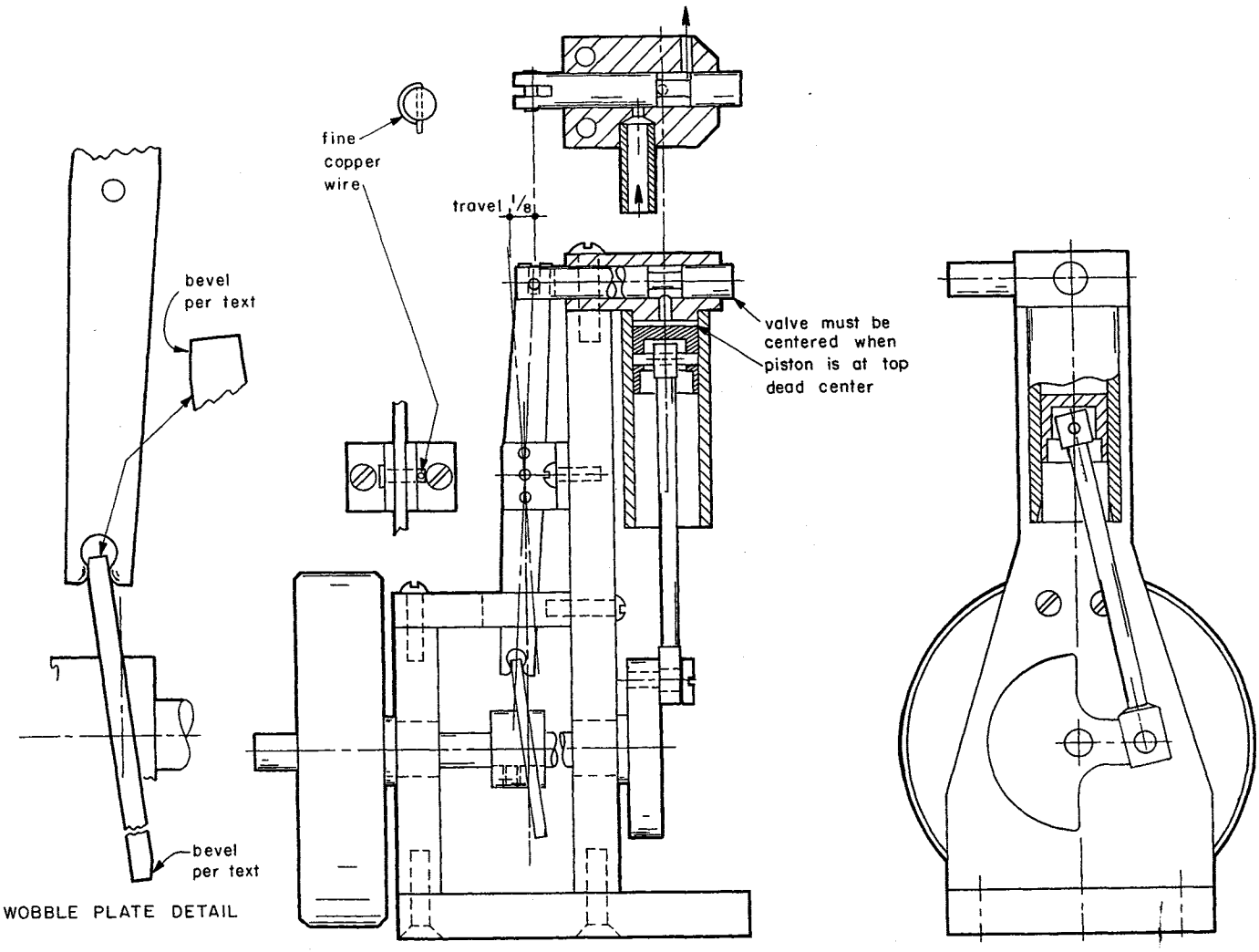
14 Wobble Plate Engine

This isn't a model of any large engine and it doesn't have the usual construction and appearance of small steam engines. Bernard Leahy told of a model he saw with a cylinder made from the tube of a bicycle tire pump and fitted with a valve across the end. This is a showoff engine using this idea and an unusual valve mechanism. You surely can see a lot of action.

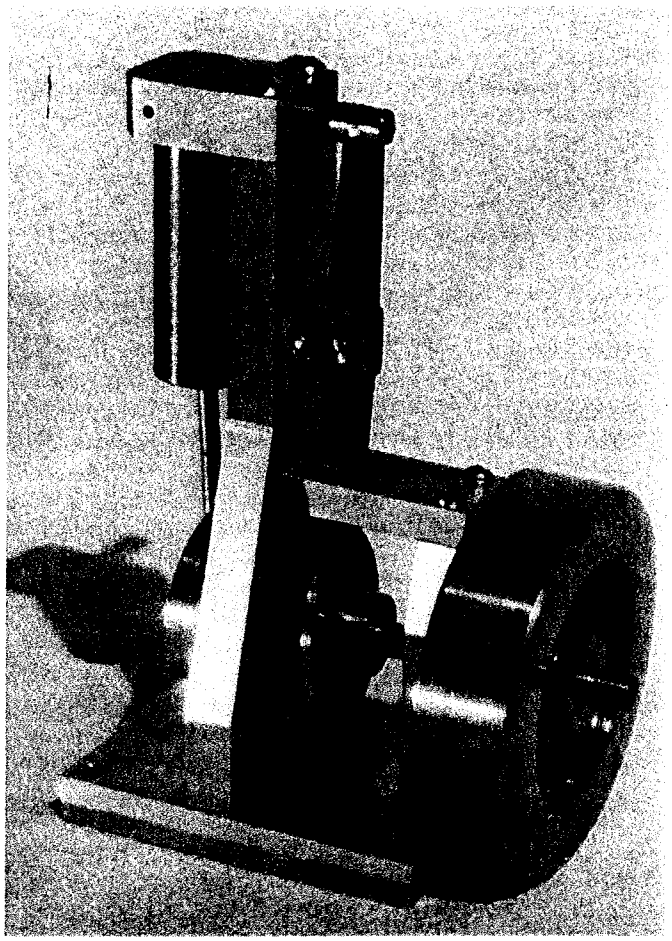
The construction is not difficult. It is important to avoid too much looseness in the valve linkage. Getting 1/8" of travel in the wobble disk is important and requires a bit of careful soldering. The bar from the bearing over to the column serves to back up the valve lever against the disk thrust and it adds support to the tall slender column. We hope this small model appeals to the owners of 3 and 5 inch lathes. If all the dimensions are doubled it makes a good model for those who don't like to work quite so small. Most of the parts are straight machine shop practice.

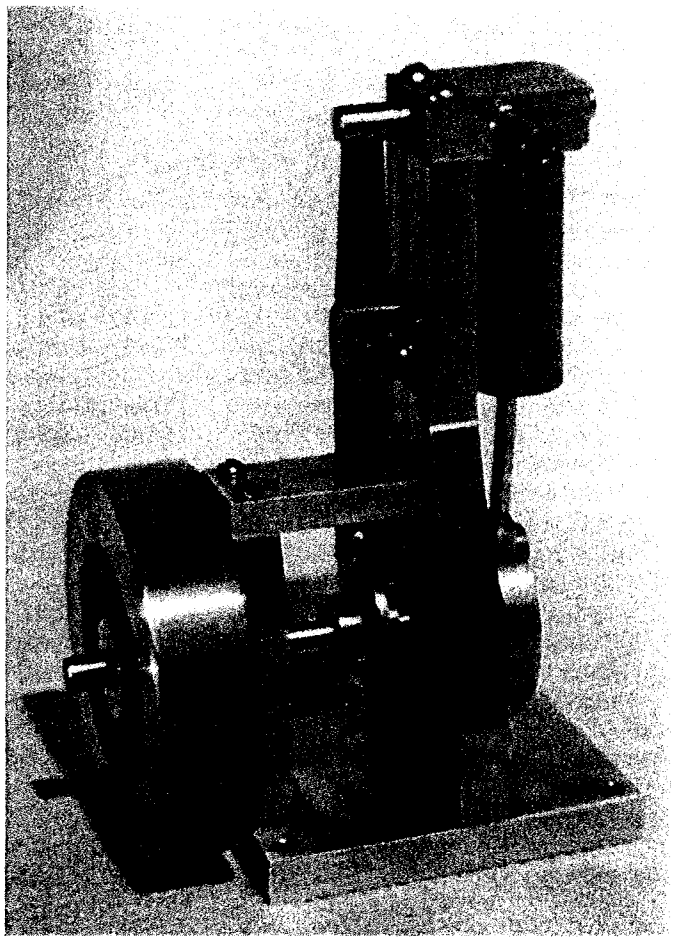
On the **COLUMN** it is good to have the 13/32", 7/16" and 5/16" hole spacing accurately straddle the centerline. This applies to the bolt spacing on the **BASE, LEVER GUIDE, LEVER PIVOT** and **VALVE BODY** which are all related and affect the alignment and freedom of the **VALVE LEVER**.

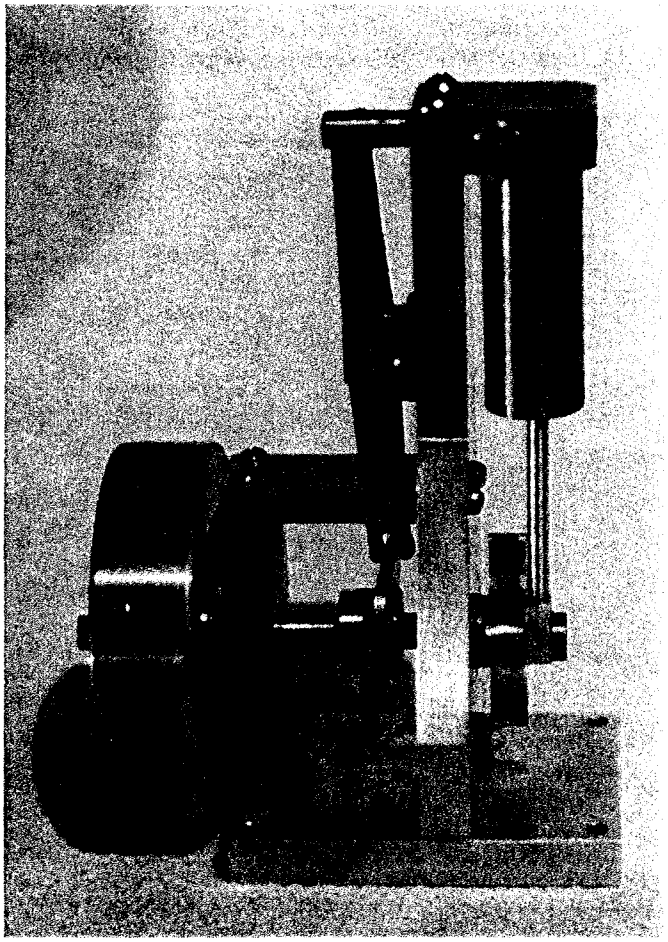
The **VALVE LEVER** and **LEVER PIVOT** are made with three pivot holes. If you lack a bit of valve travel, mount the pin in the lower holes. If there is too much travel, use the upper holes. The valve travel is centered by moving the **WOBBLE PLATE** along the shaft. By watching close in the ports you can see the edge of the 3/16" neck in the Valve as it passes each port. One extreme position of the Valve is shown in the top view of the

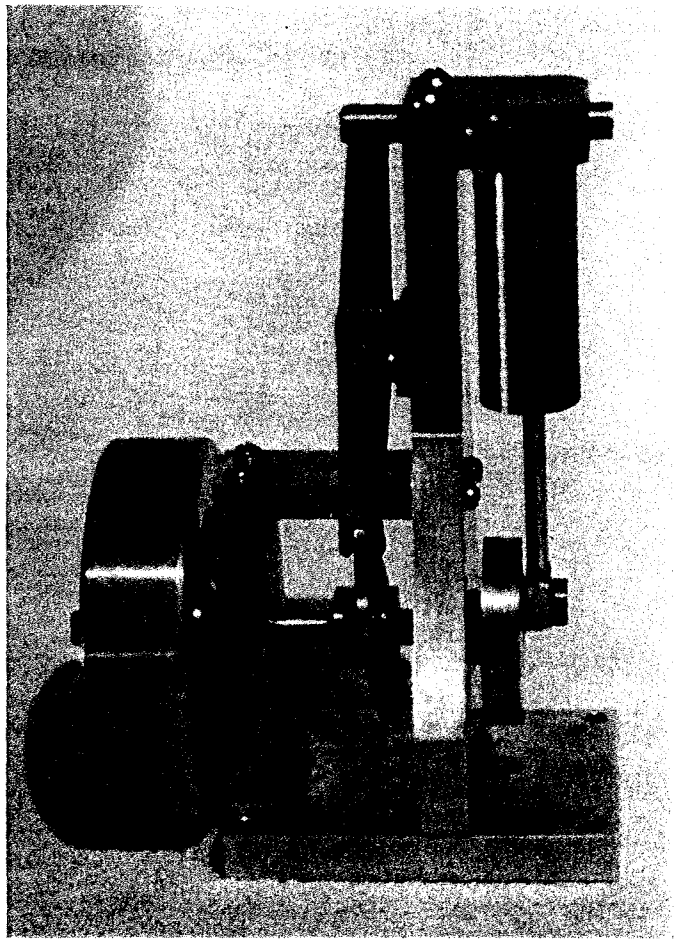


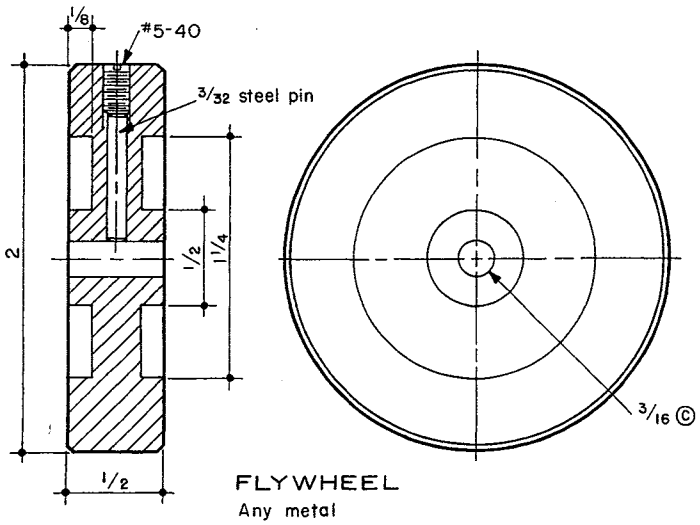
WOBBLE PLATE 3/8 Bore





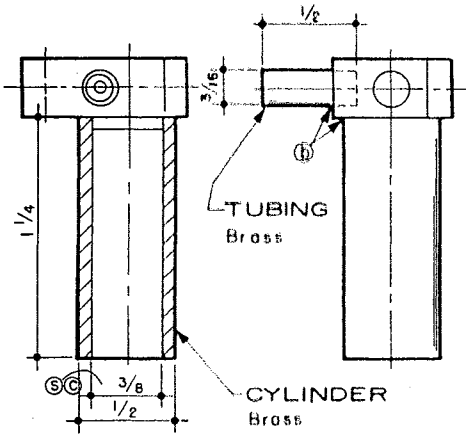


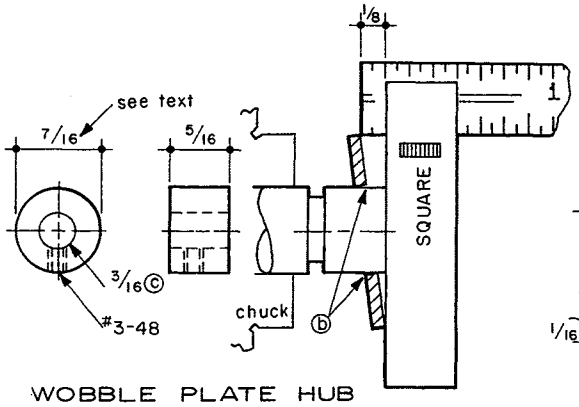




FLYWHEEL
Any metal

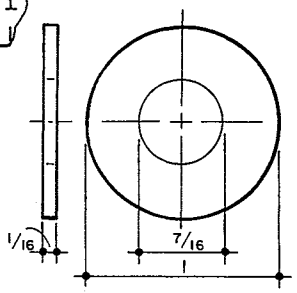
Ⓒ close fit
Ⓢ smooth
ⓑ braze or solder
Ⓟ press fit or "loctite"



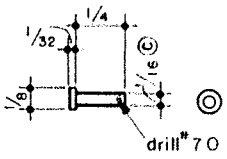


WOBBLE PLATE HUB
Brass

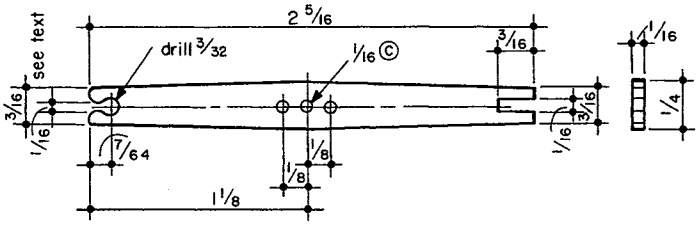
see text



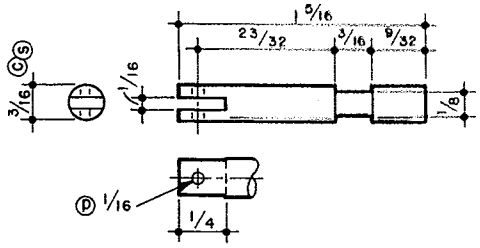
WOBBLE PLATE
Brass



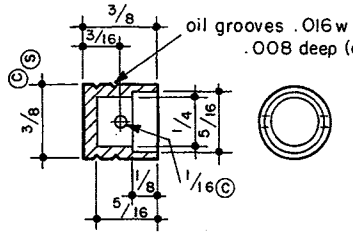
PIN
Brass



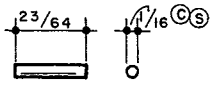
VALVE LEVER
Steel



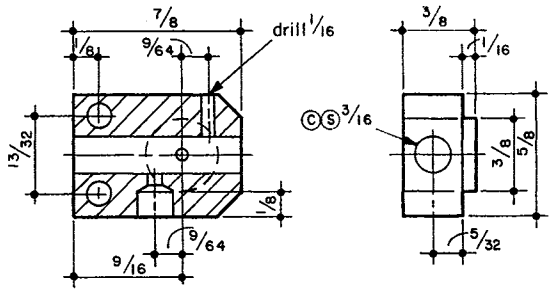
VALVE
Brass

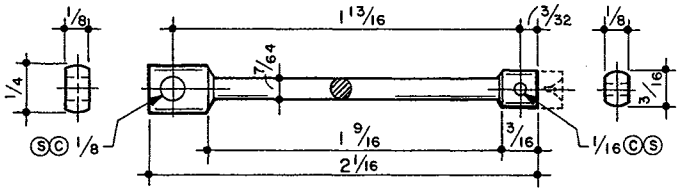


PISTON
Brass or hard aluminum

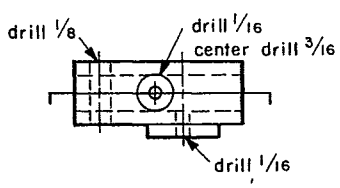


WRIST PIN
Steel

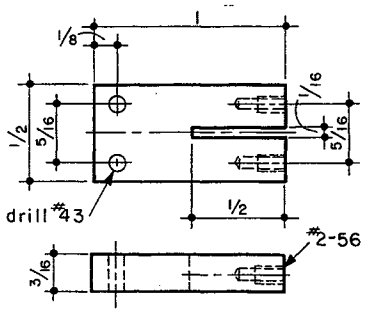




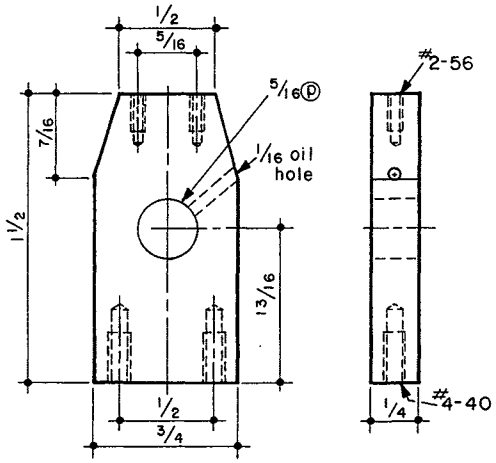
CONNECTING ROD
Brass or hard aluminum



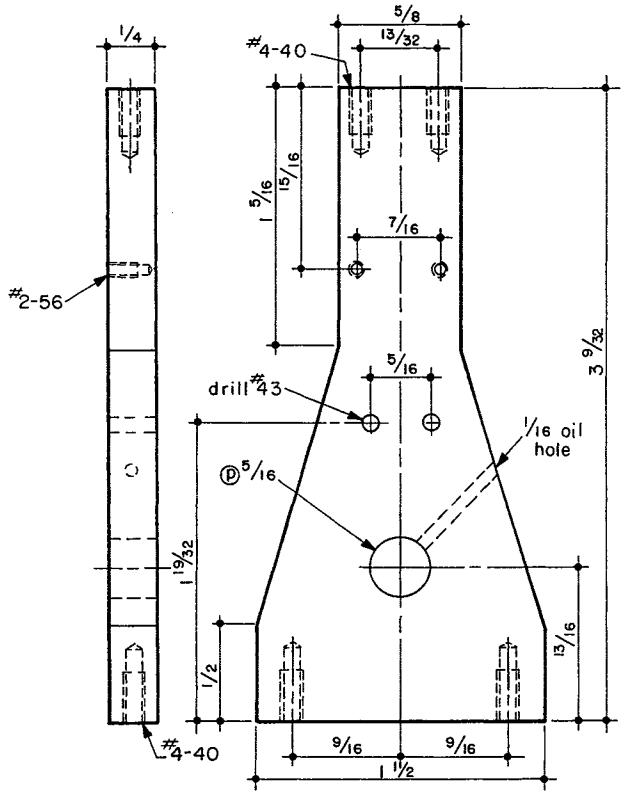
VALVE BODY
Brass



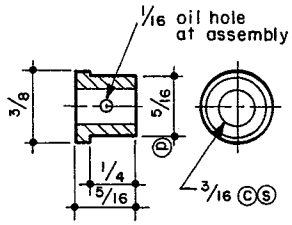
LEVER GUIDE
Aluminum



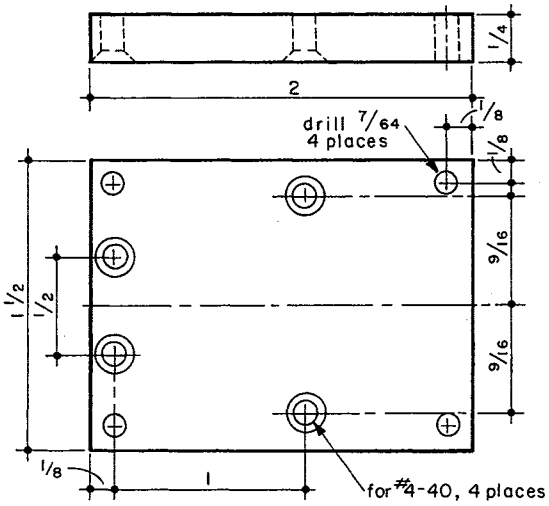
BEARING
Aluminum



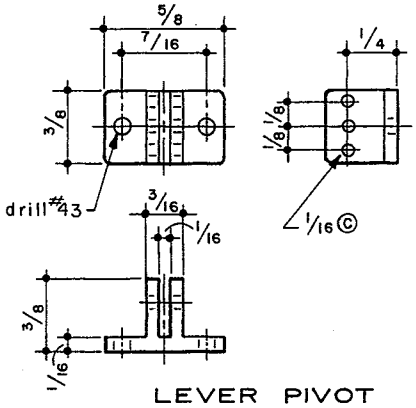
COLUMN
Aluminum



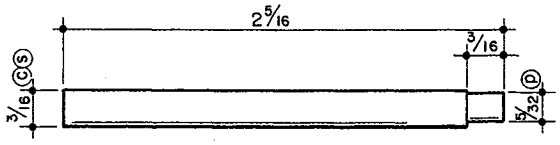
BUSHING
Bronze
2 Required



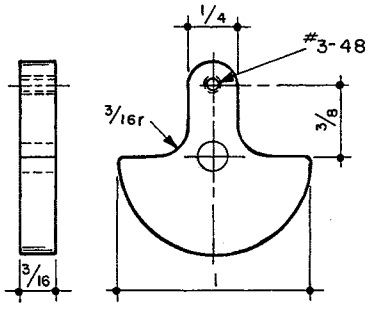
BASE
Aluminum



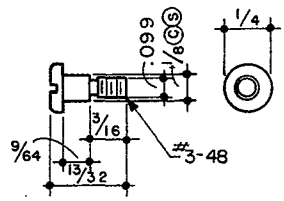
LEVER PIVOT
Brass or Aluminum



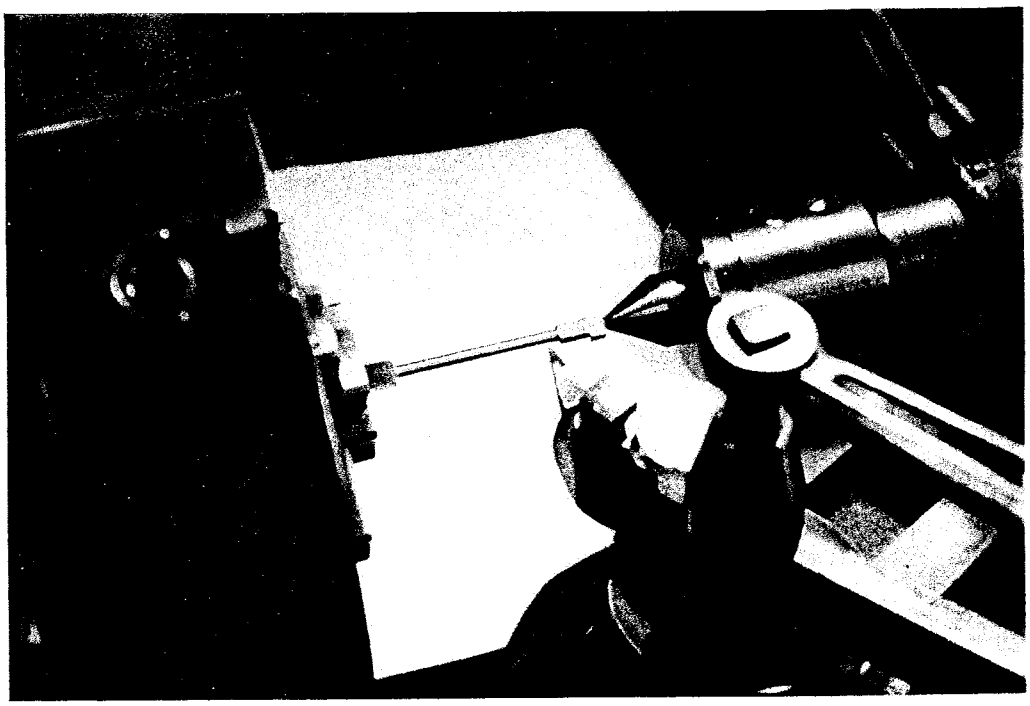
SHAFT
Steel



CRANK DISK
Steel



CRANK SCREW
Steel



Turning the connecting rod for the Wobble Plate Engine.

engine assembly. Notice that the position of the Wobble Plate and Lever apply to this top view. The break in the Valve in the main view is related to the **PISTON** position shown. The Wobble Plate is 90° out of position on the main assembly drawing.

The Wobble Plate is made first with a clean, sharp 7/16" hole. The **WOBBLE PLATE HUB** is turned until it just enters this 7/16" hole. By reducing the diameter a thousandth and trying the disk each time, you repeat until the 1/8" dimension is reached as shown. This diameter is approximately .432". With pliers in one hand, twisting the disk as far as it will go and measuring, you can produce a wobble close to 1/8". Hold the disk with the pliers in this same way when soldering them together. When soldering, it is not important that the one edge of the disk be even with the end of the Hub. It can be as much as 1/32" from the end, leaving room for the setscrew. Use a small piece of soft sheet copper or aluminum in the pliers to prevent nicks at the rim of the disk.

The **VALVE LEVER** is not too difficult. When making the lower forked end, drill the 3/32" hole first and then form the surfaces as near spherical as you can by eye. Try for the closest possible fit on the disk that you can get. You will need tiny needle files for this job. Hold the 1/16" dimension close. You will assemble and disassemble several times before you are satisfied. The center of the disk should be the same distance from the column as the hole in the lever pivot during these trials. Notice the enlarged view at the left of the assembly. It shows how two slight crescent-shaped flats are filed and polished on opposite edges of the disk. Now, if necessary, a few thousandths can be added to the 1/16" space in the fork. Make many light passes with fine file and emery cloth until the disk runs free for a whole revolution. As you make trials you will see where to file. At final assembly, load the fork and rim of the disk with light grease that will cling and not drip off. Also add a bit to the slot in the **LEVER GUIDE**.

Start with about a 3" length of 1/4" x 1/8" stock for the **CONNECTING ROD**. Prick punch the exact center of one end and chuck in the 4-jaw with about 1/4" projecting. Center with a center test indicator and make a tiny center hole for tailstock support. Loosen two adjacent jaws and extend stock out from the jaws for about 2-1/2". Tighten these two jaws and bring the tailstock up for support. Turn the 7/64" diameter starting about 5/16" from the end. Make parting cuts at 3/16" on one end and at 2-1/16" for total length. Lay out and make the 1/8" and 1/16" holes. These holes can be made before turning while the stock is square and easier to lay out and hold. Plan so the lathe center hole can be cut away later.

The **PISTON** is mostly straight turning. At final assembly, insert the **WRIST PIN** through the Piston and Rod. Using a prick punch, flow a bit of piston metal over the ends of the pin to keep it centered so it will not score the cylinder wall. Lightly dress away any raised metal with a small fine oil stone. Peen or prick punch the ends of the pin in the Valve if you do not use Loctite.

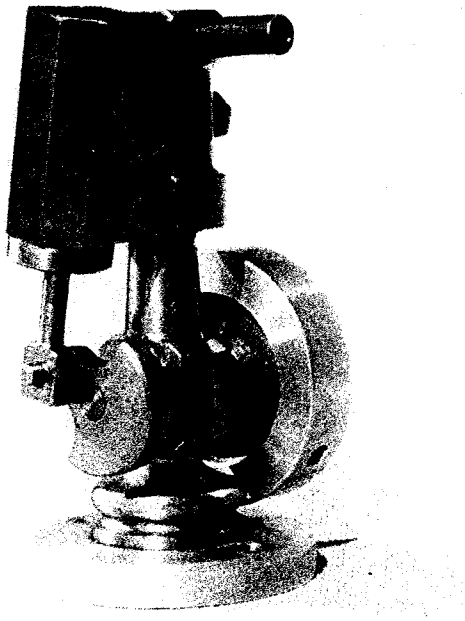
The model shown has a brass **FLYWHEEL** which is a bit heavy but it turns out that the weight is beneficial. A flat can be added to the shaft if you wish since the setscrew pushes against a soft pin. Common taps are too short to reach the shaft.

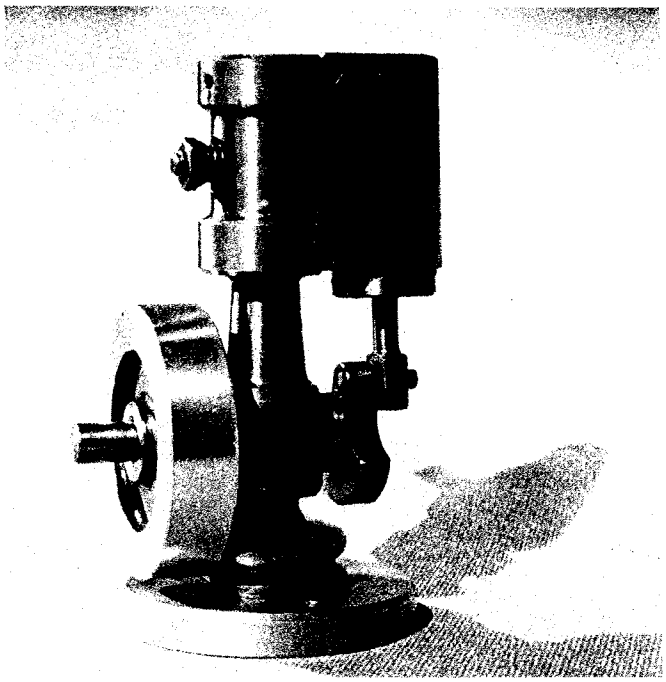
Time this engine as noted above and apply 5 to 10 psi air. Add a couple drops of oil to the intake to lube the valve and piston.

It is fun to make this engine and it is a good conversation piece.

CHAPTER

15 Fancy





This engine is a fancy way of making a wobbler, thus the name *Fancy*. The main Column is made of free machining steel, the Crankshaft is steel, the Cylinder, Piston and Rod, Bushing and Pivot Shaft are brass. Aluminum was used for the Foot and Flywheel, although they would be better if made of steel.

For the **COLUMN**, chuck a piece of 3/4" diameter steel about 3-1/2" long in the 3-jaw and drill a center for the tailstock. Turn the 3/8" dowel and brighten up the 3/4" diameter for about 5/16". Starting at this 5/16" location, turn toward the chuck to a bright, smooth 5/8" diameter. Run a band of layout dye full length on the 5/8" diameter. Scribe lines at the 7/16", 1/2" and 1" points on the Column. Make these lines strong enough to be seen when rotating. Now turn each segment to the outline shown. Since there are three places at 5/8" diameter, it is easy to locate against the vise jaws for milling the flat. Lay out the 5/16" Crank and 1/8" Pivot holes. Machine these holes square with the flat faces.

Make the Drill Jig and locating Pin. Place the Jig over a 1/8" close-fitting pin in the pivot hole and hold against the locating pin as shown and drill the 1/16" port. Turn the Jig over to get the other hole. Note: one hole goes through and the other only 5/16" deep. Pick up the port hole centerline on the flat and transfer it around onto the side to locate the steam connection. Drill and tap for a 3/16" pipe. Make the Bearing and set in the Column with Loctite. Add an oil hole. Make the Foot and attach to the Column.

Make the **CYLINDER** from an accurate and square brass block 1/2" x 5/8" x 1-1/8". Lay out and centerpunch for the 3/8" bore and 1/8" pivot. Chuck in the 4-jaw and center with a center test indicator. Bore and ream the 3/8" diameter hole. Square up the bottom with a boring bar. On the last pass before reaming, make an undercut for reamer runout. Do not leave a tiny shoulder that the Piston might strike. Chuck the Cylinder in the 4-jaw using a small protector plate at the bore end. Center on the pivot point using a center test indicator. Check for squareness in the chuck using a dial indicator. Face, undercut and drill for the Pivot Pin. Make a brass Pivot Pin or Shaft 13/16" long. Thread the end 5-40. Insert a close-fitting aluminum pin in the 3/8" Cylinder bore. Apply a thin coat of flux around the end of the 1/8" Shaft and the 1/8" hole in the cylinder. Solder the shaft into the cylinder using a tiny bit of solder. Too much solder will keep the cylinder off its seat. The solder will not stick to the aluminum.

Make the **PISTON** as shown.

For the **ROD**, chuck a 1/4" rod in the 3-jaw with about 2" projecting. Drill a center hole with a 3/64" center drill and bring the tail center up for support. Turn the 1/8" diameter long enough to cut away the center later. Thread 5-40 with a tailstock die holder. Use parting cuts to bring to final dimensions. Hold the 1/8" diameter in a small **V** groove in the milling vise and mill to 1/8" thickness. Drill and ream for the Crank Pin. Insert the Piston/Rod assembly in the Cylinder. Place the drill jig over the Pivot Pin. Run a close-fitting 3/32" pin through the jig and Crank Pin hole. Then drill the 1/16" port hole in the Cylinder.

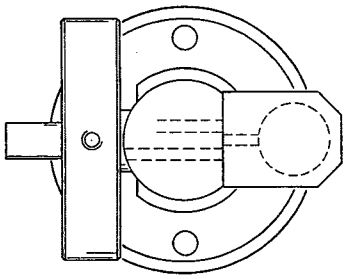
The **CRANKSHAFT** is simple and doesn't require much explanation. The shoulder on the Shaft helps square up the Disk at assembly.

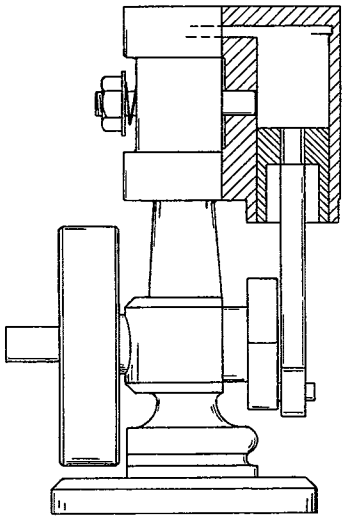
The **STEAM CONNECTION** is for 3/16" plastic aquarium tubing. You may have other ideas for driving this engine.

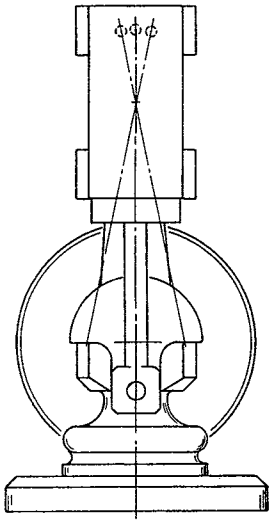
The **SPRING** proportions shown are for one found in the odds-and-ends department, which seems to do a good job.

The **FLYWHEEL** is 1-1/4" diameter x 5/16" wide and fitted with a setscrew. In this case, the taps are too short to reach the center, so the setscrew is near the surface and the pressure transmitted to the Shaft by a loose pin in the tapdrill hole.

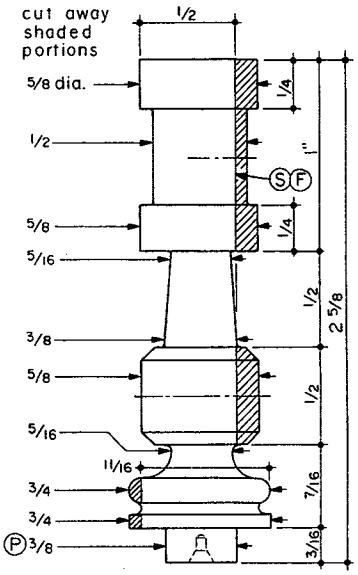
Assemble, lubricate and give your *Fancy* a trial run on 5 to 10 pounds of air.

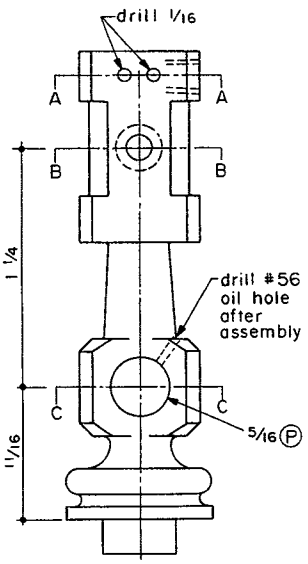




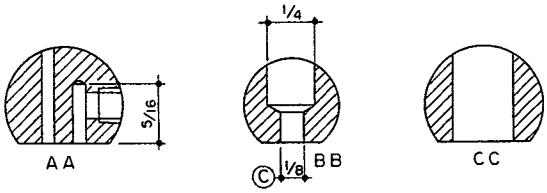


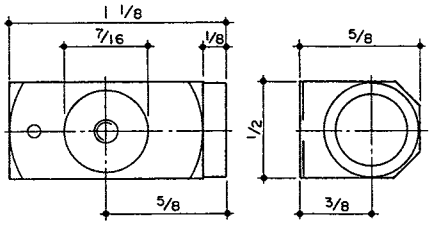
FANCY

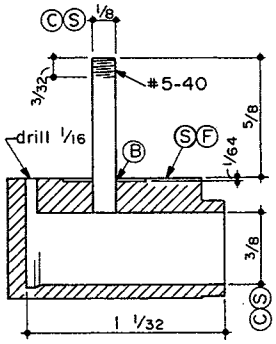




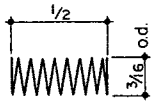
COLUMN
Steel



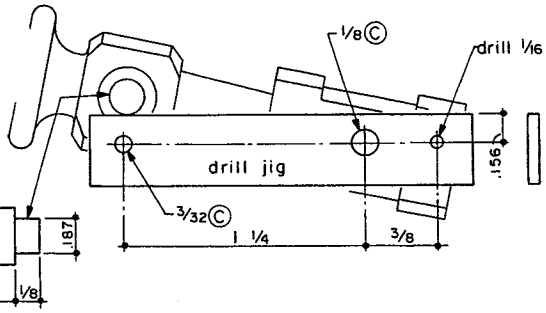




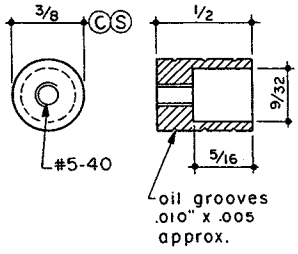
CYLINDER
Brass



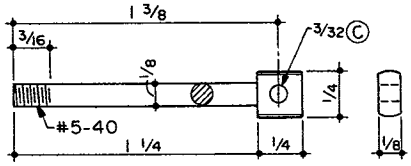
SPRING
Steel
.022" wire
approx. 8 coils



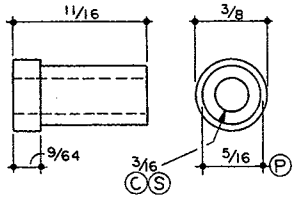
locating plug



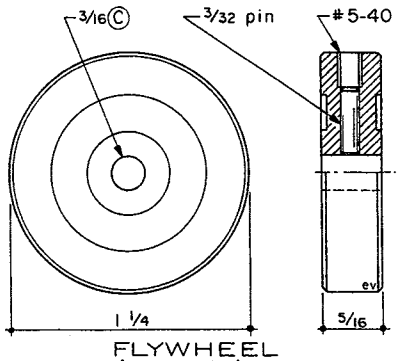
oil grooves
.010" x .005
approx.



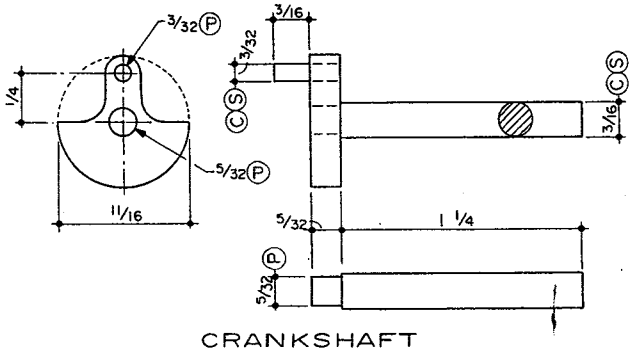
PISTON AND ROD
Brass



BEARING
Brass



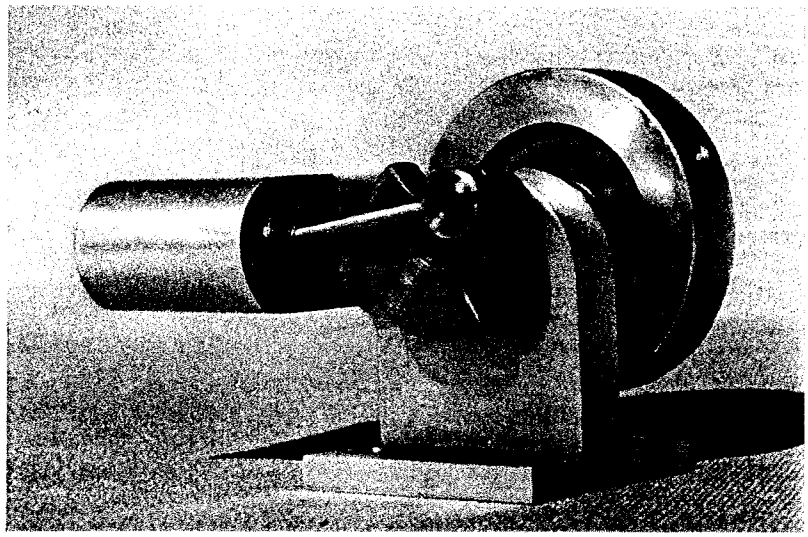
FLYWHEEL
Any metal

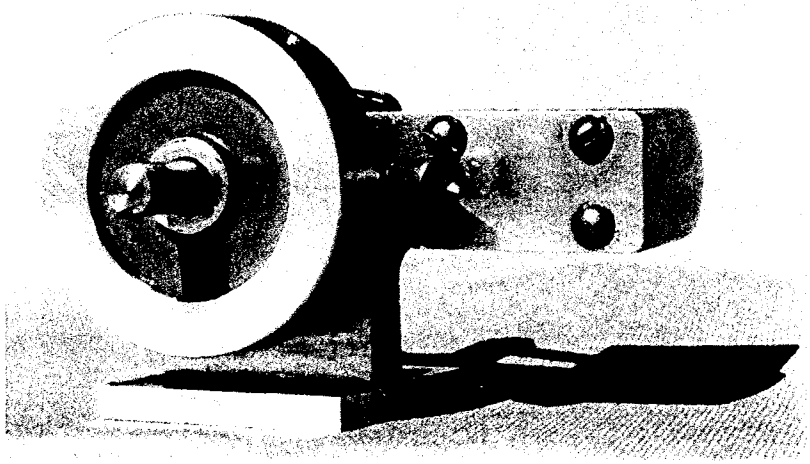


CRANKSHAFT
Steel

CHAPTER

16 Baldy





Baldy is a novelty engine which, at first glance, appears to be a piston-crank type of construction. The Piston is a ball, so no Wristpin is needed. The large parts are all aluminum on the model shown, though they can be steel or brass. The Ball, Connecting Rod, Bearing and Steam Connection are brass. The Crankshaft and Screw are steel.

Start the **FRAME** with a finished 1/4" x 1" x 1-15/16" piece of metal. Apply layout dye and lay out all the hole centers. Machine all of the holes, but do not plug the 1/16" hole until a drill has been run through the Bearing later.

Make the **BEARING** and **STEAM CONNECTION**. This Connection is for 3/16" plastic tubing but you may have other ideas for this, depending on how you will eventually drive and use this engine. Drill and turn the 3/16" stock and remove it from the chuck. Enter the end into a 1/8" hole in some scrap stock held in a vise and apply heat with a torch. When it's almost red hot, slowly bend to the required shape. Cut it to length and remove all burrs. Solder the Steam Connection to the Bearing and set the Bearing in the Frame with Loctite. Drill the steam passage through the Bearing and plug the hole in the Frame using a press fit or Loctite.

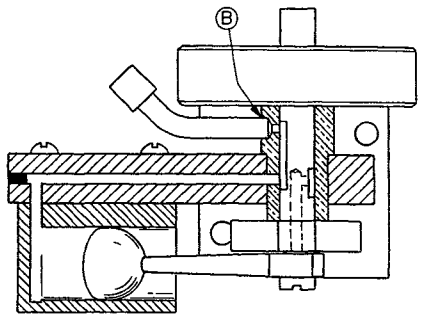
For the **CYLINDER,** start with a piece 1/2" x 9/16" x 13/16" and lay out the centers for the 3/8" bore, four screw holes and the 1/16" port hole and prick punch. These holes must match the holes in the Frame. Center in the 4-jaw using a center test indicator and make the 3/8" bore. Square up the bottom with a boring bar. On the last pass before reaming, make a light undercut for reamer runout so that you do not leave a shoulder for the Piston to strike. Do not break into the bore when drilling and tapping the four screw holes. A bottoming tap is required.

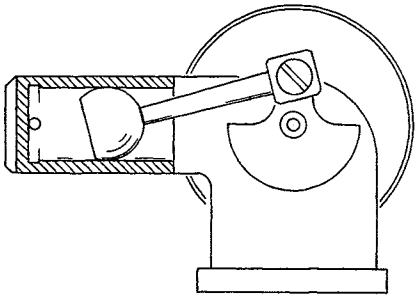
Make the **CRANKSHAFT** as shown. The important thing here is the accurate location and depth of the Valve flats 180° apart and the throw of the Crank set midway between the flats as shown in the assembly view. The Piston is halfway in its stroke and getting full steam. Attach the Crank Disk to the Shaft with a press fit or Loctite.

The **FOOT** and **SHOULDER SCREW** need no explanation. The thread on the screw is best made using a tailstock die holder.

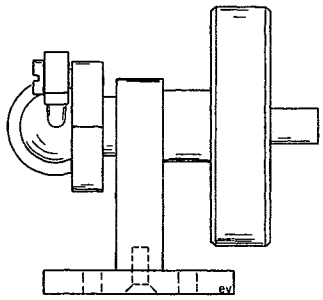
A 3/8" diameter ball is the **PISTON** for this engine. The one shown was made with a small ball-turning fixture on a lathe. Cole's Power Models lists 3/8" stainless steel, bronze and nylon balls in their catalog. A nylon ball seems like a good one to try on a compressed air engine. If you wish to try a free-hand job on a lathe, the method is slow but can produce a fairly accurate ball. First, chuck a piece of steel about 3/64" thick x 3/4" x 3/4" in the 4-jaw and bore out a clean smooth 9/32" hole. Make a light face cut about 1/2" diameter to bring up a sharp clean corner in the hole. This, then, becomes a gauge. The sharp edge of the hole exactly matches the surface of a sphere at any angle the gauge may be held. Chuck a 13/32" or larger bar in the 3-jaw and turn to a diameter of .380". Face the end and make a parting cut 3/8" from the end and about 1/4" wide, leaving a neck diameter of 1/4". Now, start turning the shape of a ball. Take lighter cuts as the ball takes shape. When you can "mike" about .390 in all directions coat the ball with layout dye. Hold the gauge lightly against the ball and rotate the spindle by hand. The sharp edge of the gauge will scrape away the dye on the high spots and show you where to file. Repeat this until you can read .375 in all directions, or you can, at these last passes, use the Cylinder as a gauge until the ball is a close, free fit when oscillated in all directions. The last pass may be only polishing with fine emery. In this case you have the advantage of needing a spherical condition only on a band about 3/16" wide at the center. Drill and tap for the Connecting Rod. Make a final parting cut at 9/32".

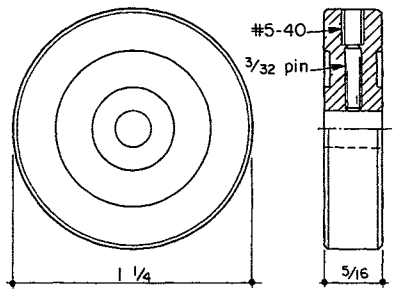
For the **CONNECTING ROD**, lay



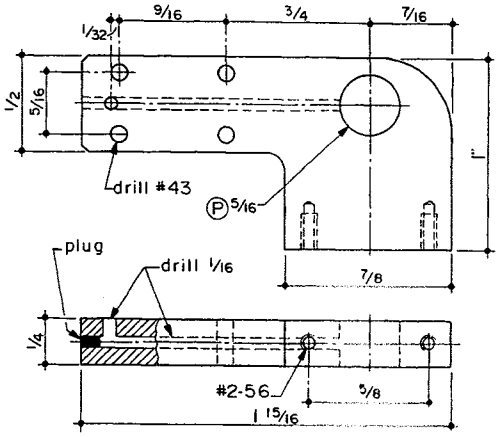


BALDY

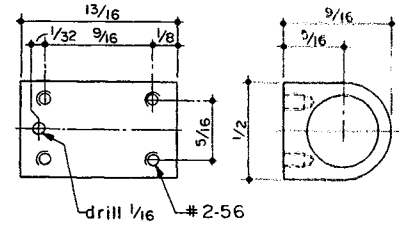


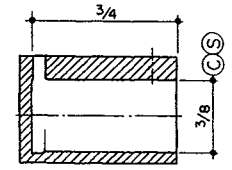


FLYWHEEL
Any Metal

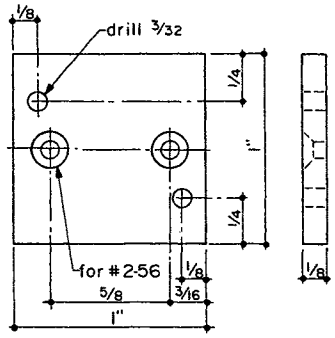


FRAME
Aluminum

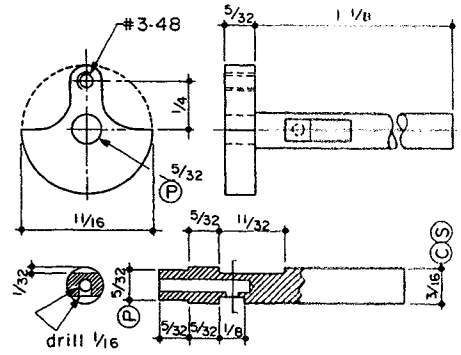




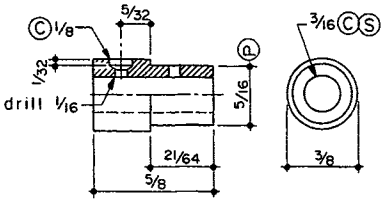
CYLINDER
Aluminum



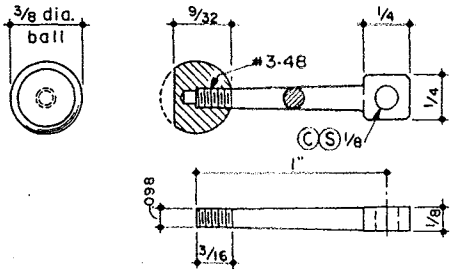
FOOT
Aluminum

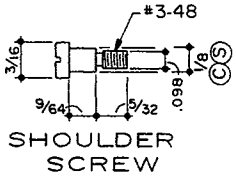


CRANKSHAFT
Steel

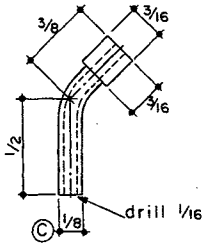


BEARING
Brass

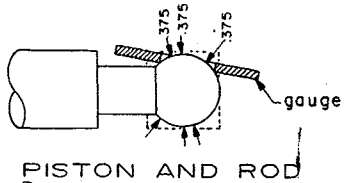




SHOULDER
SCREW
Steel



STEAM
CONNECTION
Brass



PISTON AND ROD
Brass

out and prick punch the center of the end of a 1/8" x 1/4" bar. Chuck in the 4-jaw with about 1/4" projecting from the jaws. Center with a center test indicator and drill a center hole with a tiny 3/64" center drill. Mark two adjacent jaws with chalk. Loosen these two jaws and extend the bar out about 1-1/2" from the jaws. Hold the piece against the tailstock center and tighten the two marked jaws. Turn and thread, keeping in mind enough length to remove the center hole later. Cut to length and ream 1/8" for the Crank screw. If the thread fit is loose, apply Loctite and turn into the ball to the right length and set aside to cure. (This will not work on nylon.)

The **FLYWHEEL** is 1-1/4" diameter x 5/16" wide and fitted with a setscrew. The small taps are not long enough to reach the center, so a free-fitting pin in the tapdrill hole transmits the pressure to the shaft.

Assemble and lubricate *Baldy* and give it a trial run on about 5 to 10 pounds of air. After a few hours of watching *Baldy* perform, you're ready to start on your next project.

CHAPTER

17 Pumping Engine

The general idea for this engine came from an old illustration sent in by Chuck Sleppy from Troy, Ohio. The yoke type of piston rod transmits the steam pressure directly to the pump. The connecting rods are light duty, mostly for the purpose of timing. This engine was first made in 1981 with double-acting pumps. The pumps were not satisfactory and the engine was set aside. Later, they were cut down to single action. There was no improvement until now with this design. The Pumps now are bare Cylinders with separate outside Valves piped to them. The passages and Valves are larger and they pump a good stream. Overall, this Pumping Engine resembles the old city waterworks pump with catwalk, railings and ladder. The parts are generally not difficult to make.

There are four **COLUMNS** that are related to five parts, the **FLOOR, BASE, CATWALK, BEARING BEAMS** and **TABLE**. The Columns should be as near alike as you can make them. Flathead screws are used top and bottom so the lower or upper section of the unit can be removed and serviced. There are hole patterns on all five parts that are related and can affect assembly and alignment.

The **FLOOR** is plain blue anodized aluminum on the model shown, with 1/2" squares scribed to resemble floor tile. You may use any material you wish.

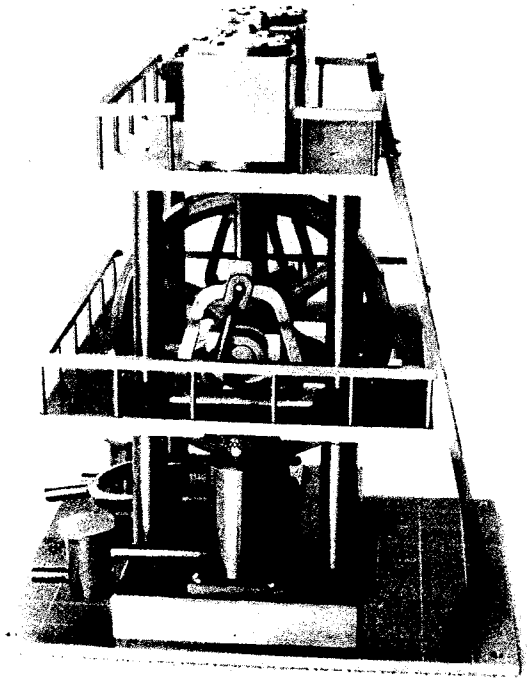
The **BASE, BEAMS, CATWALK** and **TABLE** require careful but not difficult layout, drilling and tapping. A series of drilled holes joined by straight saw cuts and filing form the center openings in the Catwalk.

On the Catwalk and Table a series of 1/16" holes are drilled for the **RAILING** (if you choose to add the Railing and Ladder). The Railing pieces are notched, bent and soldered, then the hole patterns in the Catwalk and table are duplicated on the Railing. On the model shown, all the 1/16" pins were set in the Railing with Loctite and set aside. At assembly, Loctite was used in the lower ends of the pins. 3/32" square brass was ordered from a supply house but it was out of stock so 1/8" stock on hand was cut into 3/32" strips. The 3/32" x 1/8" Rails look OK.

The **LADDER** construction is similar to the Railing. The method of mounting the Ladder with 1/16" pins permits the Ladder to be eased up and out for service or repair. The Railing and Ladder add quite a bit to the appearance though the proportions may be challenged. A miniature man of a size to match the Ladder may not match the Railing height. You will probably have some good ideas along this line.

The steam **CYLINDERS** are 1" cubes. Before making the 1/2" bore, mill the 1/16" x 3/16" ports and then drill the 1/16" holes at 11 degrees. The **HEADS** can be used as jigs for spotting the 12 bolt holes. Keep the bolt pattern parallel to the valve face for sake of the steam manifold and valve rod.

For the **STEAM CHEST**, lay out all lines and centers

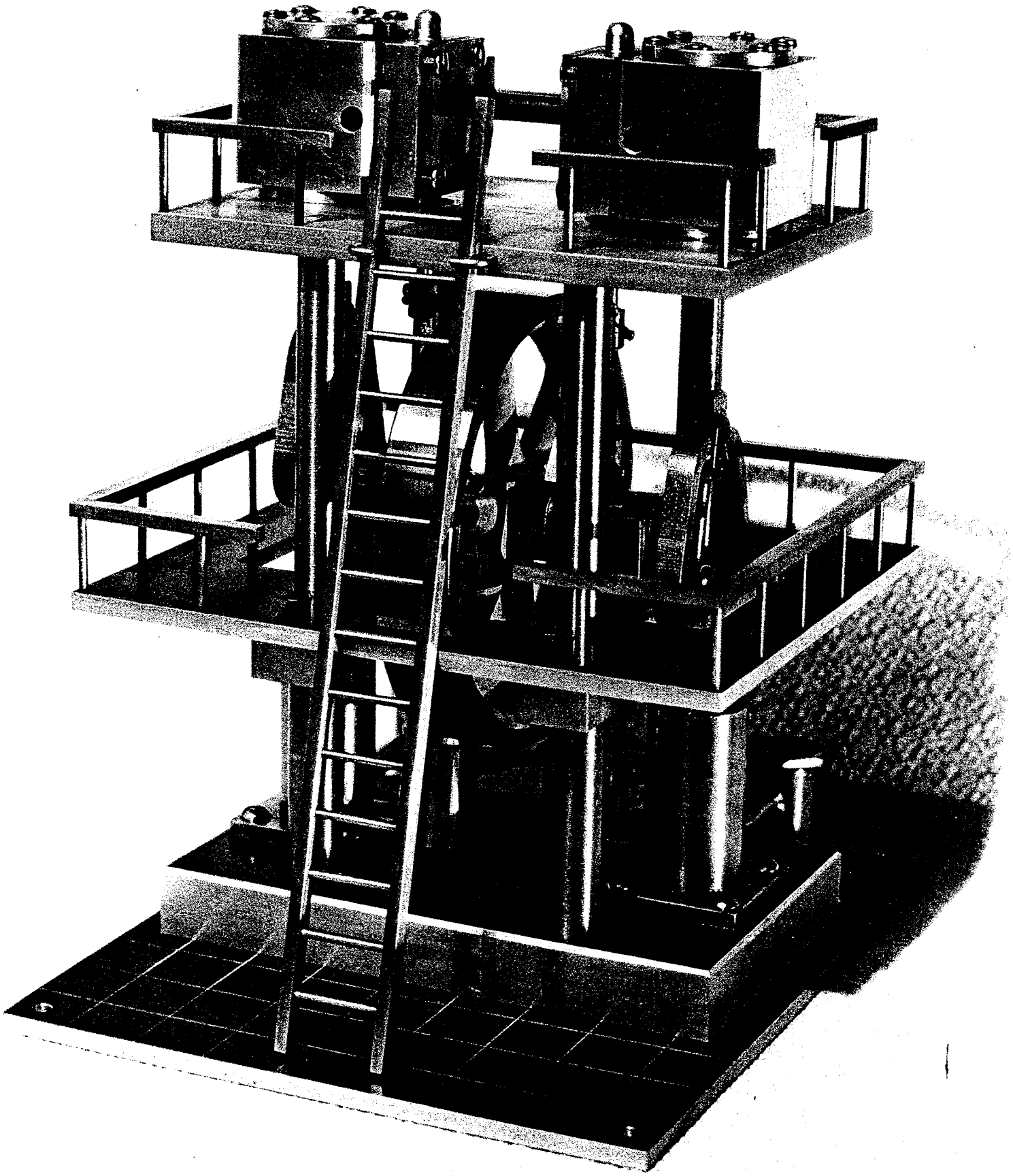


on a 1/4" x 13/16" x 1-3/8" block. Chuck in the 4-jaw and pick up the center of the blind 3/16" boss with a center test indicator and turn to shape. Repeat for the packing end, carefully drilling the deep 1/16" hole with a new drill to avoid drill wandering. Drill four holes, saw and file the 7/16" x 5/8" opening in the center. If the steam connection stud holes break through, just cement the studs in place. Make the two blocks for the **STEAM MANIFOLD**. Solder the blind block to the 3/16" tube. At final assembly, mount the blocks on the Steam Chests with Loctite in the other block. When cured, drill 5/64" through the tube.

When making the **VALVE, NUT** and **VALVE ROD**, try for a close fit of the Nut in the valve and the Rod thread in the Nut. These parts must be free so the Valve floats on its seat held by the steam pressure.

The **PISTON ROD/YOKE/PLUNGER** is the result of a near miss in design, intentional design and a gamble. The **CONNECTING ROD** will not drop into the opening in the Yoke. The Yoke is quite clumsy looking so effort was made to keep it narrow. By starting the Rod diagonally as shown and gently pressing it, the fork will spring enough to let the crank end enter the Yoke. A check showed no serious permanent set. It is easier to remove than insert. This was done several times. These parts were double-checked against the drawing, so if it is close to print it should work. If you have fears, the ends can be shortened slightly to reduce the springing. Assemble

Pumping Engine



rods and pins and run fine soft copper wire through the fork pins in such a way as to prevent turning in the fork, forcing the pin to rotate in the Yoke. A turn of the wire around the connecting rod shank and binding tight does the trick.

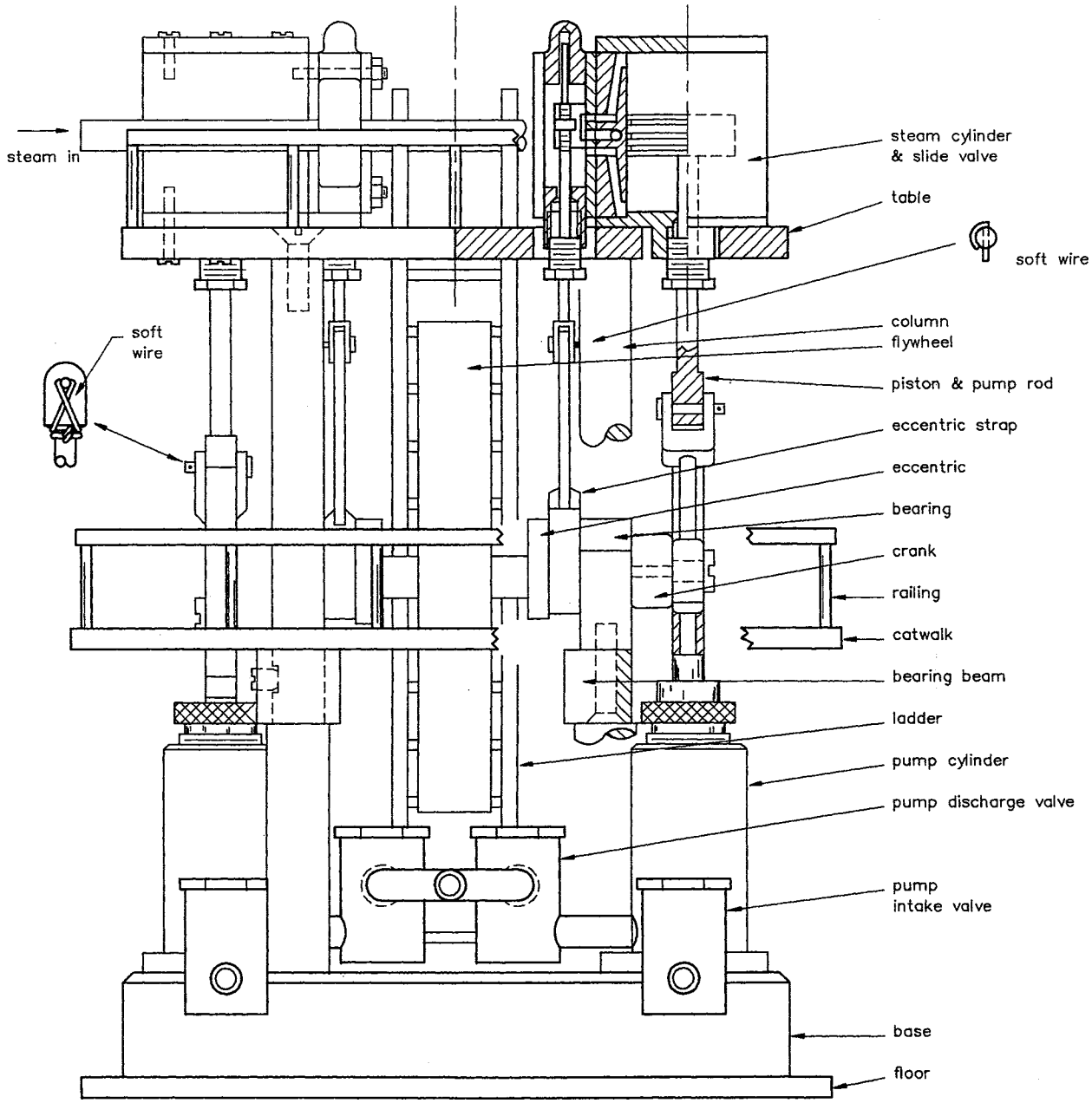
If you wish, spanner wrench holes can be drilled into the **PISTON** for easier assembly. You may have to make a forked tool for this. If the **PISTON ROD** is made about 1/32" long you will have a bit of adjustment in centering the Piston between the heads. Dress the Rod flush with the end of the Piston.

When making the **ECCENTRIC**, spot the setscrew on the centerline through the offset. It helps when timing the Valve.

Note the flats on the **CRANKSHAFT** are 180 degrees apart. This makes one pump discharge while the other is on the intake stroke. Here again, spot the setscrew in the **CRANK ARM** on the centerline through shaft and screw holes.

The **PUMP CYLINDERS** require no compl icated operations. The **PACKNUTS** can be drilled or notched for a spanner wrench. The **PACKING** in all cases on this model is 1/16" graphited asbestos. Use your favorite packing. Set the Packnuts very light.

On the **VALVE BODIES**, all the 3/16" tubing connections are soldered into the bodies. These tubes are all threaded in the lathe using a tailstock die holder before parting off to length. Note the **INTAKE** connections are in line while the **DISCHARGE** connections are at right angles to each other and made Right Hand and Left



PUMPING ENGINE

Hand. On all four Bodies, a 3/16" steel ball is used to make seats for the stainless steel balls. Drop the steel ball down into the Body and, using a brass rod and light hammer, give a sharp blow to form the seat. The **COVERS** are shallow and they have a 3/64" projection to limit the rise of the ball to about 1/32". These projections can be cut back if more rise is needed.

The **PUMP DISCHARGE MANIFOLD** is simple bent tubing. The short piece is scalloped to fit around the bend and soldered. This is cut-and-try filing until a couple of projections wrap around the tube. They can be spread apart on a 3/16" diameter rod and hammered and filed for a close fit and good soldering. Drill through after soldering.

When all the parts are made, assemble the Bearings to the Beams and slide the Beams on to the Columns.

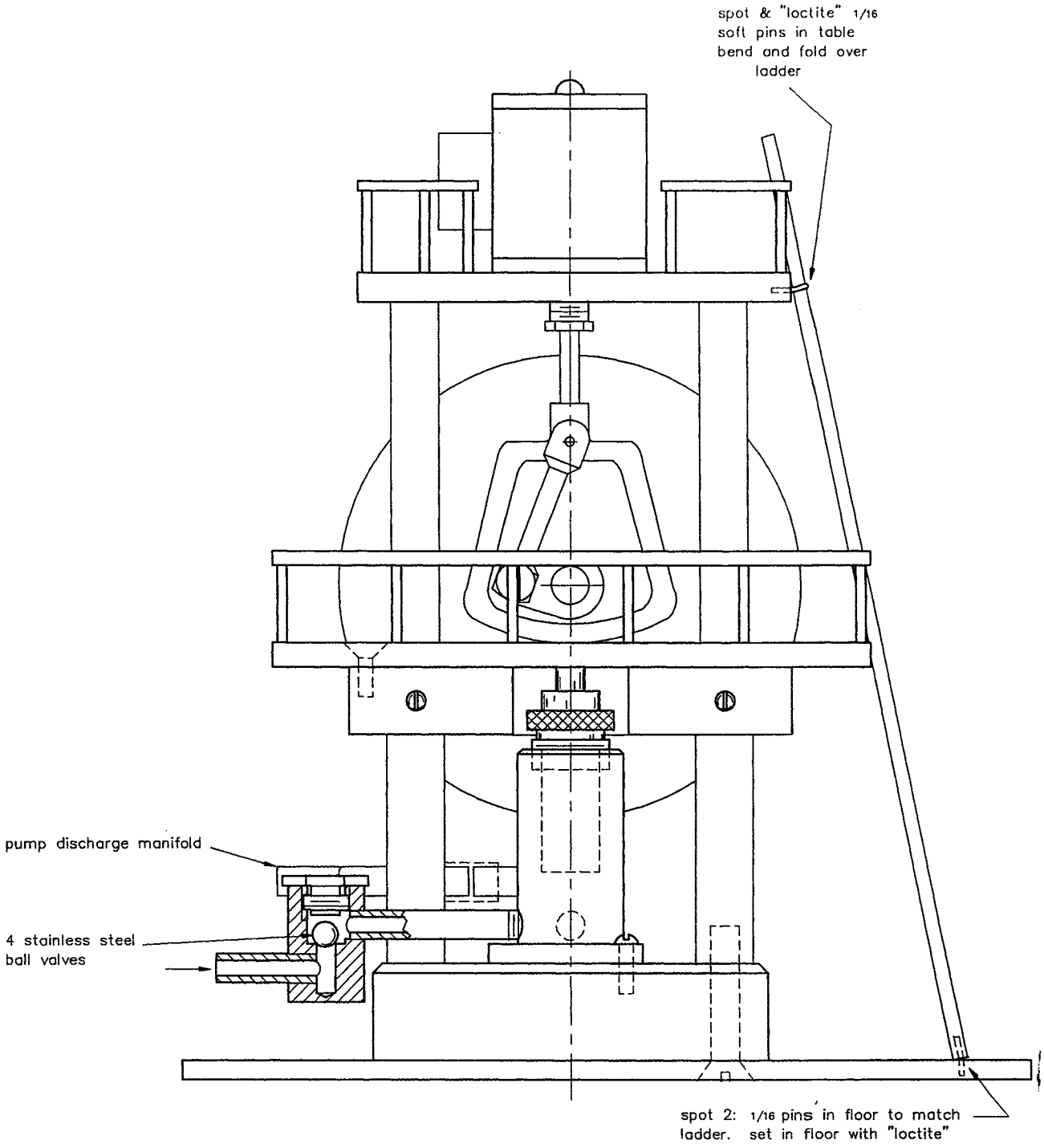
Assemble the Pumps and Valves on the Base.

Assemble the Floor/Base/Pump assembly to the Column/Beam assemblies using #10-32 flathead screws. Note the Ladder is opposite the Pump intake Valves. Adjust so the shaft turns free in the bearings.

Attach the Catwalk. Note the Ladder mounting.

Assemble the entire Steam Cylinder, Heads, Valving and Piston Rod/Yoke/Plunger to the Table. Attach the Steam Chest less Covers so Valves can be timed later. Add Packing to all stuffing boxes. Note the Ladder is opposite the Steam Intake Manifold. See photos page 79.

Lower the Table assembly down onto the Columns with the Pump Plungers entering the Pump Bodies. Set the flat head screws in the top of the Columns. Add



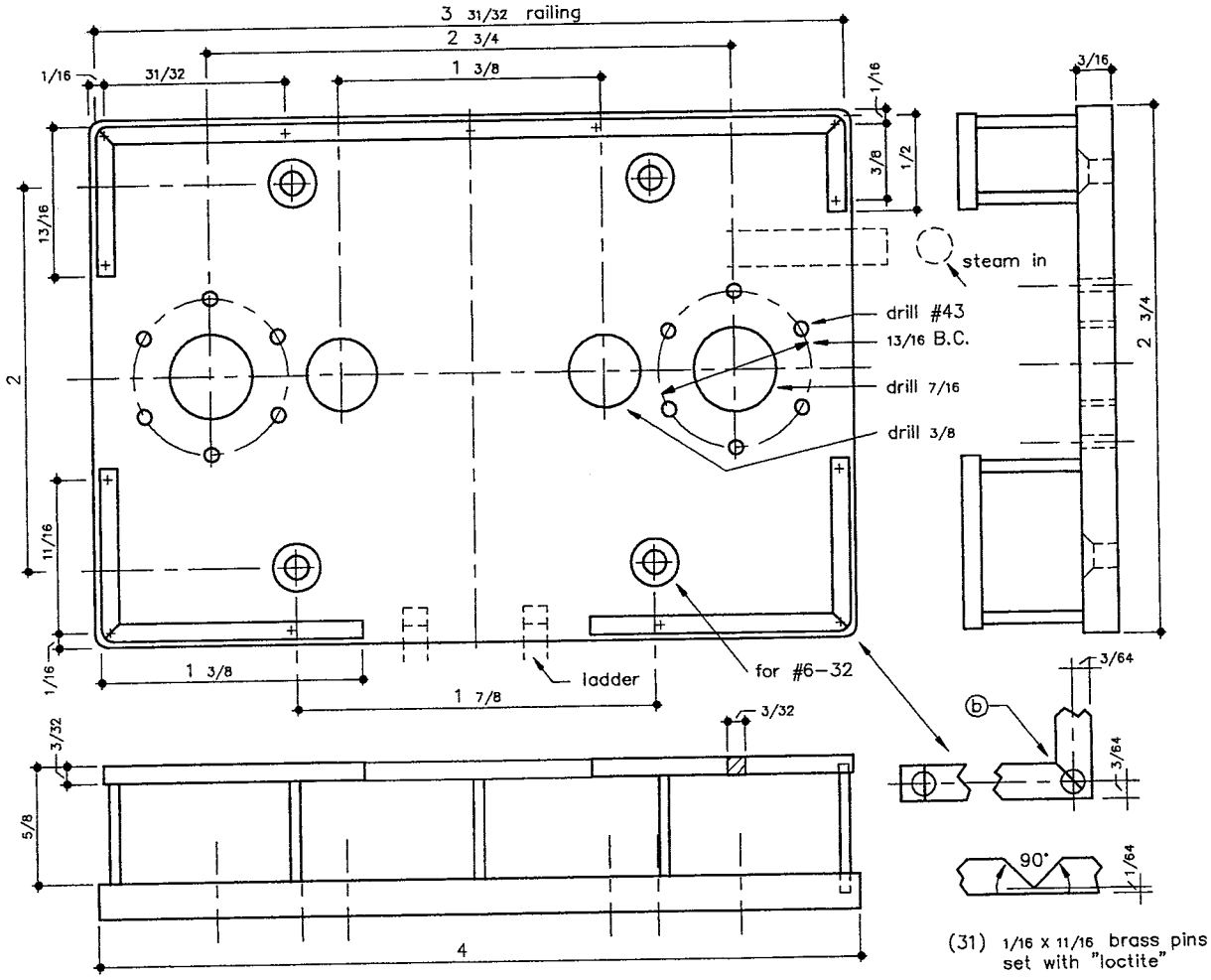
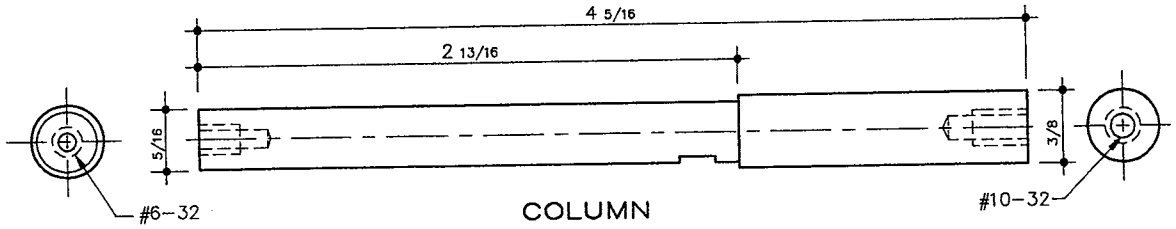
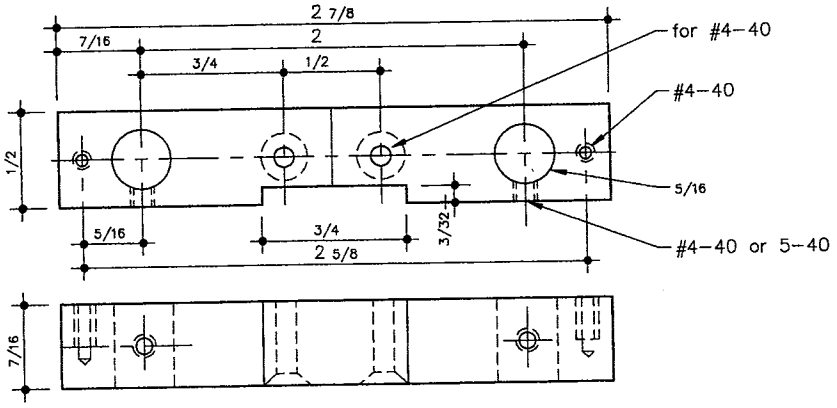


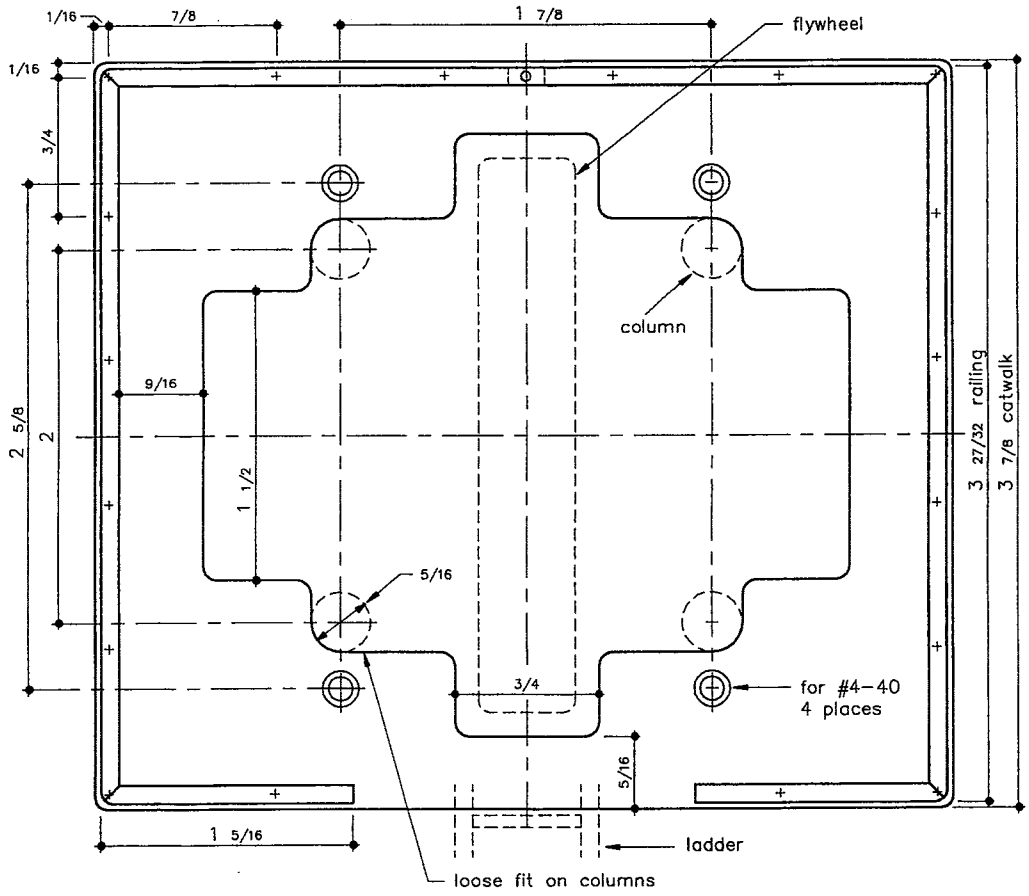
TABLE — RAILING
Aluminum — Brass

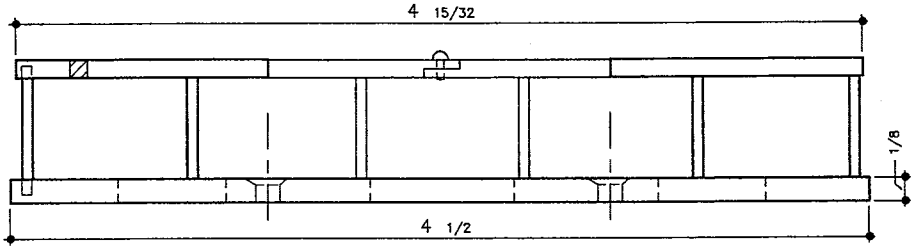


COLUMN
Steel
4 Required



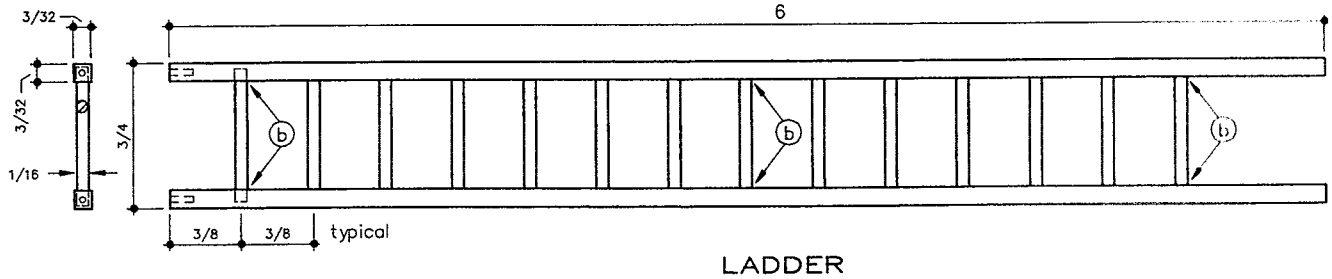
BEARING BEAM
Aluminum
2 Required





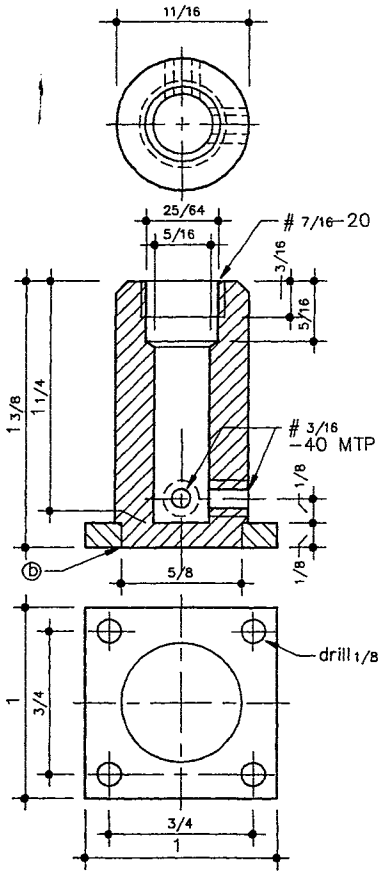
CATWALK — RAILING

Aluminum Brass

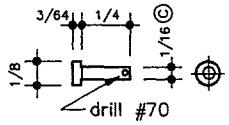


LADDER

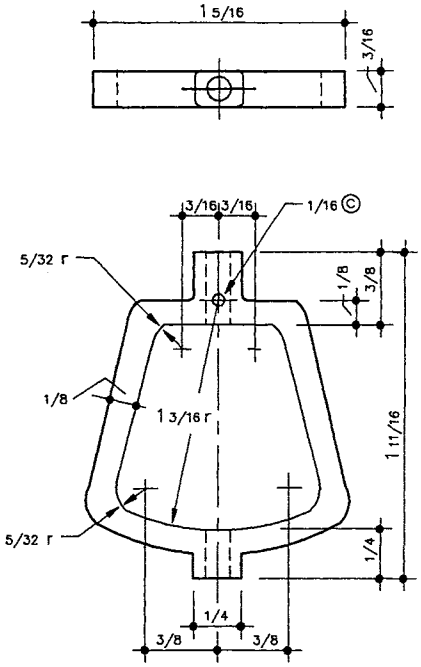
Brass



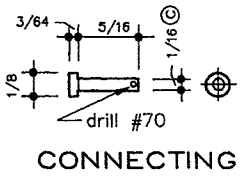
PUMP CYLINDER
Brass
2 Required



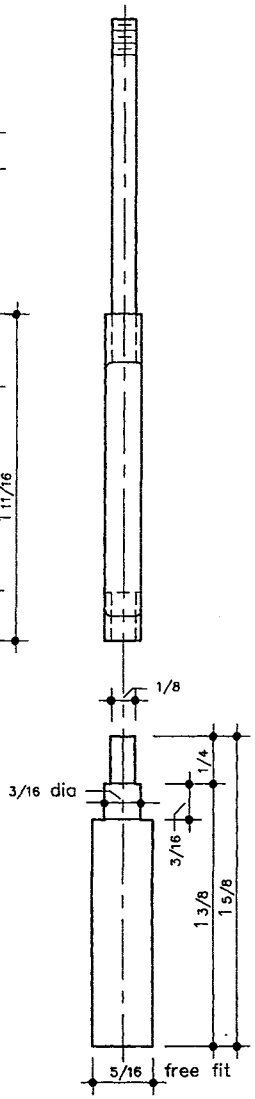
VALVE ROD PIN
Brass
2 Required



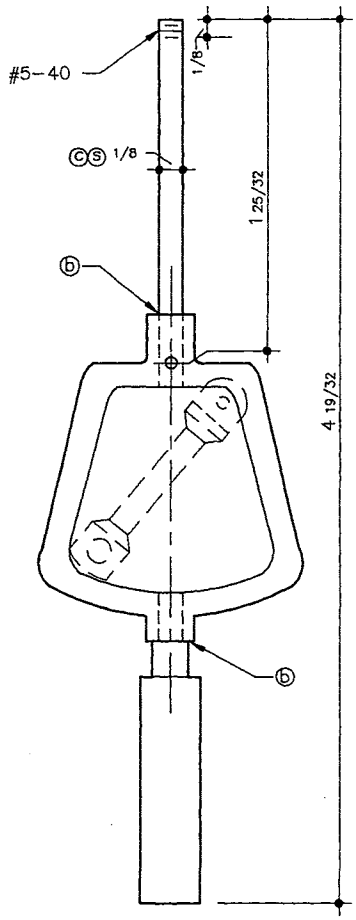
YOKE
Brass
2 Required



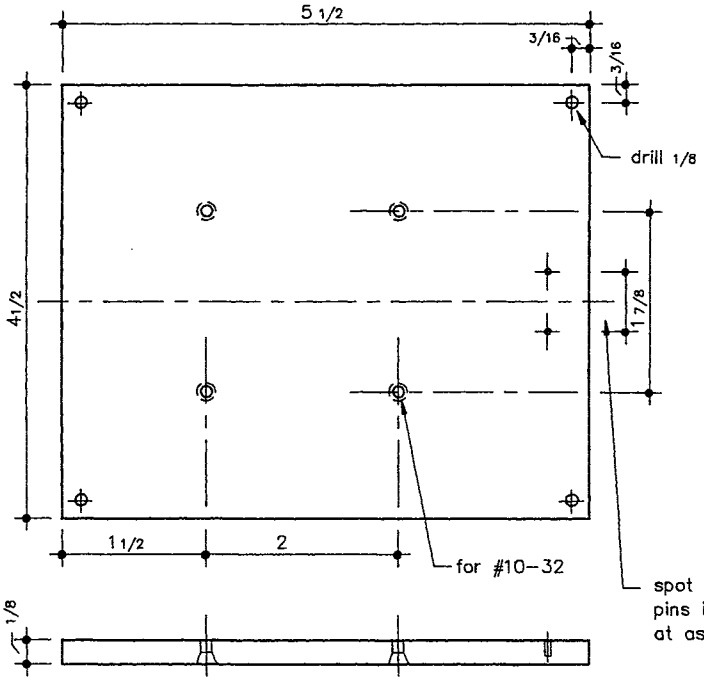
CONNECTING ROD PIN
Brass
2 Required



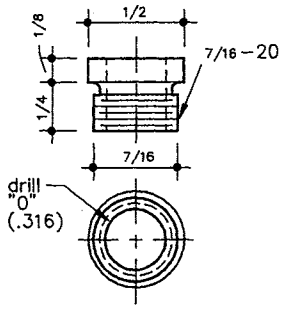
PLUNGER
Brass
2 Required



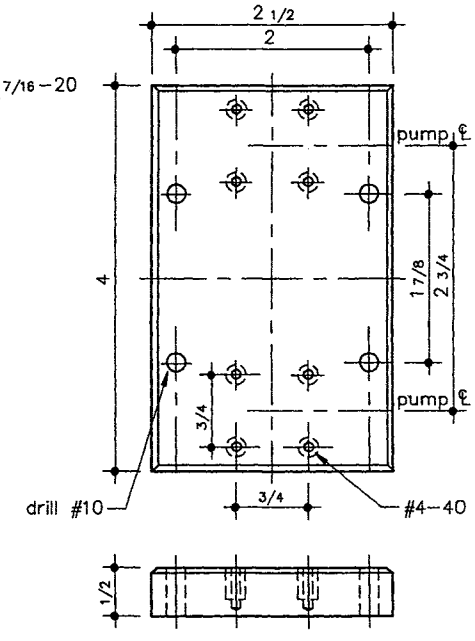
PISTON ROD–PUMP PLUNGER ASSEMBLY
Brass
2 Required



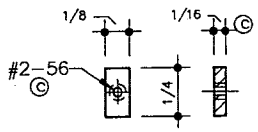
FLOOR
Aluminum or Steel



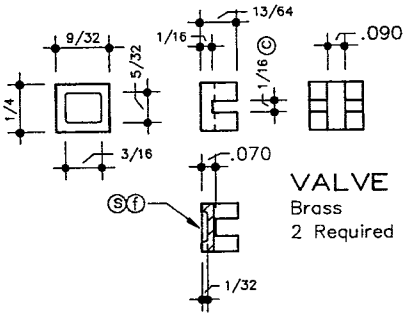
PUMP PACKNUT
Brass
2 Required



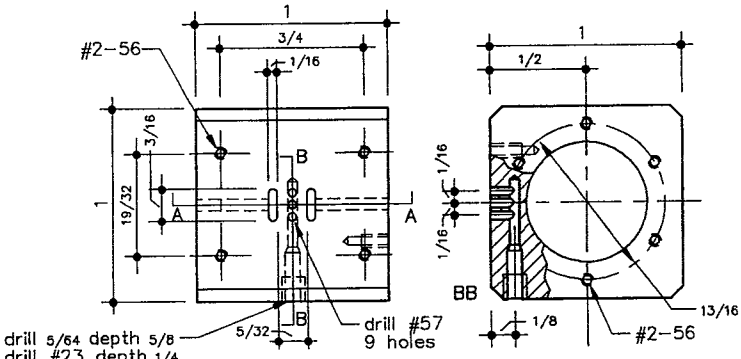
BASE
Aluminum or Steel

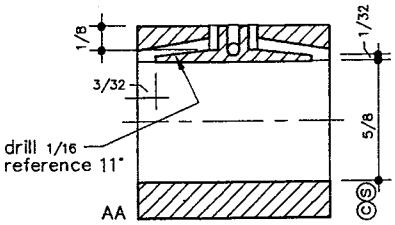


VALVE NUT
Brass
2 Required

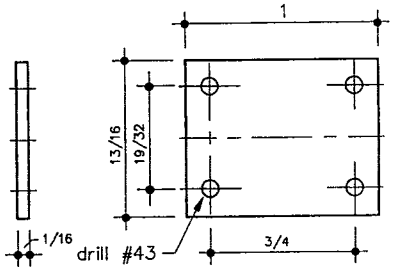


VALVE
Brass
2 Required

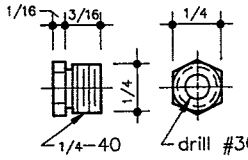




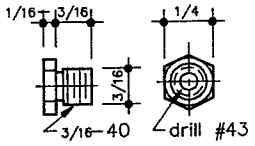
STEAM CYLINDER
Aluminum or Brass
2 Required



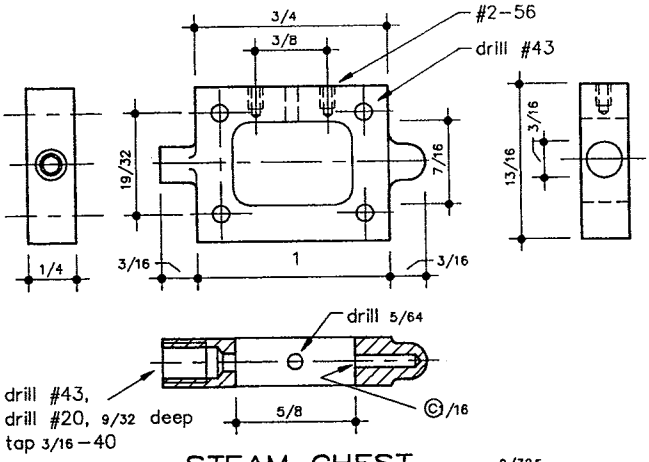
STEAM CHEST COVER
Aluminum or Brass
2 Required



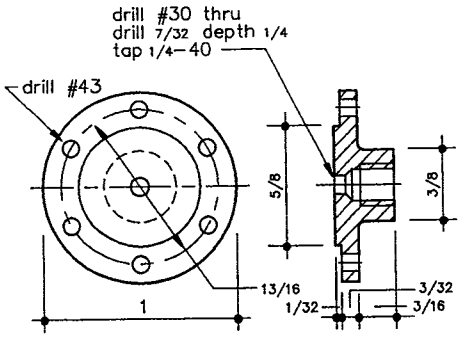
CYLINDER PACKNUT
Brass
2 Required



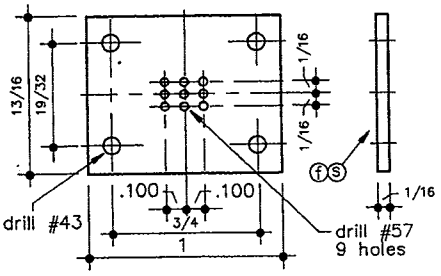
STEAM CHEST PACKNUT
Brass
2 Required



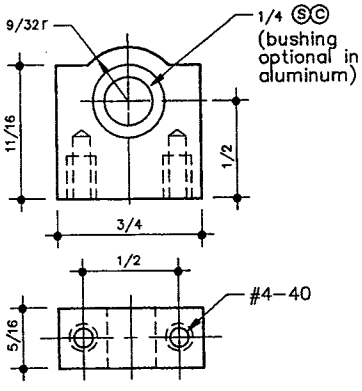
STEAM CHEST
Aluminum or Brass
2 Required



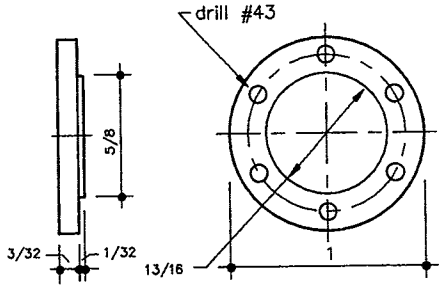
INBOARD HEAD
Aluminum or Brass
2 Required



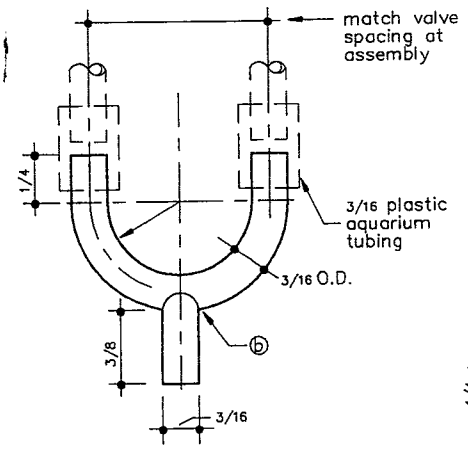
VALVE PLATE
Brass
2 Required



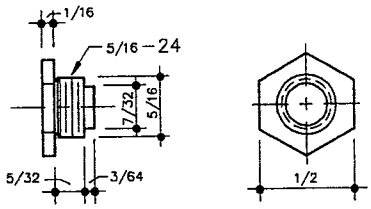
BEARING
Aluminum or Brass
2 Required



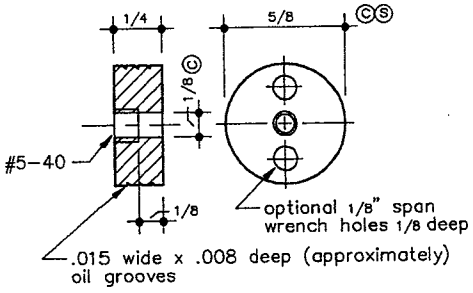
OUTBOARD HEAD
Aluminum or Brass
2 Required



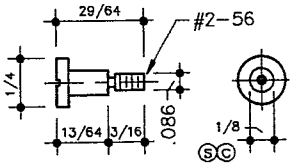
PUMP DISCHARGE MANIFOLD
Brass Tubing



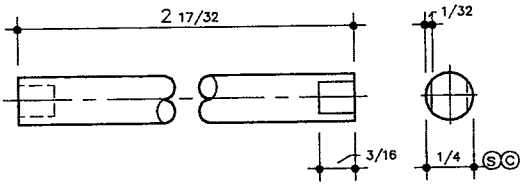
VALVE COVER
Brass
4 Required



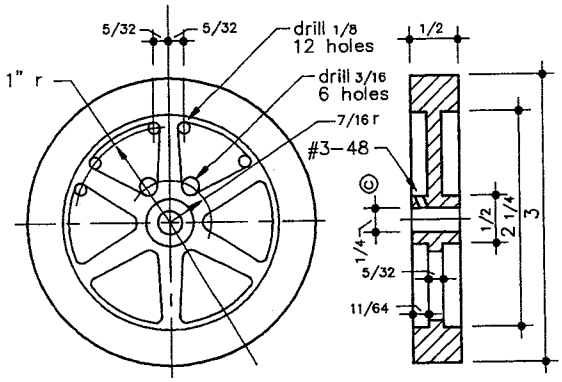
STEAM PISTON
Brass
2 Required



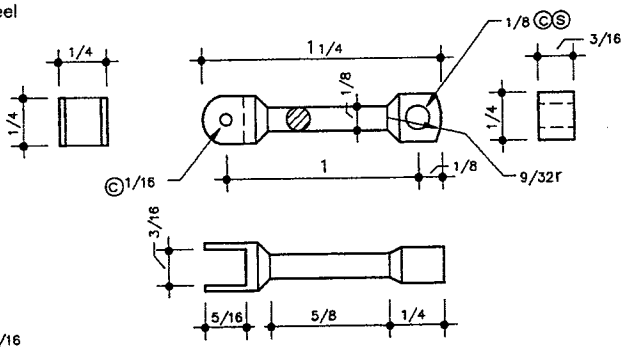
CRANK SCREW
Steel
2 Required



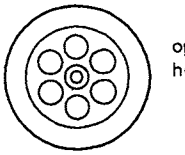
CRANKSHAFT
Steel

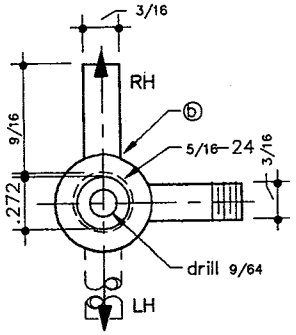


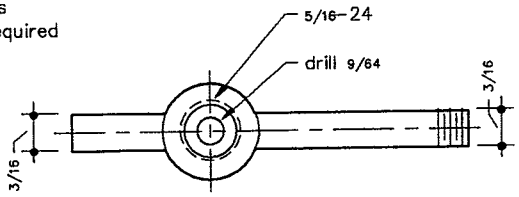
FLYWHEEL
Any metal

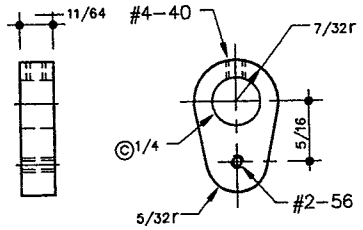


CONNECTOR ROD
Brass
2 Required

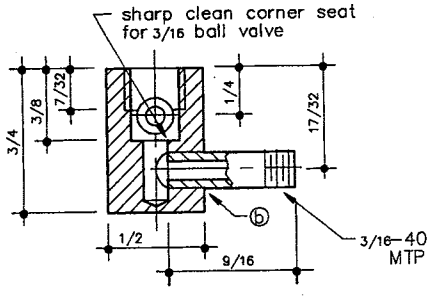




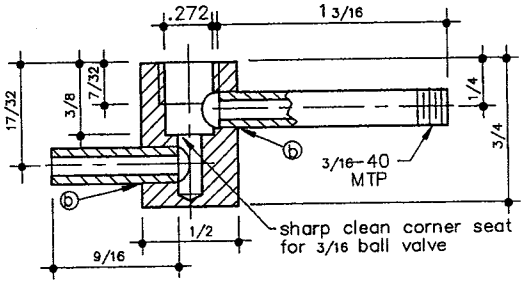




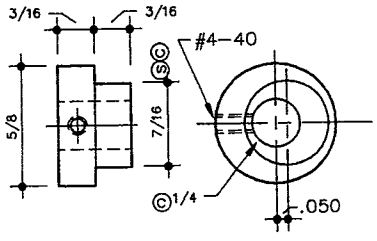
CRANK
Steel
2 Required



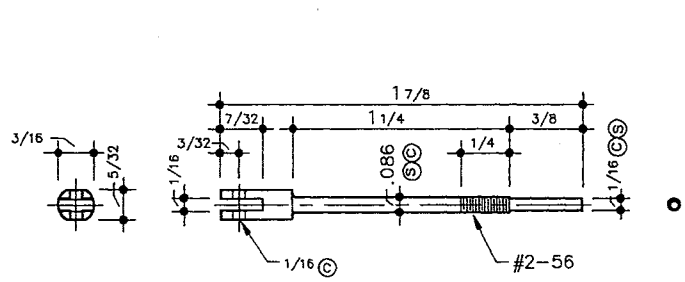
PUMP DISCHARGE VALVE
Brass body & tubing
Tubing wall .035"
2 Required (1: RH 1: LH)



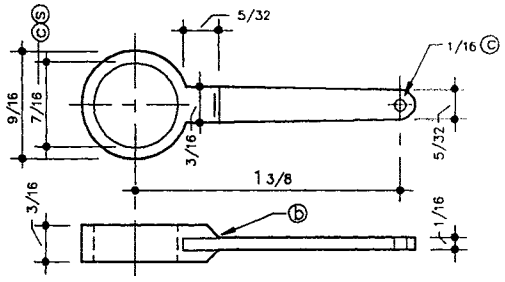
PUMP INTAKE VALVE
Brass body & tubing
Tubing wall .035"
2 Required



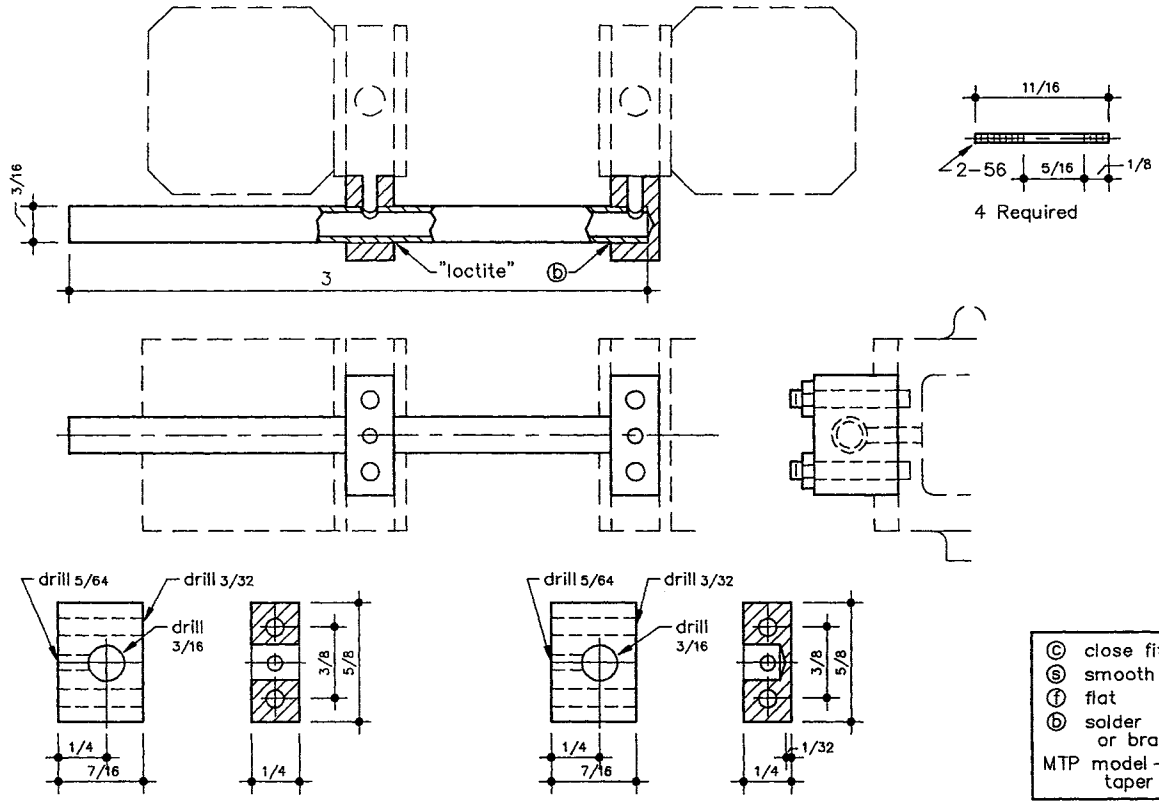
ECCENTRIC
Steel
2 Required



VALVE ROD
Brass
2 Required



ECCENTRIC STRAP
Brass
2 Required



STEAM INTAKE MANIFOLD
Brass

Packing to both Pumps. This takes a bit of patience, some tweezers and time. Perhaps you can add the Packing earlier and carefully withdraw the Plungers and reinsert when mounting the Table assembly. A radius or short taper on the ends of the Plungers will help.

Slide the Crank Shaft through the Bearing, one Eccentric, Eccentric Strap, Flywheel, the other Eccentric and Strap and the other Bearing. Leave all these parts loose for now.

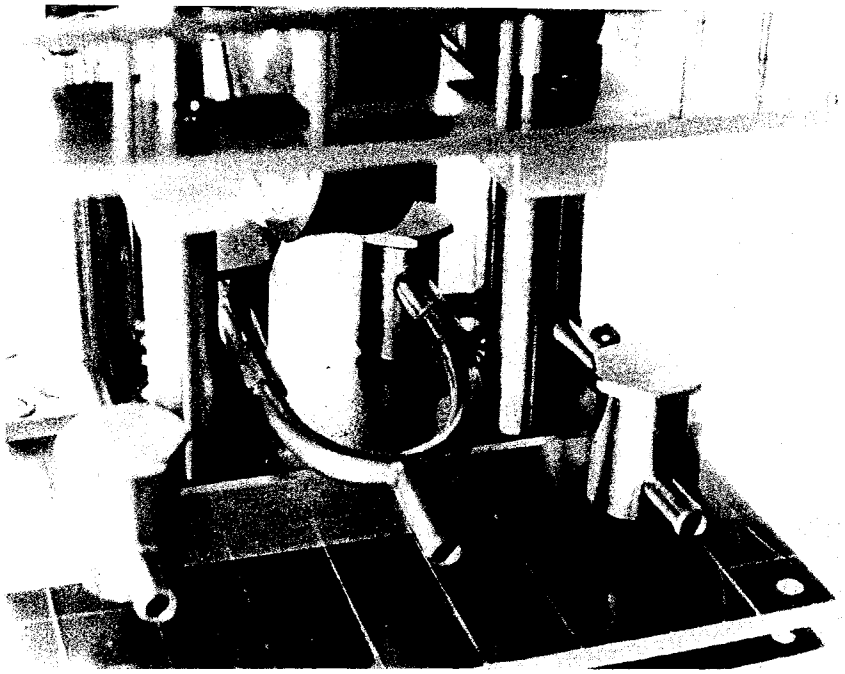
Draw the Shaft flush with one Bearing face. Hold a Crank Arm in place and push the Shaft through it until the Shaft is flush with the other Bearing face. Hold the other Crank Arm in place and push the Shaft back through it. Spot the Crank setscrews on the Shaft flats and tighten. Make sure the Shaft turns free.

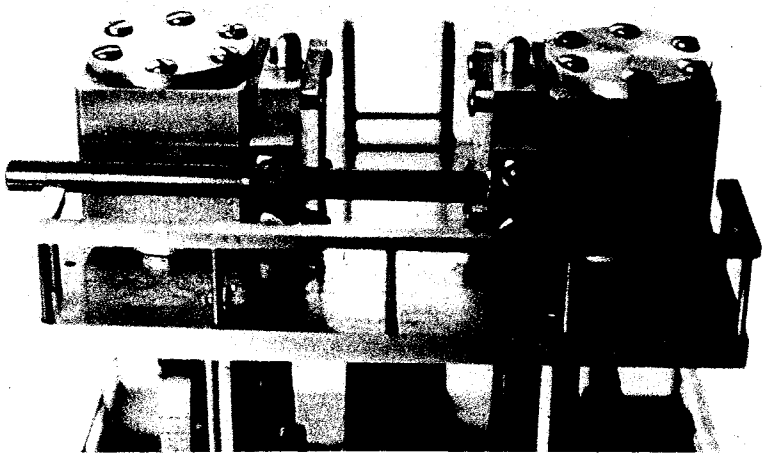
Insert pins through the Valve Rods and Straps. Snug up the Eccentric setscrew only enough to drive the Valve Rod. Adjust the Valve Rod until the Valve holes are equally exposed at each end of the stroke. Bits of fine copper wire can be inserted to retain the pins. Attach the Steam Chest covers.

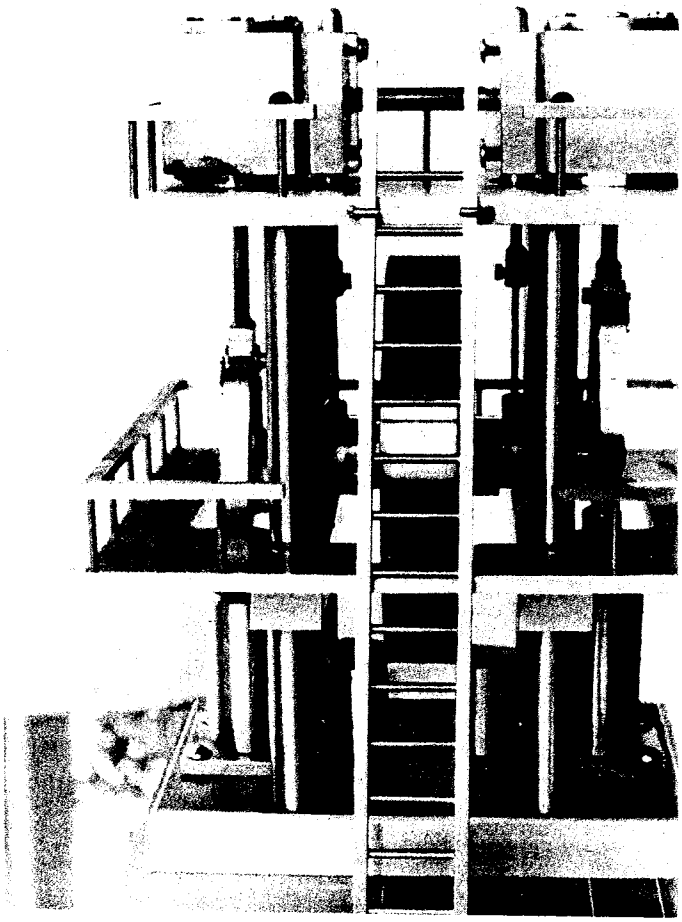
Tighten the Flywheel midway on the shaft. Insert the two crank shoulder screws. Rotate the Flywheel until one Piston is at extreme dead-center and tighten its Eccentric 90 degrees from the crank. Do the same with the other Eccentric either to both lead or both follow its crank.

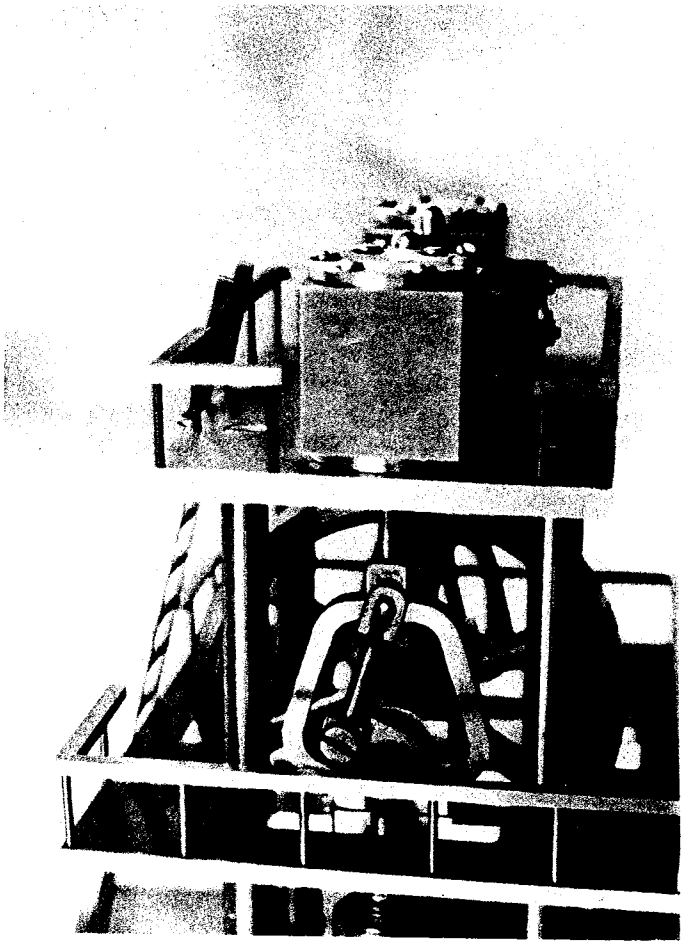
Ten to 15 pounds of air drives this engine easily. Clear, light mineral oil was chosen for pumpage. It prevents rust and lubricates. Actually, the engine runs too fast to depict the working of the large pumping units in the city waterworks. It is hard to slow down. A heavy Flywheel helps to reduce the speed a bit, so if you make a Flywheel, make it heavy. You may be able to add 1/4" to its diameter. See the detail photos on page 79.

The Pump Discharge Manifold is shown in the upper photo of the Pumping Engine while the two Steam Cylinders, Table and Railing are in the photo at the right. The Ladder shows clearly in the direct frontal view below and the Yoke and Pump Plunger Assembly are illustrated in the lower right picture.



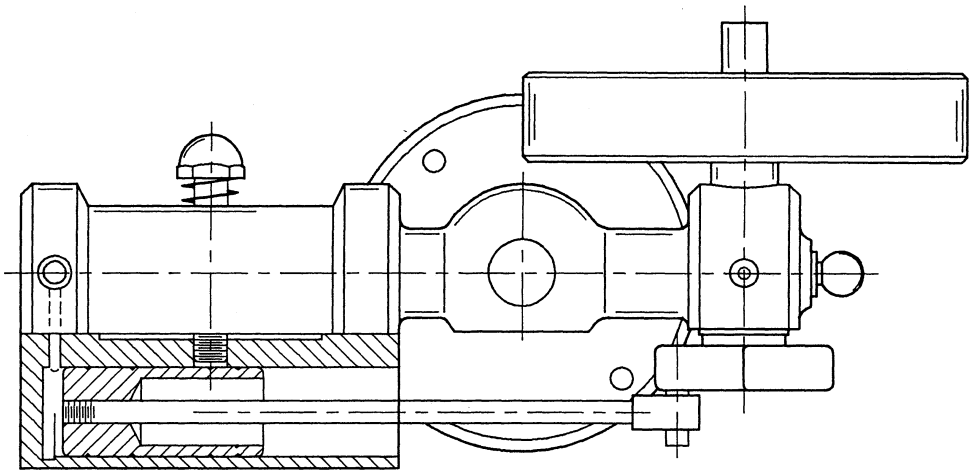


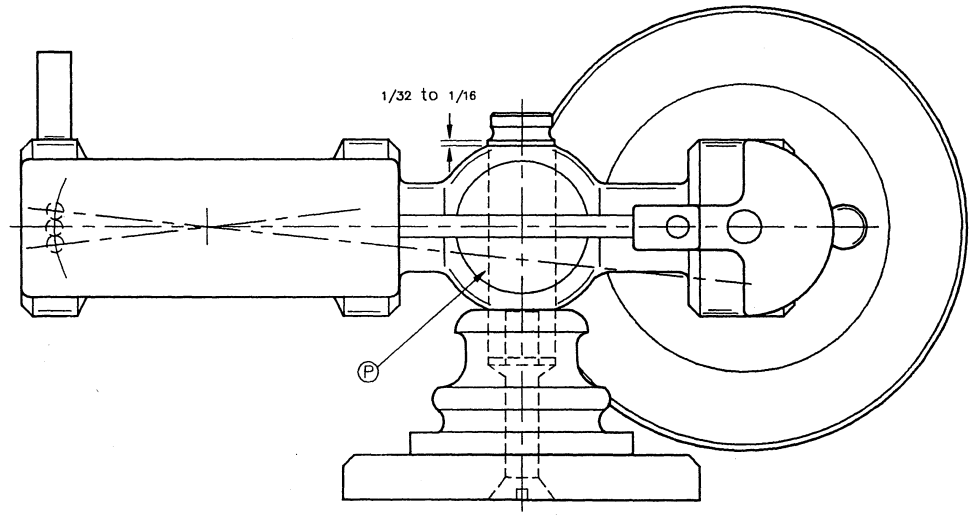




CHAPTER

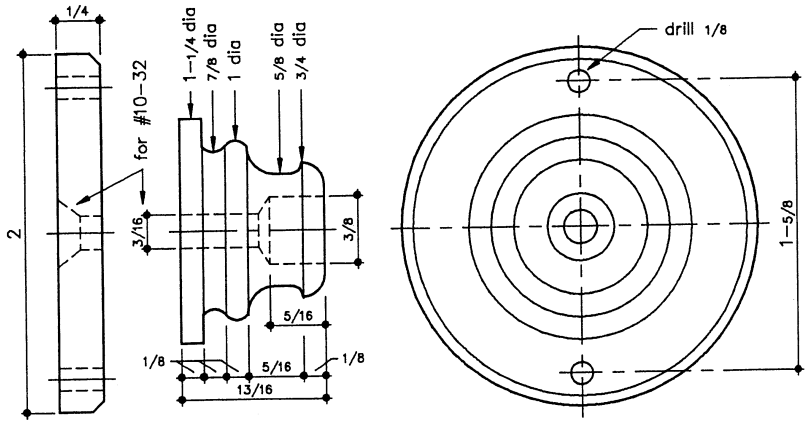
18 Fancy II





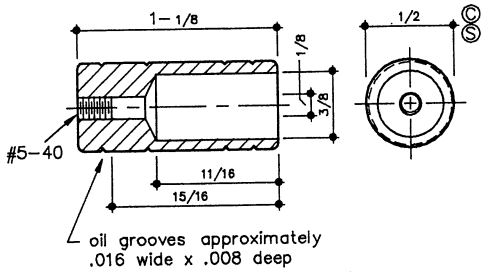
Back in January, 1981, plans for a small engine which we called *Fancy* were published . It was a popular engine among those who like lathe work. *Fancy II* is similar but larger and horizontal.

For the engine **BODY**, chuck about 5-1/2" to 6" length of 1" round stock in the 3-jaw with about 4-3/4" projecting. Make a center hole for tailstock support and turn the O.D. until it is a uniform diameter and bright. It can be a bit under size. Paint a band of layout dye the full length and scribe lines for all the major shoulders and ball center. Turn the various diameters and shape the ball by eye, filing until round and to your satisfaction. Other shapes can be used instead of the ball shape. Don't hesitate to try your own ideas. The small knob on the Bearing end was to be an oil cup but the oil did not flow. It was left as an ornament and an oil hole drilled from the top down through the Bushing. You can omit the 3/8" projection and the ornament if you wish. Mount in the cross-slide, mill and cut away the shaded portion down to the 13/16" dimension. In this case the vise was removable and, with the Body still in the jaws, moved to the bench and the centers for the Shaft Bushing and Cylinder Pivot laid out. Return to the mill and pick up these two centers with a wiggler, and bore and ream to size. This way the holes are sure to be perpendicular to the flats you just made. Grip squarely in a vise, lay out and make the 3/8" hole for the **CENTER POST**. Counterdrill 5/16" for the spring.

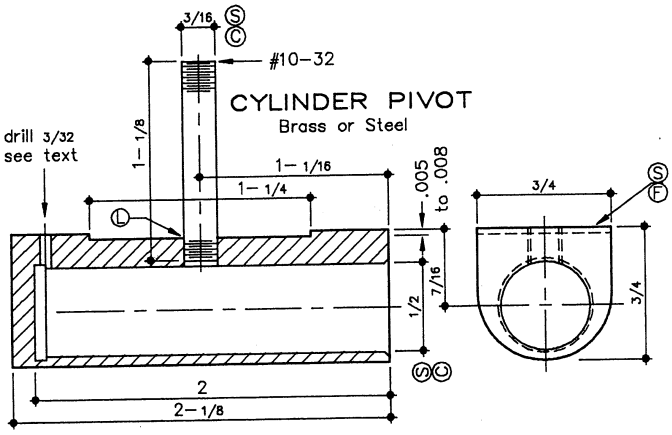


BASE
Aluminum or Steel

Ⓒ close fit
Ⓢ smooth
Ⓑ braze or solder
Ⓟ press fit or "loctite"
Ⓕ flat
Ⓛ "loctite"

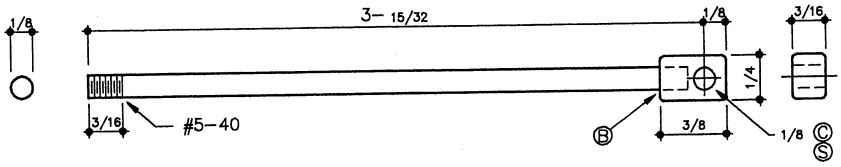


PISTON
Brass or Aluminum

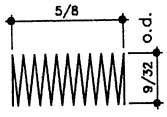


CYLINDER PIVOT
Brass or Steel

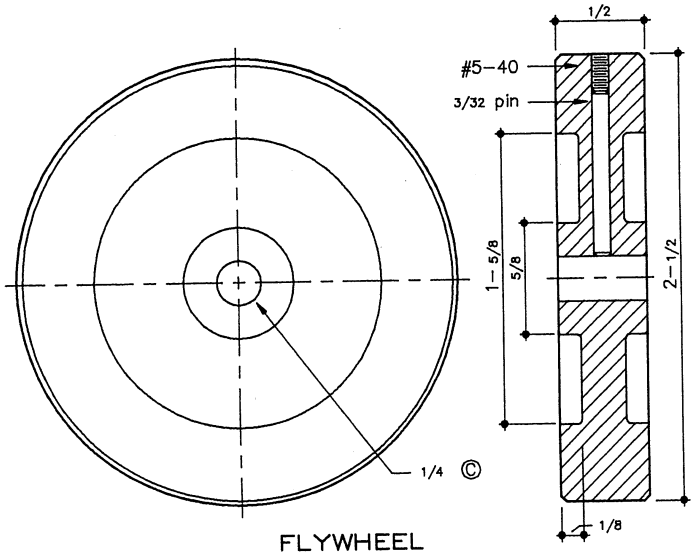
CYLINDER
Aluminum or Brass



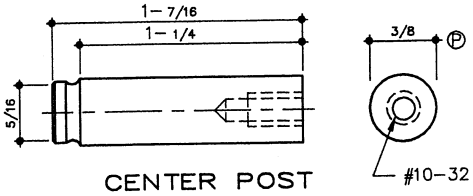
CONNECTING ROD
Brass or Steel



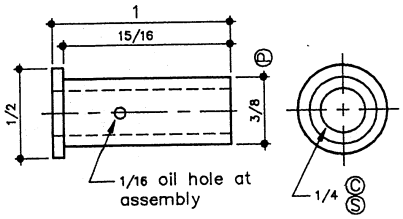
SPRING
Bronze
.036 wire diameter
approximately 8 coils



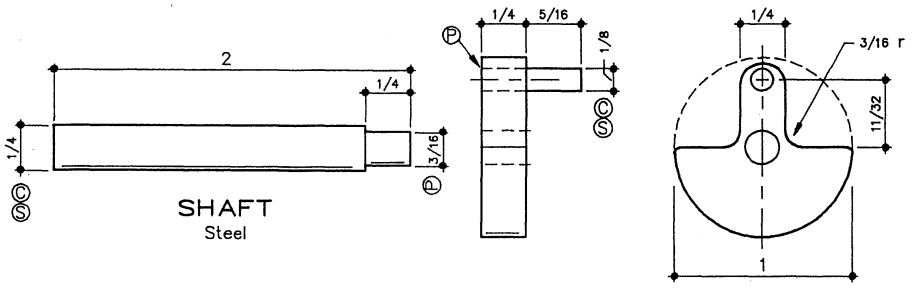
FLYWHEEL
Any metal



CENTER POST
Aluminum

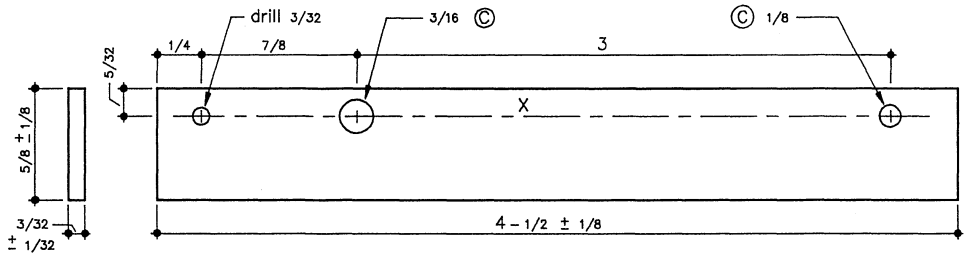


BEARING BUSHING
Brass or Bronze

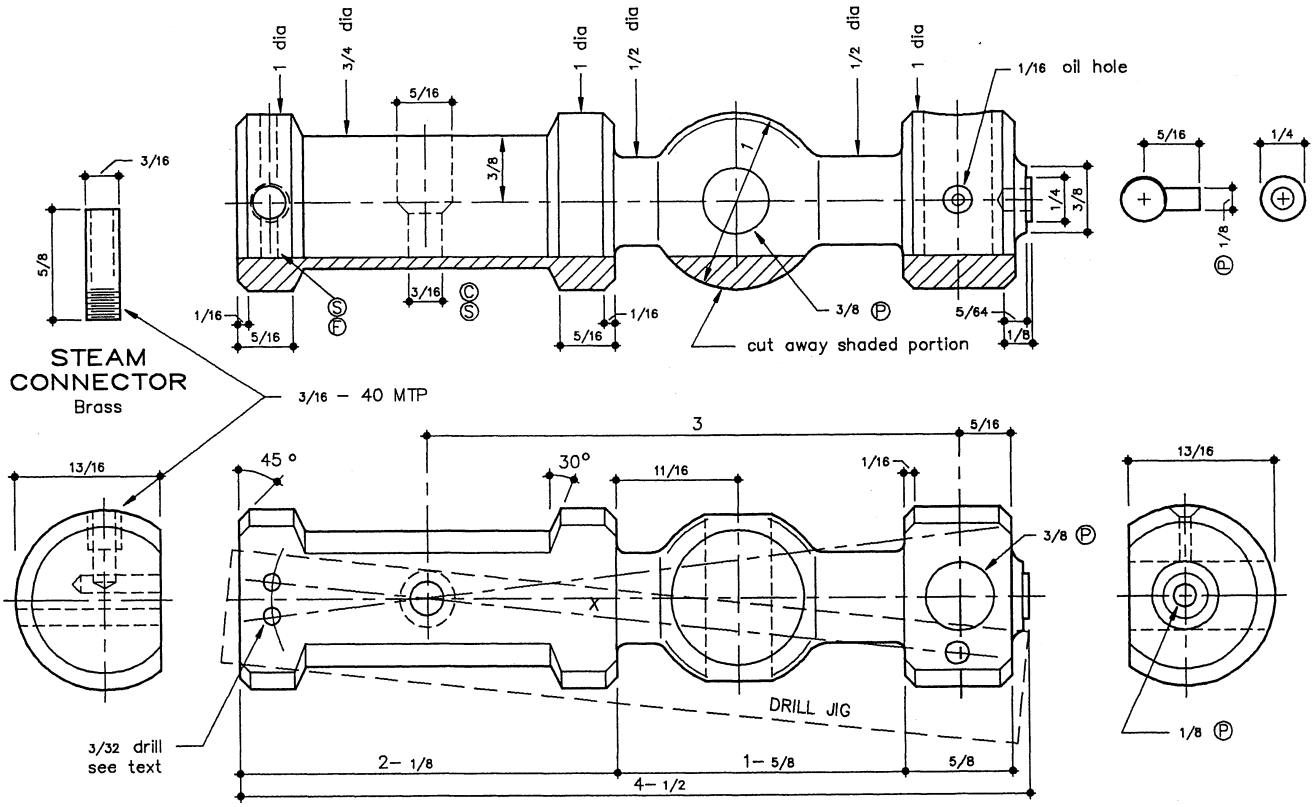


SHAFT
Steel

CRANK DISK
Steel

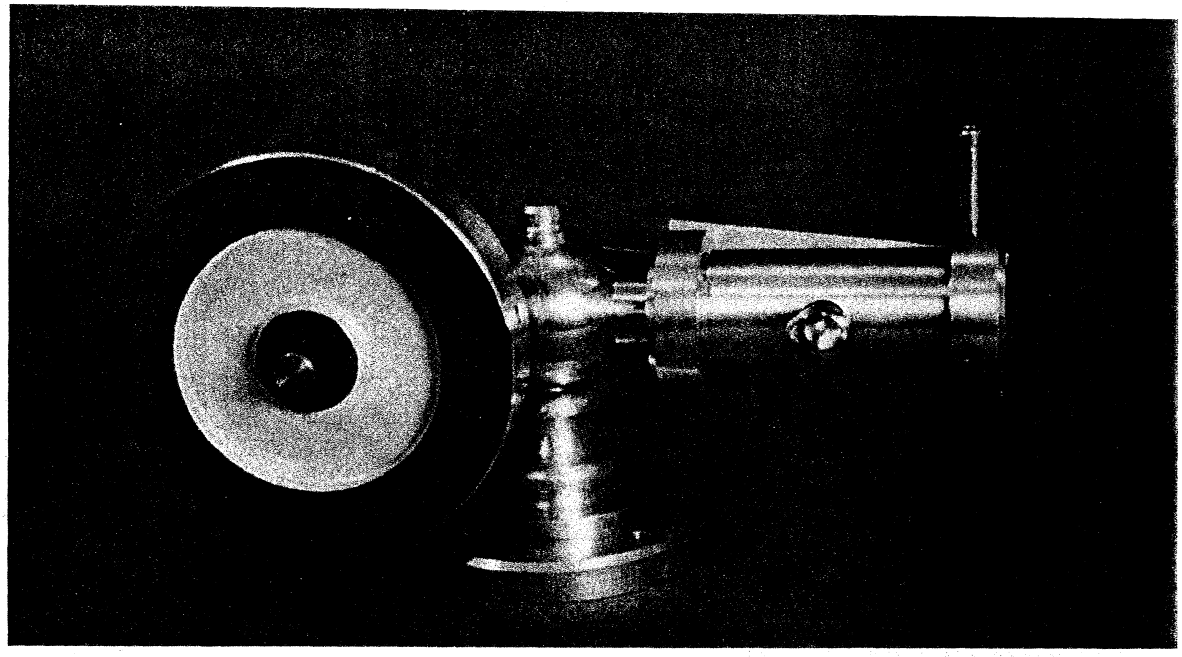


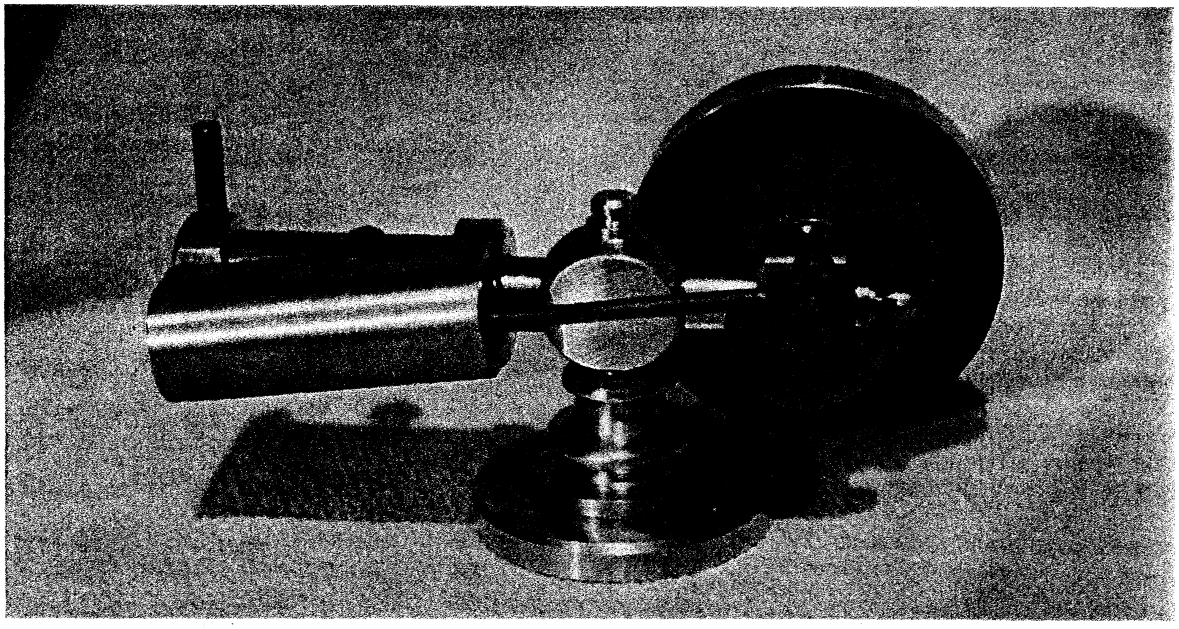
DRILL JIG
Steel

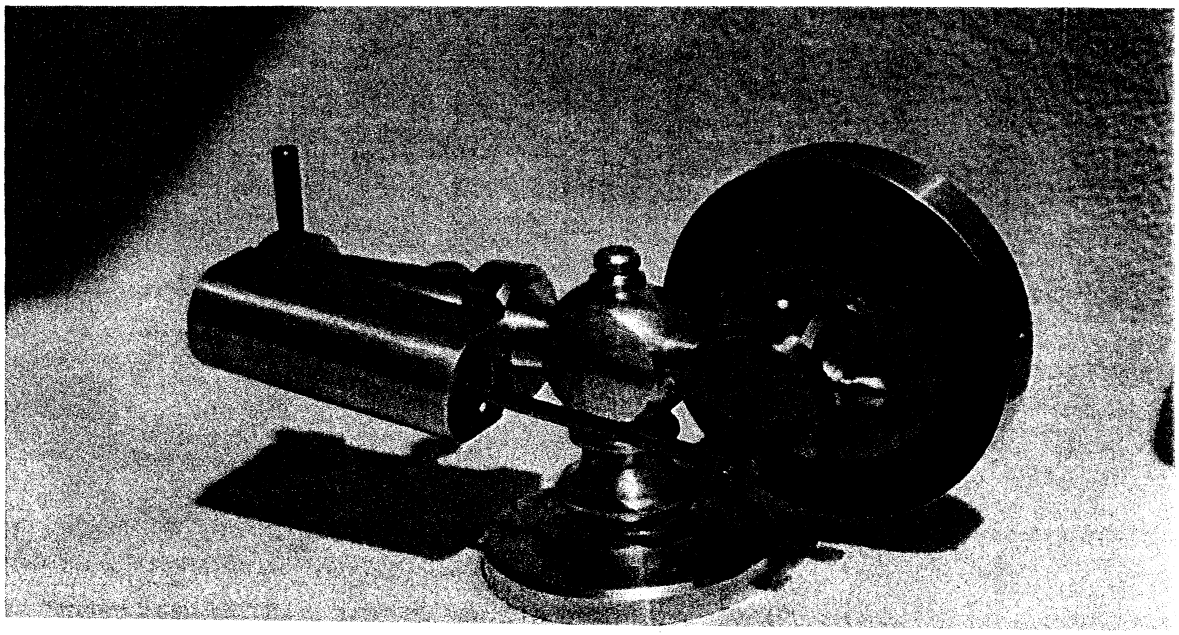


STEAM CONNECTOR
Brass

ENGINE BODY
Aluminum







Make the **DRILL JIG**. Insert close-fitting pins in the 3/16" and 3/8" holes in the Body. Place the Jig over the 3/16" pin and hold the Jig against the 3/8" pin while drilling a 3/32" port hole. Turn the Jig over to make the other 3/32" port hole. Drill the Steam Passages and tap the Steam Connection.

Make and set the **CENTER POST** into the Body with Loctite.

Square up the end of a piece of 3/4" x 3/4" stock for the **CYLINDER.** Prick punch 7/16" from one face and center in the 4-jaw using a center test indicator and bore 1/2". Chuck in the 4-jaw, lightly true up and undercut the sealing surface. Tap #10-32 as square and true as possible.

Make the **CYLINDER PIVOT** and set squarely with loctite.

The **PISTON** is made a bit long since there are no guides. Assemble the Piston and **CONNECTING ROD** and insert in the Cylinder. Mount the Drill Jig over the pivot and run a close-fitting 1/8" pin through the Jig and crank pin hole in the Connecting Rod. Drill the 3/32" port hole in the Cylinder.

The outside surface of the Cylinder can be rounded as shown. It improves the appearance of the engine. This can be shaped or milled and given a final fine finish with file and emery.

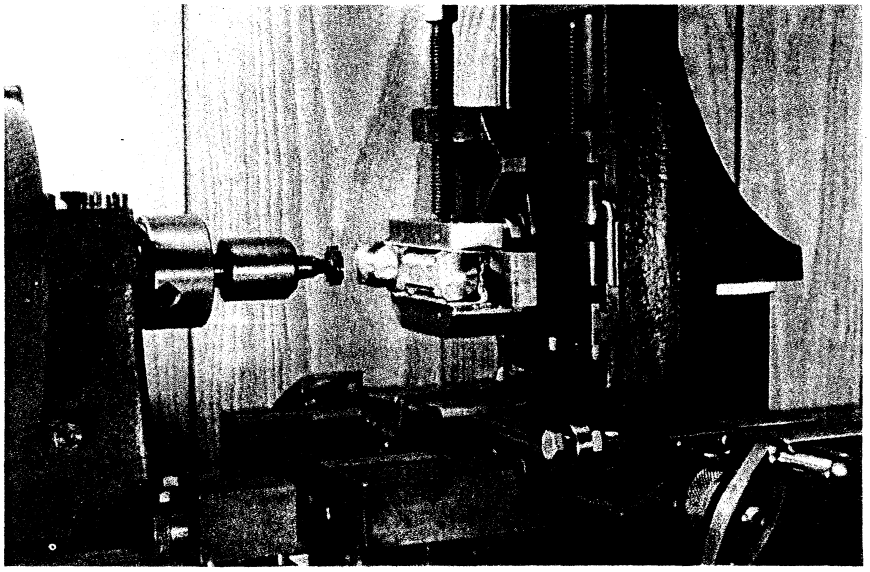
The **SPRING** used here came from the odds-and-ends department and has the proportions shown. Go over your spring collection and try for one near these dimensions and give it a try. You can tell from the effort it takes to rock the Cylinder. It should hold snug without too much drag. This surface is a good place for light "Moly" lube.

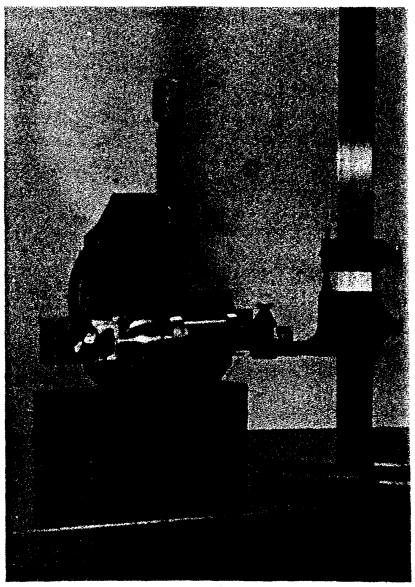
Since the common tap is too short to thread deep in the **FLYWHEEL**, a pin is used ahead of the setscrew. At final assembly, spot a flat on the **SHAFT** for this pin.

The **BASE** is mostly turning and can be shaped any way you wish. The proportions here looked fairly good when made in metal. Again, don't hesitate to try your own ideas. One lone #10-32 flat head screw holds the Body and Base together.

The **STEAM CONNECTION** is 3/16", so common aquarium tubing can be used, in this case on compressed air. Make the connection to suit your air or steam line.

This engine ran good on 5 to 10 psi air and will give pleasure for years.

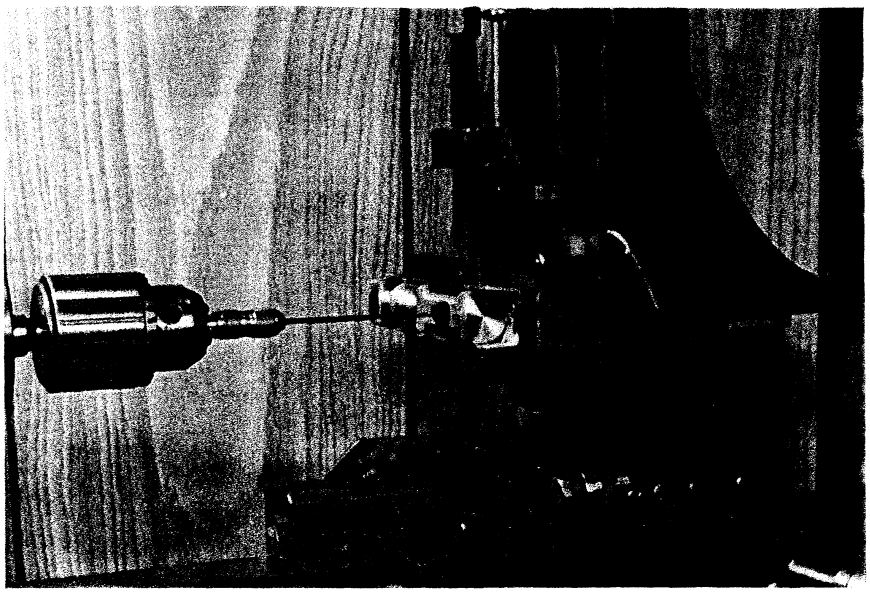




Above — Milling the flats on the engine body.

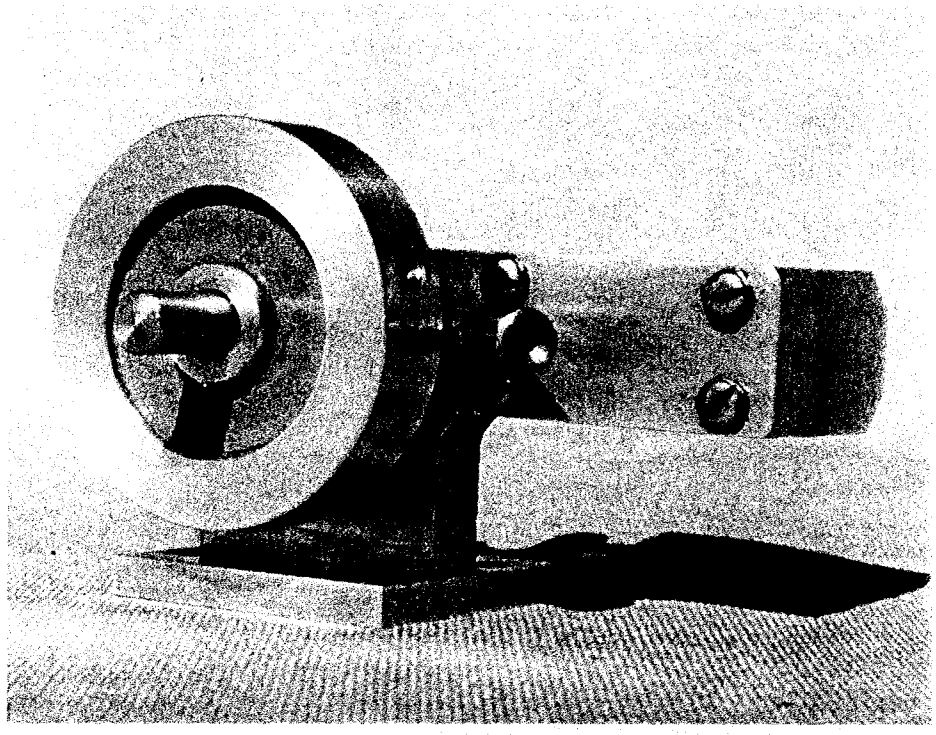
Left — Laying out the shaft and pivot centers. The vise was removed wihtout disturbing the body.

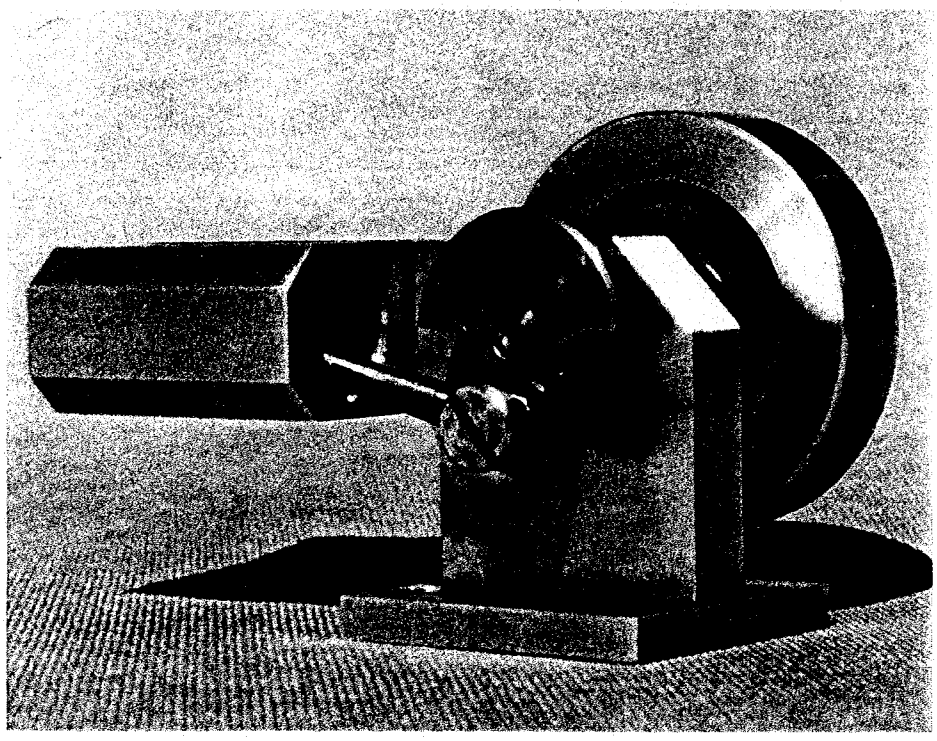
Below — Picking up the center for the pivot hole with a wiggler.



CHAPTER

19 Standby





This engine has a piston-wrist-pin-connecting rod type of construction like an auto engine. Simple valving is done in the slots in the Crankshaft.

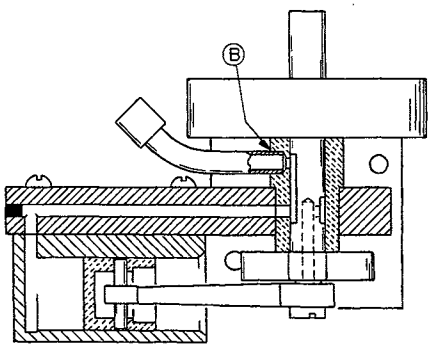
Start the **FRAME** with a finished 1/4" x 1" x 2" piece of metal. Apply layout dye and lay out all hole centers. Machine all holes, but do not plug the 1/16" hole until a drill has been run through the bearing later.

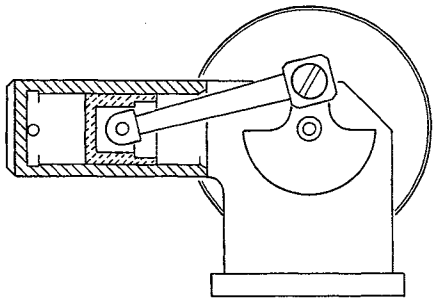
Make the **BEARING** and steam connnection. This connection is for 3/16" plastic tubing. You may have other ideas for this, depending on how you will eventually drive and use this engine. Drill and turn the 3/16" stock and remove from the chuck. Enter the end into 1/8" hole in some scrap stock held in a vise and apply heat with a torch. When almost red hot, slowly bend it to the required shape. Cut it to length and remove burrs. Solder the steam connection to the bearing and set the bearing in the frame with Loctite. Drill the steam passage through the bearing and plug the hole in the frame using a press fit or Loctite.

For the **CYLINDER**, start with a piece 1/2" x 9/16" x 1" and lay out the centers for the 3/8" bore, four screw holes and the 1/16" port hole and prick punch. These holes must match the holes in the Frame. Center in the 4-jaw using a center test indicator; make the 3/8" bore. Square up the bottom with a boring bar. On the last pass before reaming, make a light undercut for reamer runout so as not to leave a shoulder for the Piston to strike. Do not break into the bore when drilling and tapping (with a bottoming tap) the four screw holes.

Make the **CRANKSHAFT** as shown. The important thing here is the accurate location and depth of the valve flats 180 degrees apart and the throw of the crank set midway between the flats, as shown in the assembly view. The piston is halfway in its stroke and getting full steam. Attach the crank disk to the shaft with a press fit or Loctite.

The **PISTON**, **FOOT** and **SHOULDER SCREW** need no explanation. The thread on the screw is best made





STANDBY

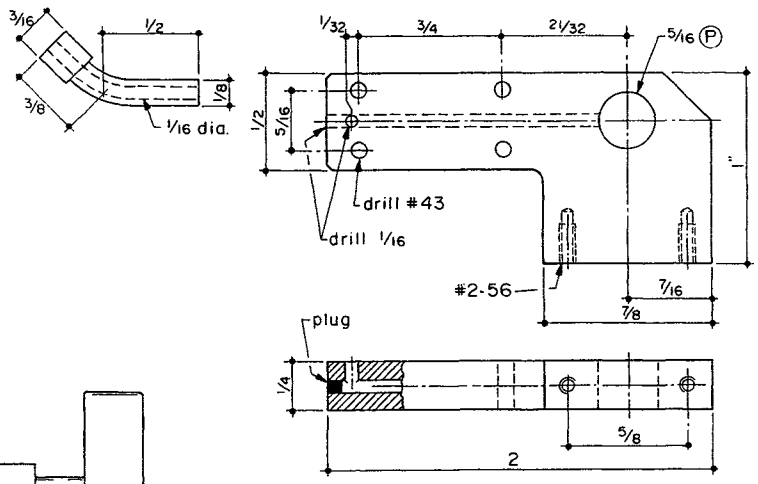
using a tailstock die holder.

For the **CONNECTING ROD**, use 1/8" x 1/4" stock and lay out the center on the end and prick punch. Chuck in a 4-jaw with about 1/4" projecting and center it with a center test indicator. Centerdrill with a tiny 3/64" center drill. Mark two adjacent jaws with chalk. Free these two jaws and move the stock out so about 1-1/2" projects from the jaws. Retighten the two marked jaws while holding the piece against the tailstock center. Turn the center portion and make parting cuts at each end down so about 1/8" diameter remains. Remove from the chuck and lay out and ream the 1/8" and 1/16" holes. Then you can file or mill the Piston end down to the 3/32" x 3/16" dimensions shown. Finish to length.

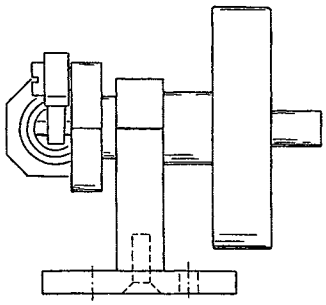
The **FLYWHEEL** is 1-1/4" x 5/16" wide and is fitted with a setscrew. The small taps are not long enough to reach the center, so a free fitting pin in the tapdrill hole transmits the pressure to the shaft.

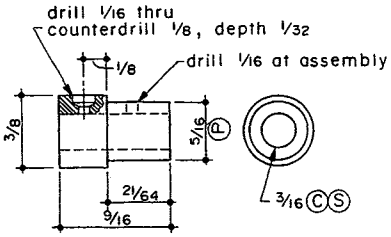
At assembly, insert a 1/16" x 11/32" long steel Wrist Pin in the Piston through the Connecting Rod. Make a light prick punch mark at each end of the Pin, flowing a tiny bit of the Piston metal over the ends as a retainer. Use an oil stone to remove any raised metal that might bind the Piston in the Cylinder.

If all has gone well, you can now lubricate it and give it a trial run on 5 to 10 pounds of air.

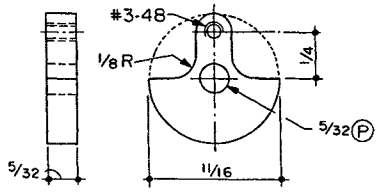


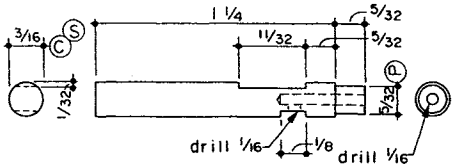
FRAME
Aluminum



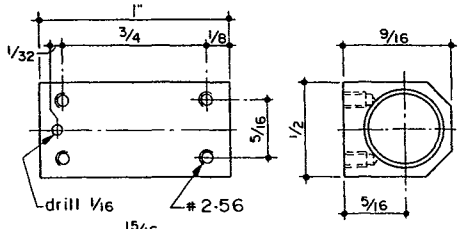


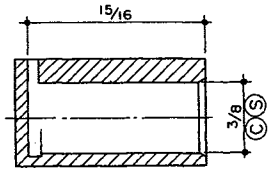
BEARING
Brass



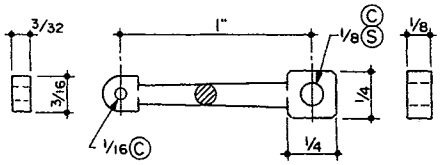


CRANKSHAFT
Steel

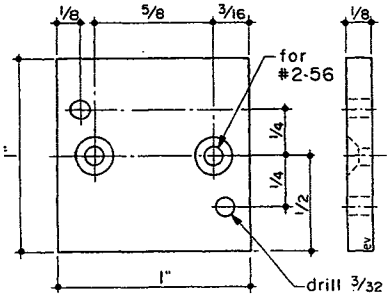




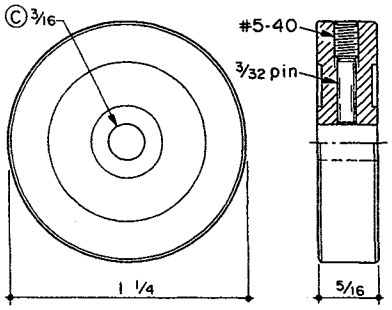
CYLINDER
Hard Aluminum



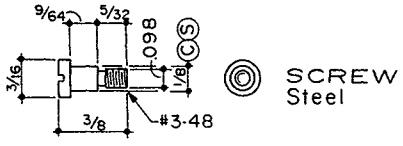
CONNECTING ROD
Brass



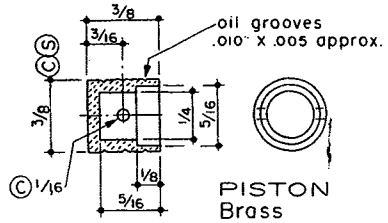
FOOT
Aluminum



FLYWHEEL
Any Metal



SCREW
Steel



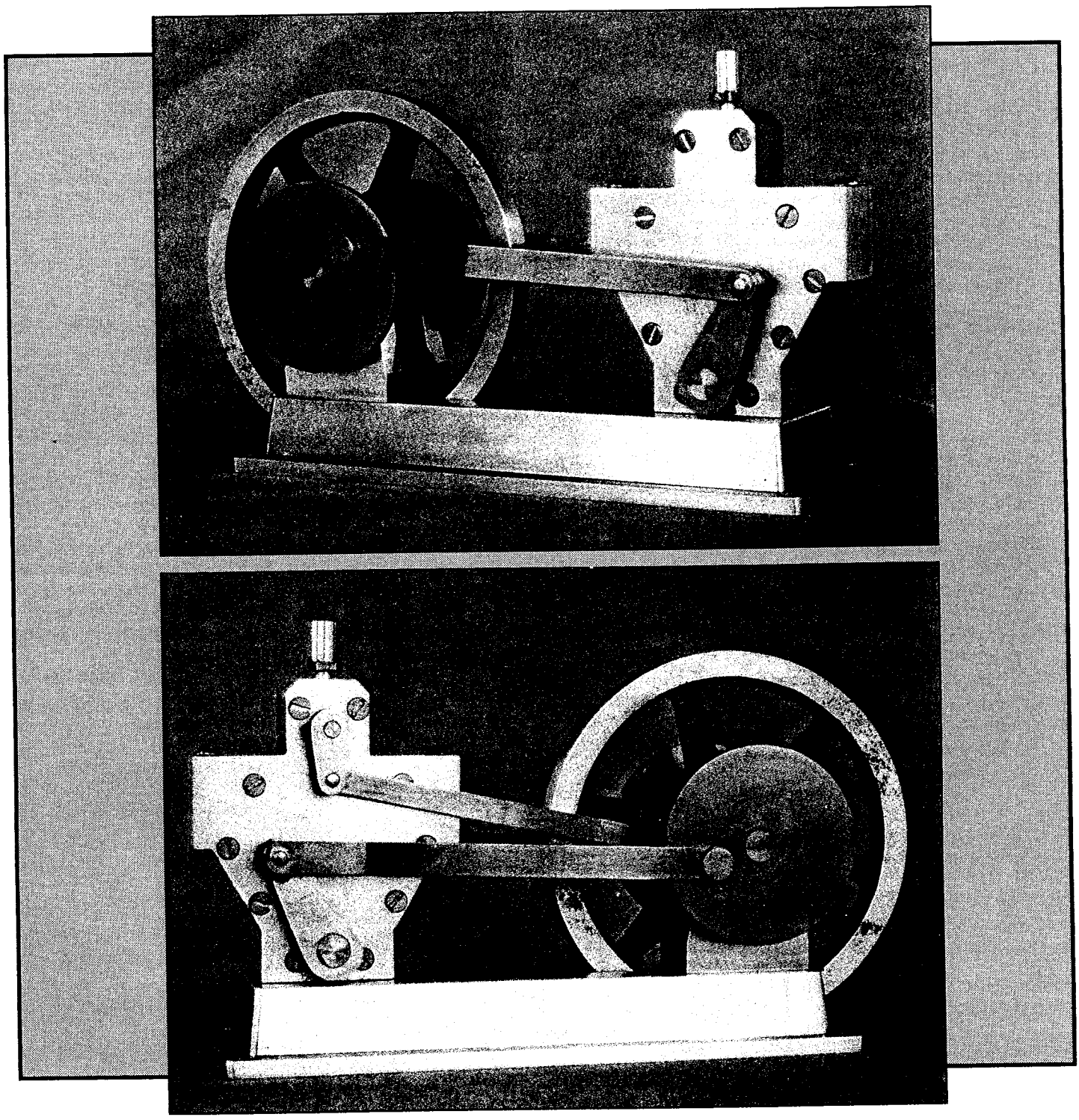
PISTON
Brass

CHAPTER

20

Take a look at this pistonless

Kimble Engine



The suggestion for this engine came from Basil Moored of Cadillac, Michigan, and it makes an interesting project. Miniaturizing it was a bit of a problem. Here it is more of a compressed air engine than Live Steam, but it is a good conversation piece and fun to show off. Some will say it is over-simplified but it was hard to find room for stuffing boxes, etc. Close fits at the shaft openings with some lubrication makes a fair seal on compressed air. It ran fine on as little as 5 pounds of air and slow enough to see the action. This is not intended as a hard working engine, but you may make changes to suit your ideas.

The drawings show most of the details, so only some passing remarks will be made on problems that came up during design and construction.

On the **BASE**, make the optional 1/16" bevel the last operation. In that way you have square surfaces for layout and machining.

When making the **FLYWHEEL**, lay out and drill all 24 holes before turning. Scribe lines tangent to the holes; saw and file the spokes to shape, then center in the 4-jaw using a center test indicator and turn and bore.

The engine **BODY** and **VANE** (what do you call them? It isn't a cylinder nor is the vane a piston) are critical in thickness. When all is done, the Vane should be about 1/2 thousandths free between the two covers. When making the Vane and **VANE SHAFT**, try for a very close and square fit at the "mortise and tenon." Keep the Shaft flats in the same plane and parallel to the Vane so the position of the Arms indicate the position of the Vane hidden inside the Body. Don't pile on too much solder. It will interfere with the Vane movement.

The **VANE SPRING** is a cut-and-try job. The general proportions are shown. You may make several before you're satisfied. It should only be strong enough to hold the seal against the bore with a minimum of drag.

When making the **CRANK DISKS**, **VANE ARMS** and **CONNECTING RODS**, in each case clamp the two together so spacing between the holes is identical. The Right Hand and Left Hand form for the Arms and the disks make it possible to assemble with the set screws on the outside for easy access. On the Vane Arms, especially, spot the set screws carefully at 90 degrees from the Arm centerline.

The two **BEARINGS** are mounted on the Base and lined up in the cross-slide milling attachment for boring and reaming for the Shaft. Mark each so they can be returned to the spot where they were machined. The Bearings on the model shown are fairly hard aluminum, though brass is perhaps more durable.

To plug the 1/16" holes called for in the **BODY** in operation 4, a small piece of aluminum was chucked and turned to about .065" diameter for about 1-1/2 times the required length and then carefully filed to a taper that entered the hole about half way. A very light dab of Loctite was applied and the pin driven in, cut off and filed flush. Note that the pins mentioned in operation 10 must dress flush in the valve bore.

The **VALVE** is a fine, close-fitting turning job. The steam passages were done with an indexing setup.

TIMING this engine takes a bit of patience. Assemble the engine omitting the Front Cover (Valve Shaft side), the front Vane Arm and Connecting Rod. Just snug up the set screw in the rear Crank disk.

Mount the Valve Arm loose on the Valve Shaft with the Eccentric Strap in place. Rotate the Valve until the marks on the end line up with one or the other port marks on the Body. Hold in that position and rotate the Flywheel until the Arm is in the same extreme position. Snug up the Valve Arm set screw. Now 180° rotation of the Flywheel should show the Valve lined up with the other set of scribed lines. If it doesn't quite match, divide the difference and give it a try and tighten the set screw. Scribe the line **C** across the Arm and Shaft.

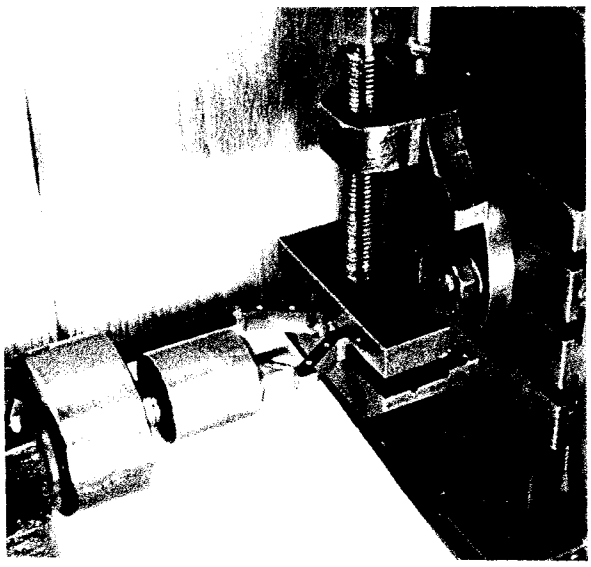
With the Valve at one extreme, rotate the rear Crank Disk until the Arm and Vane are verticle at midstroke. Tighten the Crank Disk set screw. Now, when the Vane is vertical, the Valve should be at one end of its stroke with full steam flowing to the Vane as shown in the assembly drawing.

Make sure there is a coat of light oil on the Vane and inside the Body. Remove Valve Arm and assemble Cover to Body. Remount Valve Arm, lining up with the mark on the end of the Valve Shaft. Add Vane Arm, Connecting Rod and Crank Disk and snug up set screws. Rotate the Flywheel. If it turns free, seat the set screws. If there is a bit of binding, juggle the Disk and Arm slightly to match the opposite Arm and Disk until the engine turns free.

Add a few drops of light oil in the air inlet before attaching the air line. If all is well, the engine will run good on as little as 5 to 10 pounds of air.

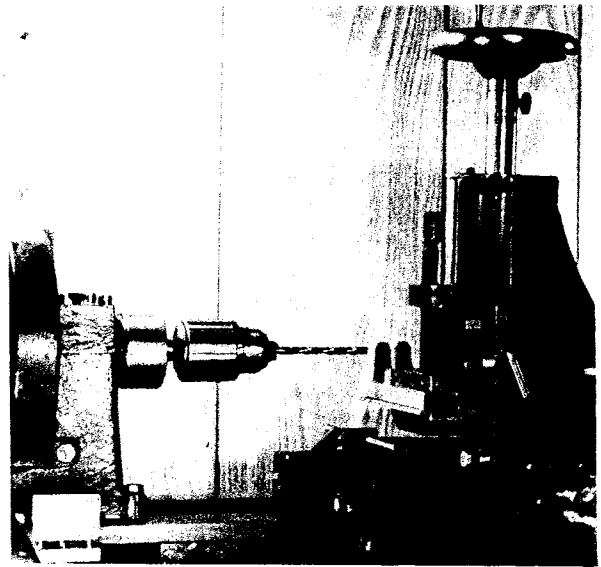
No attempt has been made to control the exhaust.

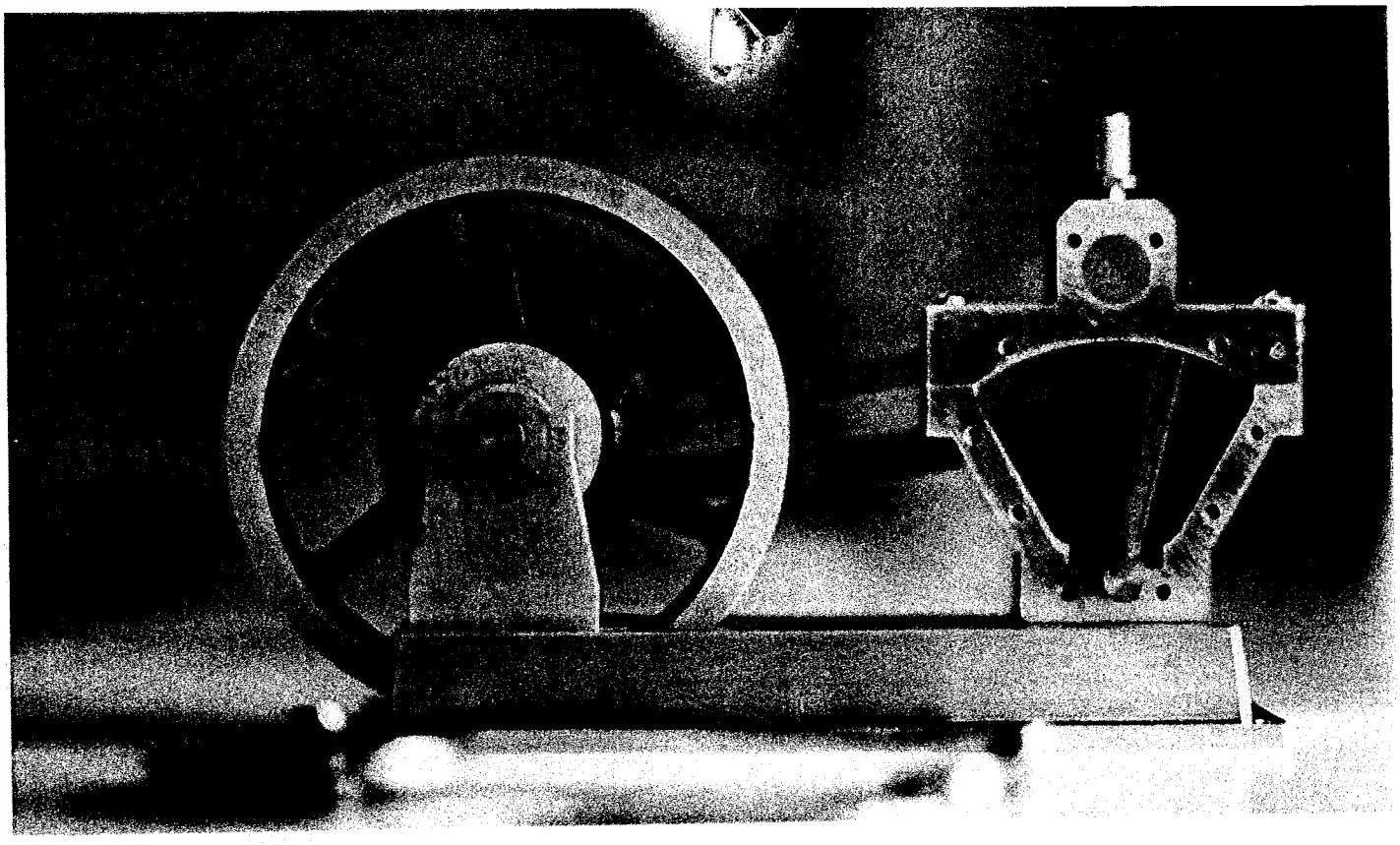
You should have a lot of fun building and operating this unusual engine for your friends for many years to come.



Milling the Engine Body (**left**) as shown in Step 9 on the drawings.

Boring for the Crankshaft (**right**) in the Bearings mounted on the Base.

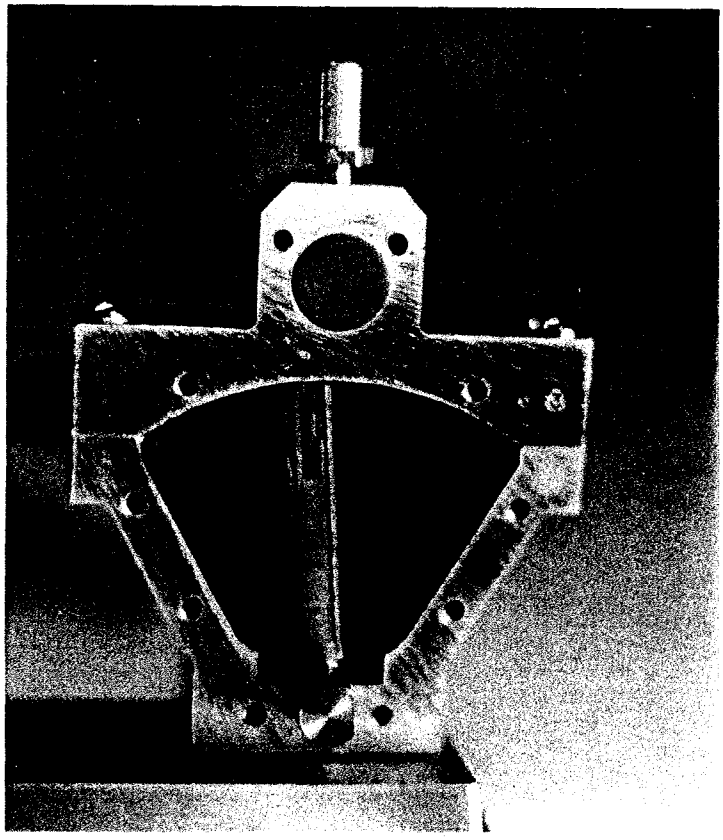




THE KIMBLE STORY

by William C. Fitt

with lots of help from Chet Sperry



A view of the Engine with the Vane exposed is shown on the opposite page.

A detail of the Seal with its Spring (above), and its location in the completed Vane (right)

When **MODELTEC**er Basil Moored stopped in one day to ask if we could copy a tattered old flyer about a steam engine, we asked if we could make a few extra copies for our files. It was an unusual engine shown in a copy of the flyer printed in reduced size on the facing page. We explained that Elmer Verburg would surely be interested in this engine and so we sent him a copy. As is typical of these events with Elmer, he soon called to say that he had built the engine and had it running! The plans and instructions for building one of these intriguing projects is given on these pages.

Since the Kimble engine was built in Kalamazoo, Michigan, we checked with **MODELTEC**er Chet Sperry of that city and he collected some material about the firm for us.

J. Emory Kimble was born in Brady Township, Kalamazoo County, Michigan, on November 16th, 1850. He left the farm home at the age of 20 and entered the grocery trade with his father in Vicksburg, Michigan, but sold the business in 1873. Emory then began operating one of the first steam threshers in Kalamazoo County and was involved in that operation for four years.

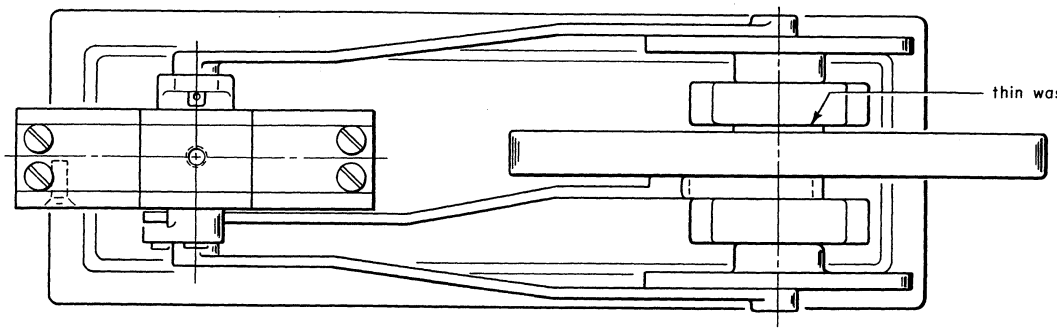
He then invented a separator and manufactured that in partnership with J. K. Wagner and John Fleming under the name of the Kimble Manuafcturing Company. That business was eventually sold to a Mr. den Blyker and, with Mr. den Blyker, Emory Kimble was engaged for a time in the manufacture of threshing engines.

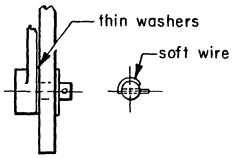
He invented the accolating piston engine known as the Kimble Engine which was manufactured by the Comstock Manufacturing Company of Comstock, Michigan, near Kalamazoo. This is the engine which Elmer Verburg's model is patterned after. The engines were made in sizes from 2 to 45 horsepower. In 1898, they enlarged their quarters to handle expanded orders, including shipments to Mexico, Norway, Belgium, Russia and Hawaii . . . and a large shipment to Dallas, Texas. The plant was a building 60; x 100' with a basement in which was located a gas plant that produced lighting for the building. On that level was also a boiler for heating the plant and for testing the engines . . . and a water wheel that operated the machinery in the plant. "By taking a half turn on the lever that opens the gate to let the water in on the wheel, all of the machinery was started. Everything runs in such smooth motion that it is musical to listen," according to the writer of an early twentieth century history of Comstock. On the floor above, manufacturing of the engines was carried on, employing 20 workmen and turning out about 25 engines per month. The firm had its own foundry in separate buildings to provide the castings for their engine production.

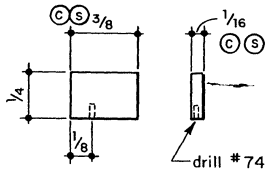
Apparently never idle, Emory next designed and built the Jewel automobile engine which was manufactured by the C. H. Dutton Company of Kalamazoo. (The C. H. Dutton Company was still using a 75HP Jewel engine to run the machine shop line shaft when Chet Sperry went to work there in 1941. The Jewel I.C. engine was later replaced by electric motors but the line shaft still propelled the machinery in the shop until they closed their doors about 1960!)

Later, Mr. Kimble designed the Gem automatic engine for the Clark Manufacturing Company of Kalamazoo and, still later, invented the governor made by the Eclipse Governor Company of Vicksburg. The Eclipse Governor Company was formed in 1892 as a co-partnership with J. E. Kimble, Ransom Kimble and Dr. McKain which carried on the operations until 1899. At that point a stock company was formed to operate the businesses with J. E. Kimble as President, his wife, Frankie, as Vice President and their son, Roy, as Secretary and Treasurer.

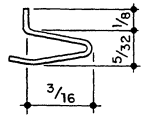
Records of the final days of the Kimble story seem to be lost in antiquity but, through the interests of Basil Moored, the ingenuity of Elmer Verburg and the inquisitiveness of Chet Sperry, the inventive prowess of J. Emory Kimble will be recorded for future generations.



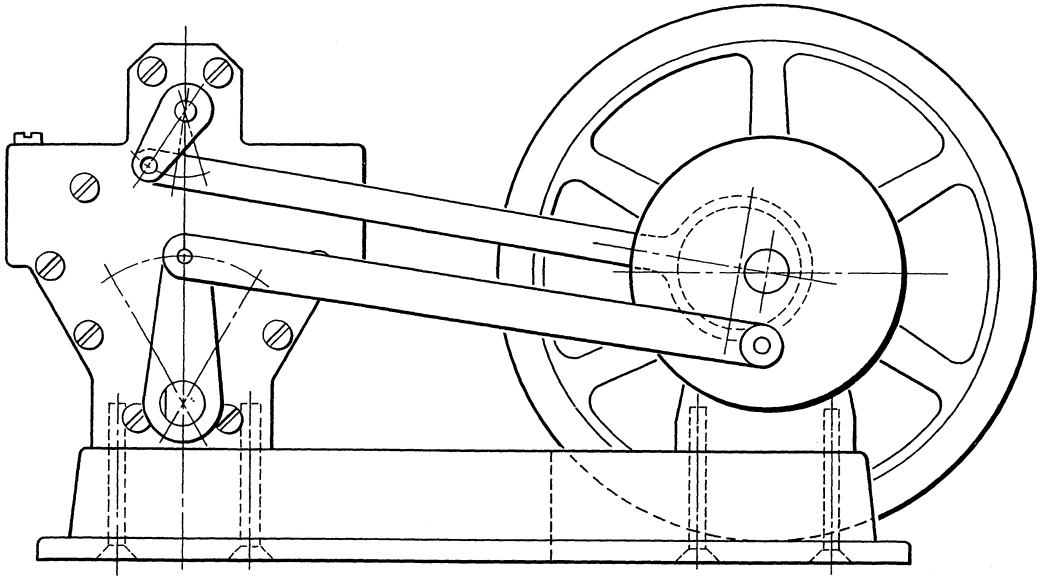


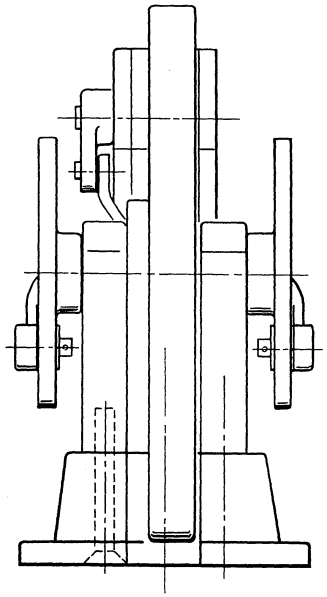


SEAL
Brass



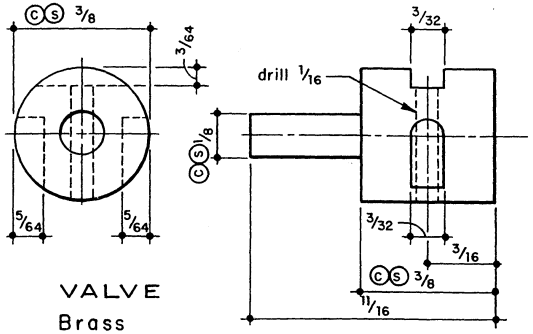
SPRING
Stainless Steel
.016 wire



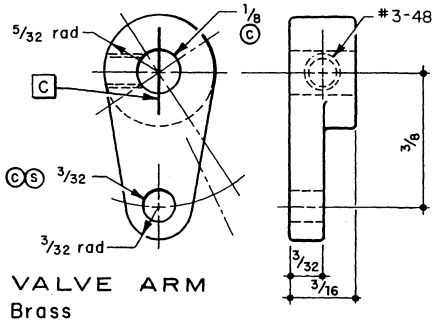


KIMBLE ENGINE

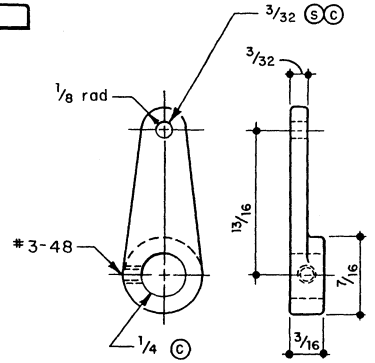
C	close fit
S	smooth
B	braze or solder
F	flat
P	parallel



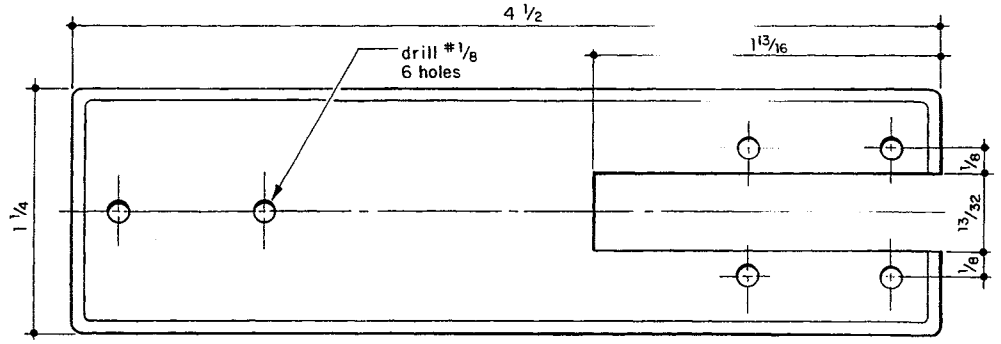
VALVE
Brass

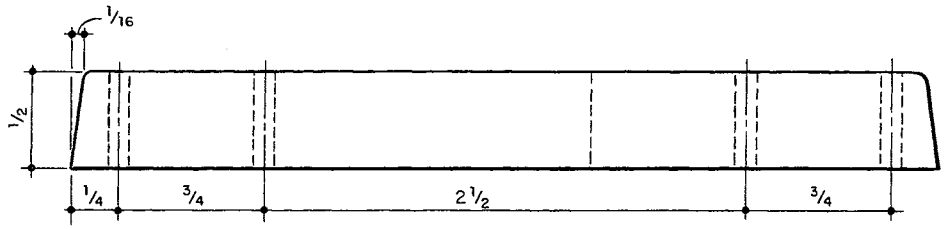


VALVE ARM
Brass

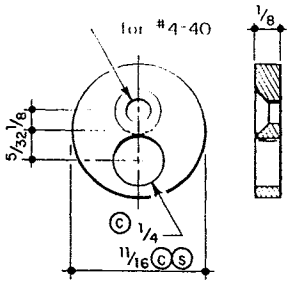


VANE ARM
Brass or Steel, 2 required:
1 right hand and 1 left hand

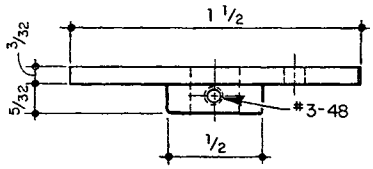


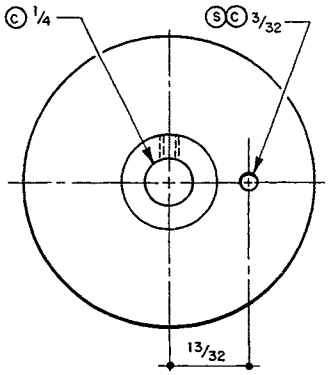


BASE
Aluminum or Steel

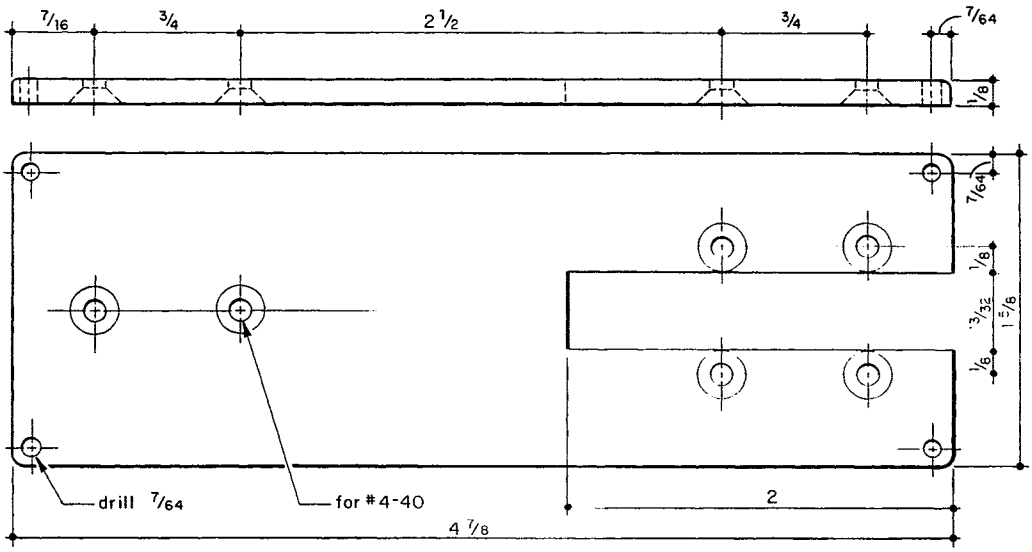


ECCENTRIC
Steel

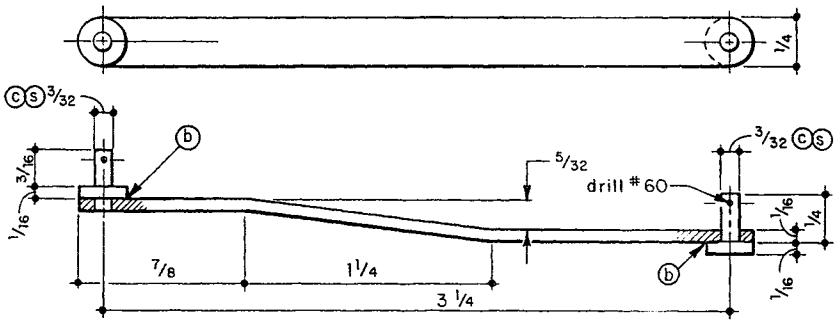




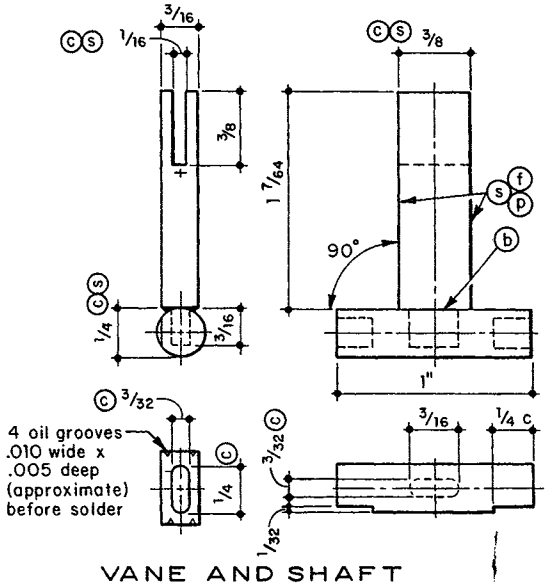
CRANK DISK
Steel, 2 required:
1 right hand
1 left hand



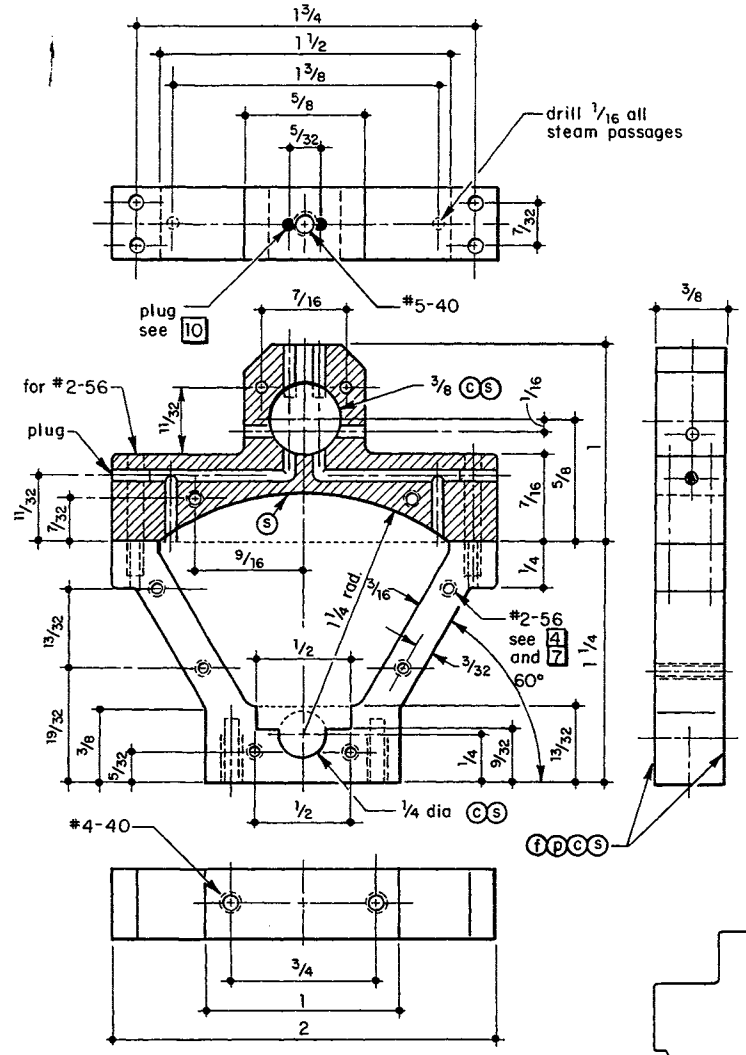
SUB-BASE
Aluminum or Steel



CONNECTING ROD
Brass, 2 required

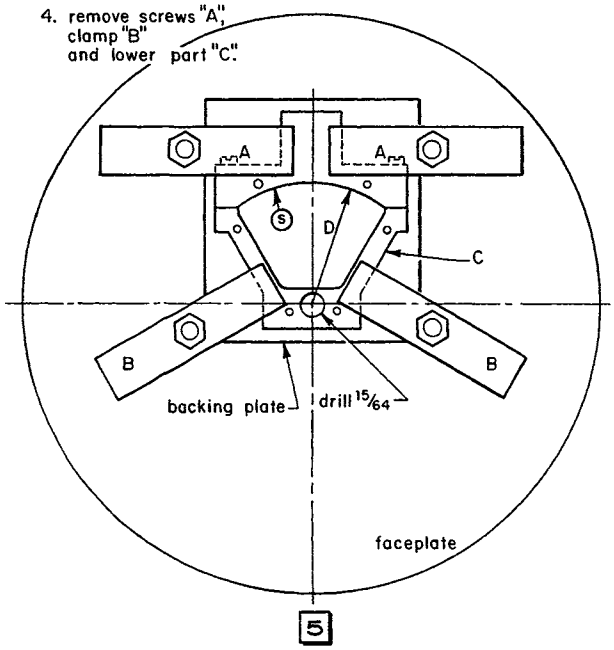


VANE AND SHAFT
Brass

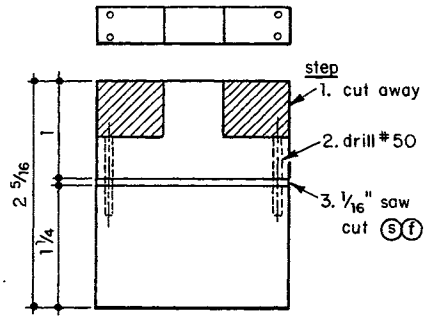


ENGINE BODY
Brass or Aluminum

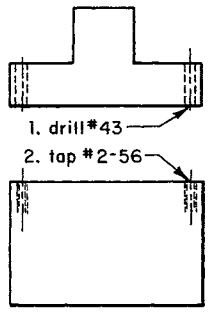
1. bolt body together
2. center body on faceplate
3. drill 15/64
4. remove screws "A", clamp "B" and lower part "C".
5. turn radius D until you reach 1 1/2" dimension shown on 10



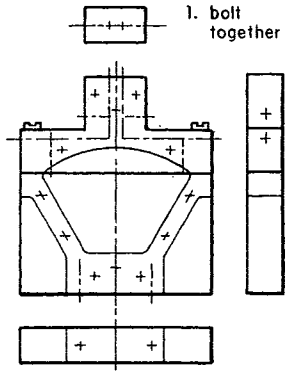
5



OPERATION 1

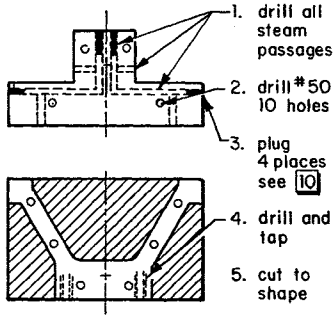


2

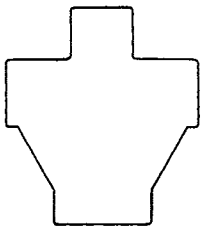


2. layout all centers and outlines

3



4

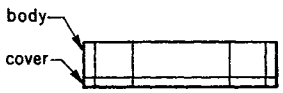


make 2 covers 3/32" thick aluminum or brass.

must be smooth and flat.

scribe around body for shape.

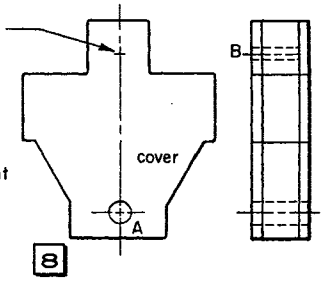
6



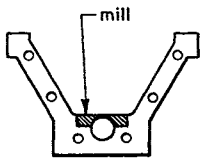
1. clamp together
2. drill #50, 10 holes and drill 15/64 each cover
3. tap body #2-56
4. drill cover #43 and countersink.

7

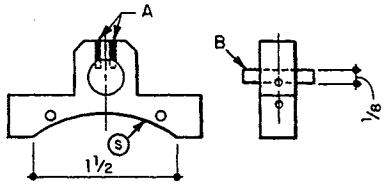
1. layout valve center
2. bolt covers to body
3. ream 1/4" at "A"
4. remove rear cover
5. drill #33 thru front cover and body, ream 1/8" at "B"



8

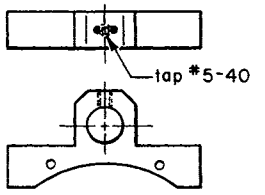


9

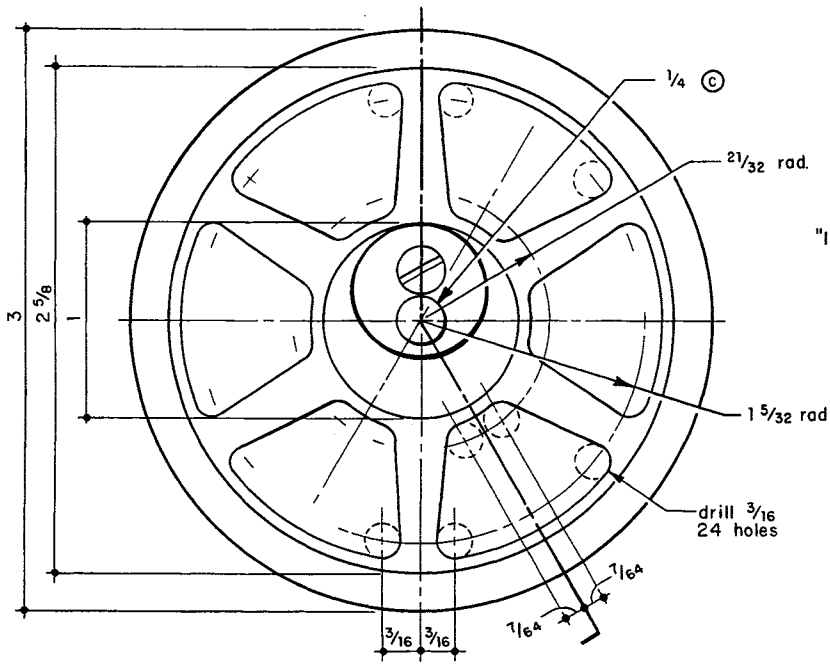


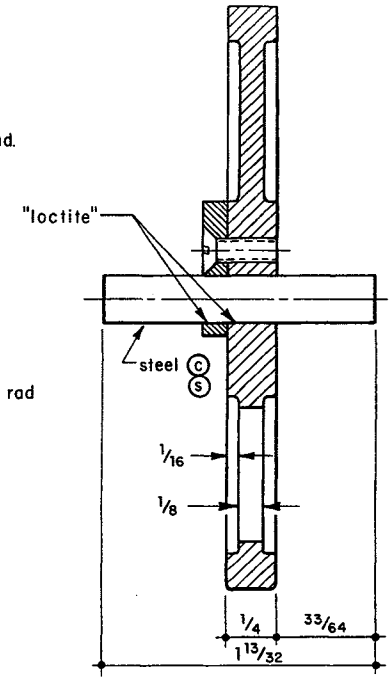
1. tightly plug holes "A" deep enough to dress flush when valve bore is reamed
2. center in chuck or faceplate indicating off close fitting pin "B"
3. bore and ream for valve

10

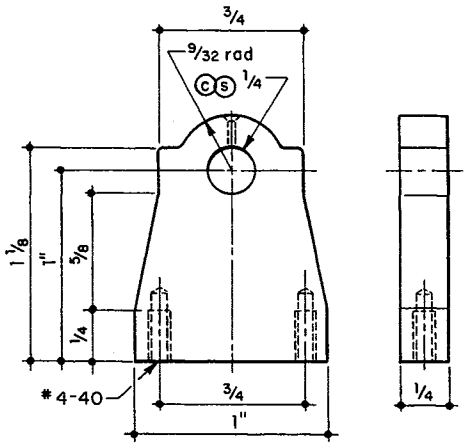


11

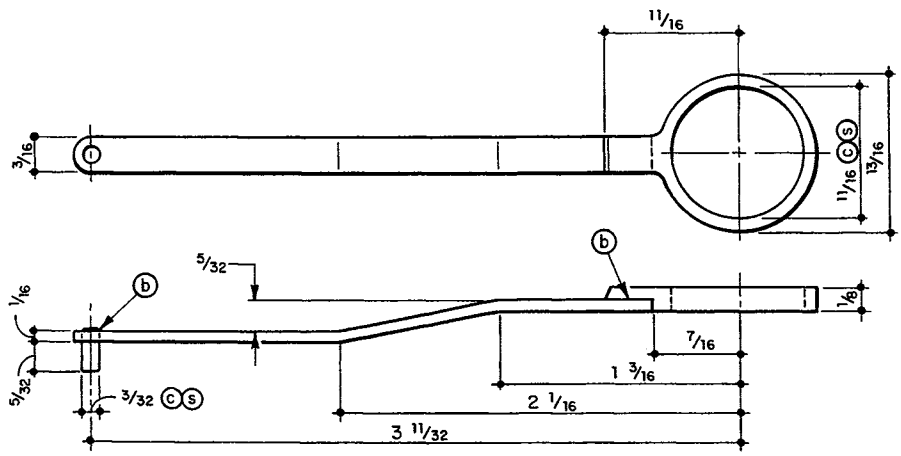




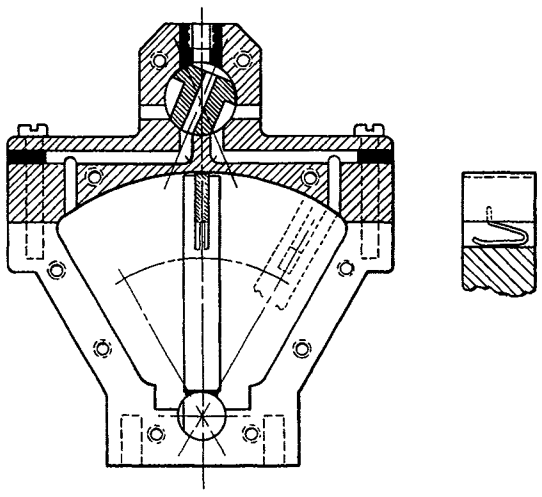
FLYWHEEL AND ECCENTRIC
Aluminum or Steel

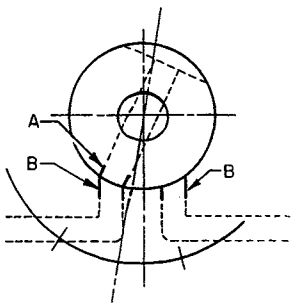


CONNECTING ROD
Brass, 2 required



ECCENTRIC STRAP
Brass





PORT SETTING

scribe lines on end of valve at "A" and face of body at "B" indicating location of ports. when valve timing is set scribe line "C" across shaft and arm. (see valve arm detail)

CHAPTER

21 *Layout and machining hint for the* Kimble Engine Rotary Valve

Here are some special instructions showing how a Rotary Valve for the Kimble steam engine was made. Perhaps this will add a little to your knowledge of machine shop work. It is a small lesson in layout and machine setup. It is also a very small part and will try your patience. A very accurate turning of the Valve was made to a close fit in the Engine Body. The outlines of the cuts were laid out to help avoid errors. Experienced machinists may not need as much detail since they can often do such jobs by just reading the dials on the feed screws.

Using a tiny vise and Vernier height gauge on a surface plate, the outlines of the cuts were made in layout dye on the Valve. The Unimat SL vertical column and head were used to machine the steam passages. An indexing fixture was mounted in the cross-slide milling attachment. In this case, a 48-tooth lathe change gear was used, 12 tooth spaces indexing 90° for the cuts. Any gear with the number of teeth divisible by four can be used.

Following is an outline of the operations:

In **Step 1**, the Valve is mounted squarely in a miniature vise which is square in all directions and set on end as shown. Bring the Vernier gauge scriber down until it just kisses the top of the Valve and record the reading on a sketch such as 3.426". Don't try to find a zero base, just read the Vernier scale as is. Subtract half of the Valve diameter and you have 3.239", which is the center. Set your Vernier at 3.239" and scribe across the end and on each side as shown.

Step 2. Lay the vise on its side and repeat the operations, giving you the two centerlines and the Valve scribed into equal divisions. Keep track of the side **X** on which the vise rested. Record your readings on a sketch.

In **Step 3**, the vise is set normal and the same method used to scribe the centers on the sides of the Valve.

Step 4 uses the same position of the vise as Step 3. By adding half of the 3/32" mill cut to 3.555", one side of the cut can be scribed. Likewise, .047" subtracted gives the lower side. These lines are scribed in the three areas where cuts will be made.

Step 5 returns to the position in Step 1 and the runout of the cut can be scribed for the intake. Prick punch and scribe the 3/32" half circle for the two exhaust ports.

Step 6 goes to the position in Step 2 and the runout for the exhaust passages scribed.

Through all six steps, the Valve remains tight in the vise. If you check the layouts and wish to go back, you can return to any line you made by setting the Vernier to the readings you recorded. There are good articles in books on reading a Vernier so no attempt is made here.

Step 7. If you are satisfied with your layout, the Valve can be removed from the vise. The Valve is now mounted in the indexing fixture, squarely mounted in the cross-slide milling attachment. In this case, it is basically a cast iron block with a close-fitting arbor flanged at one end to take the Unimat 3-jaw chuck and shouldered, keyed, and threaded at the other end to take one of the lathe change gears. An attached arm guides the indexing pin.

First, snug up the Valve in the chuck and square up the centerline on the end of the Valve with a square resting on the lathe bed. When carefully squared up, tighten the jaws.

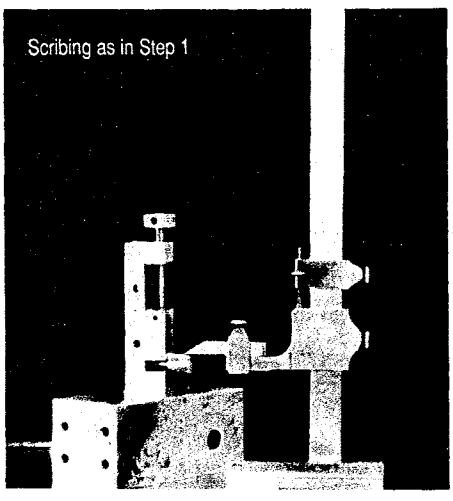
Pick up the intake center you made in Step 3, using a wiggler. Once this is established, do not touch the cross-slide. This position will be used for all three milling operations. Drill the 1/16" steam passage.

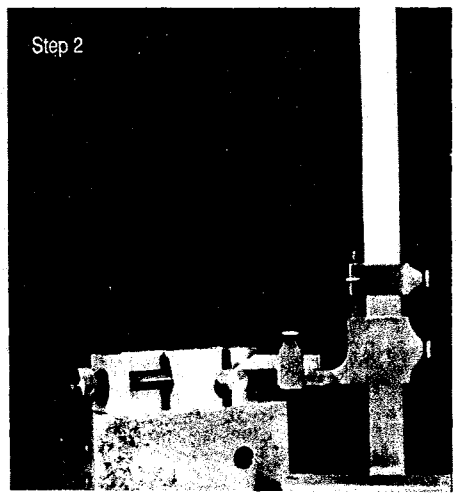
Mount the 3/32" end mill in the chuck and bring the piece in until it just touches the end of the mill. Set the carriage stop at 0 and back it up .047" or the thickness of a 3/64" drill. Take light cuts until the carriage stop is reached.

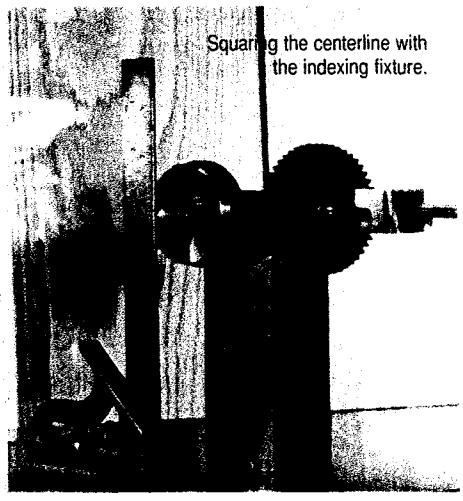
Step 8. Rotate the piece 90° as shown for milling one of the exhaust passages. Set the carriage stop at .078" and mill in easy steps, feeding the piece down into the cutter. Run the cuts until the cutter matches the half circle you scribed in Step 5.

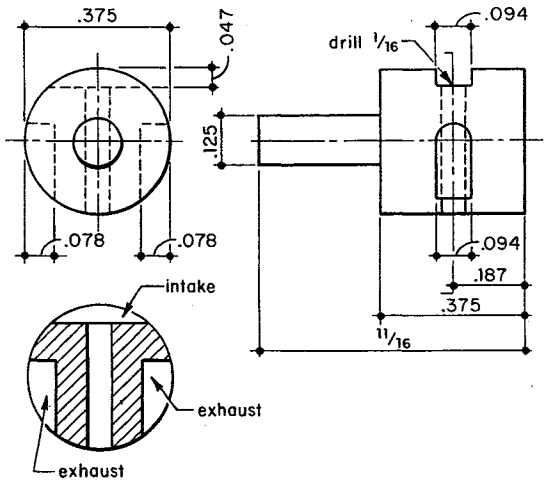
Rotate the piece 180° and repeat, feeding the piece up into the cutter.

If you have other ideas, try them out. In any case, the steps outlined here can apply to many layout jobs you may run across.

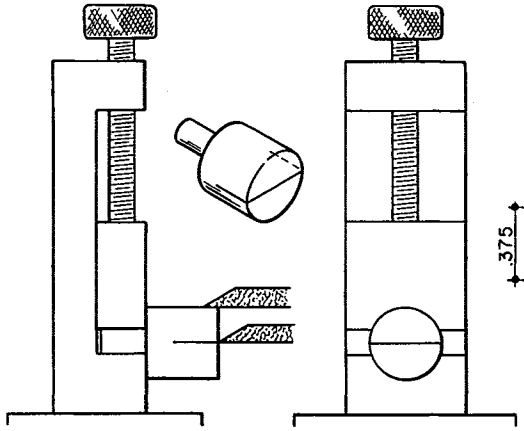

Scribing as in Step 1


Step 2

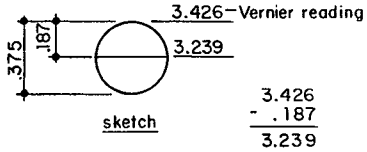

Squaring the centerline with the indexing fixture.



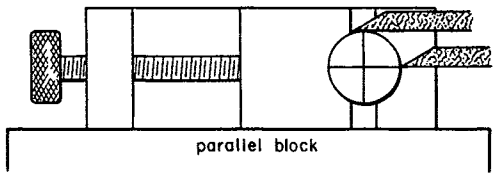
VALVE



STEP 1

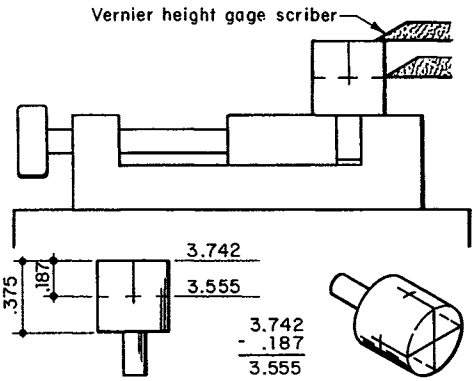


3.426
- .187
3.239



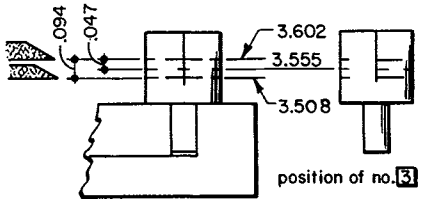
4.301
- .187
4.114

2



3.742
- .187
3.555

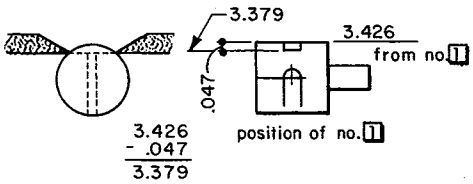
3



3.555 (from no. 3)
- .047
3.508

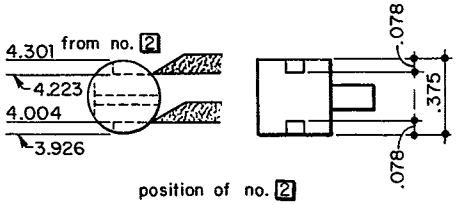
3.555
+ .047
3.602

4



3.426
- .047
3.379

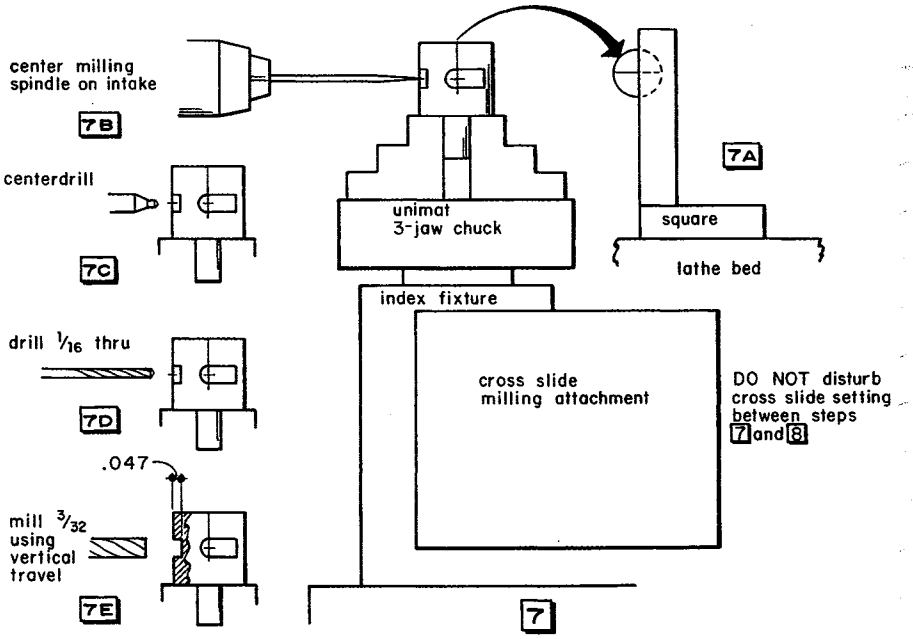
5



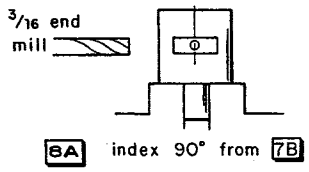
4.301
- .078
4.223

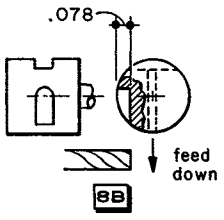
4.301
- .375
3.926
+ .078
4.004

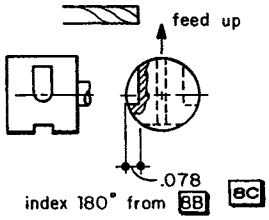
6



7







8

CHAPTER

22 V Twin

This engine is a tiny vertical twin wobbler. It features guides for the Crossheads, though it is quite a simple design. The one shown is mostly aluminum. The Pistons and Shafts are brass and the Flywheel and Crank Disks are steel.

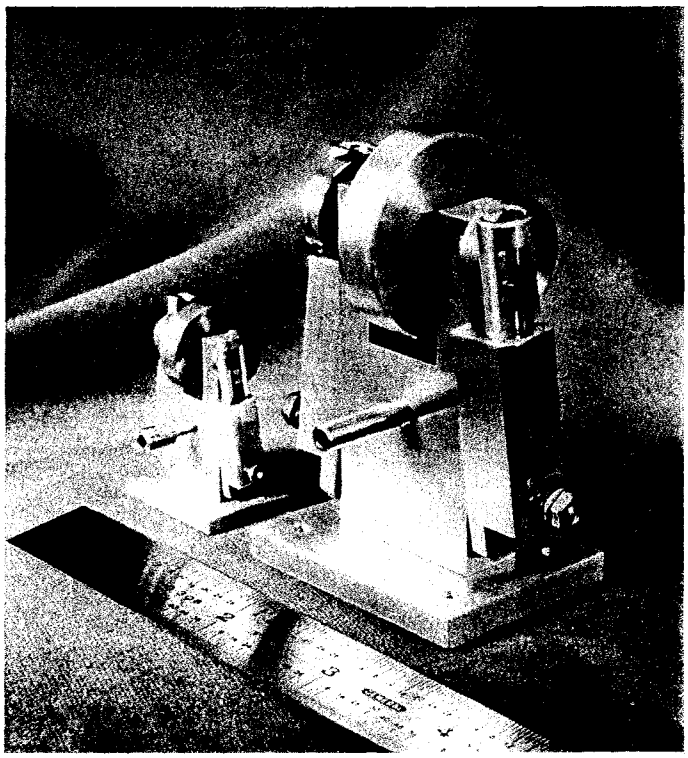
Start the **COLUMN** with clean square stock 1/4" x 3/4" x 1-1/2". Lay out and make the two Foot holes and the two Shaft holes. Mill the 3/8" opening. Make the drill jig from a 1/16" steel strip. Keep the edge **X** true and square. Insert close-fitting pins 3/32" diameter in the Column. Place the jig over the Pivot pin and hold side **X** against the Crankshaft pin. Drill #56 for the steam passage. Turn the jig over to get the other hole. Note — the two exhaust holes are shallow. Drill the intake holes from each face. Do not drill all the way through from one side. Drill the 1/16" exhaust holes and tap the SteamConnection as shown on section **AA**. Add a couple of oil holes for the Crankshaft. Make the Foot as shown.

For the **CYLINDERS**, square up the end of 5/16" x 5/16" x 1-9/16" stock and lay out the bore centerline 11/64" from one face. Center-punch and chuck in a 4-jaw, centering with a center test indicator. Turn the 9/32" diameter 9/16" long and make the 3/16" Cylinder bore. Lay out and make the Pivot hole and drill the #56 steam passage at **Y**. Mill or file to the sections shown at **A** and **B**. Later, when the Pistons are complete, insert a 3/32" close-fitting pin in the Pivot hole. Place the drill jig over this pin. Insert aPiston in the Cylinder and a 1/16" close fitting pin through the jig and the eye of the Piston. Drill #56 only 1/32" deep as shown. If you have an end mill smaller than 1/16", this is the place to use it. On this model, a 1/16" mill was used and precautions taken to keep the #56 hole outline accurate as drilled. If the mill alters the opening at **Z**, it will cancel out the accuracy your jig helped you get. Watch closely and stop short at hole **Z** and then clean up the small break-through with a needle file. Dress the Valve face smooth and flat on a sheet of very fine emery paper on a surface plate or a piece of plate glass.

Make two **PISTONS** of brass. Use the Cylinders as gauges to make close, free fits. Add oil grooves. Mill the flats and lay out the Crankpin holes. If the twoCylinders are not identical, keep eachPiston with its own Cylinder.

Make the two **SHAFTS** as shown. On theCrankshaft, make the shoulder-to-shoulder dimension about .005" greater than the width across the Column.

Make the **FLYWHEEL** and **CRANK DISKS** as shown. Set theCrank pins in the Disks with Loctite. After curing, start the assembly of the Crankshaft in the Column. Note - this is, more or less, a permanent job, so take care. It will not be easy to take apart. Insert the Crankshaft through the Column andFlywheel. Place a rubber band around the Flywheel and down around the bottom of the Column to prevent the Shaft and Flywheel from sliding around too freely. Snub it up quite tightly. Add one very tiny drop of oil to eachBearing. Rotate slightly to distribute the oil and then wipe off any excess. Now center the Shaft in the Column and carefully clean the 1/16" ends with a pipe cleaner and lacquer thinner, avoiding the 3/32" diameter of the Shaft. The oil will prevent the Loctite from locking up the Shaft in the Column. Clean the bores of the Disks with lacquer thinner and apply a small amount of #601 Locite to the bore only (not on the Shaft). Place the two Disks on the Shaft, rotating slightly to distribute the Loctite. Don't dally too long because 601 is fast acting. Line up the Crank pins 180° apart by eye and set aside to cure. If you can work up a simple, fast way to get 180°, good, but a few degrees off won't make much difference in the performance. Center the Flywheel and tighten the set screw.



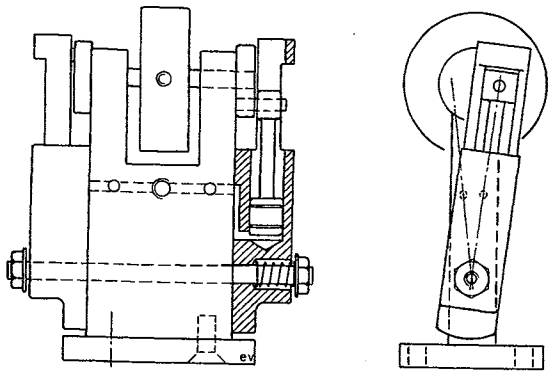
If this photo looks familiar, it is because it also appears on page 9. The *V Twin* described in this chapter is a small version of the *Twin Vertical Wobbler* presented in Chapter 2 and shows that you can take many of these designs and enlarge or reduce them to suit your particular desires, capabilities or equipment.

The **SPRINGS** are salvage and about the proportions shown.

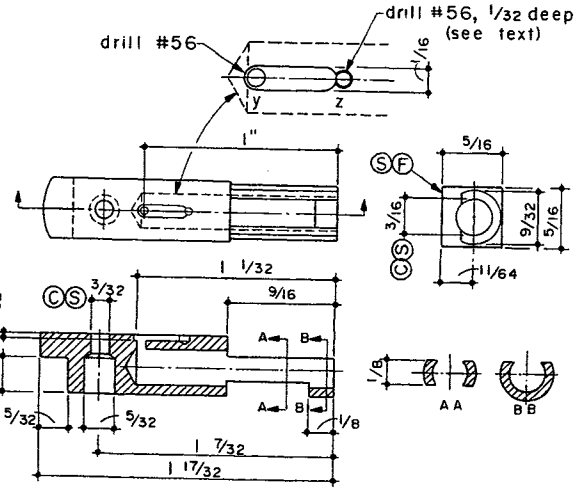
The **STEAM CONNECTION** is an adapter for 3/16" aquarium tubing.

Complete the assembly, lubricate and make a trial run on 5 to 10 pounds of air.

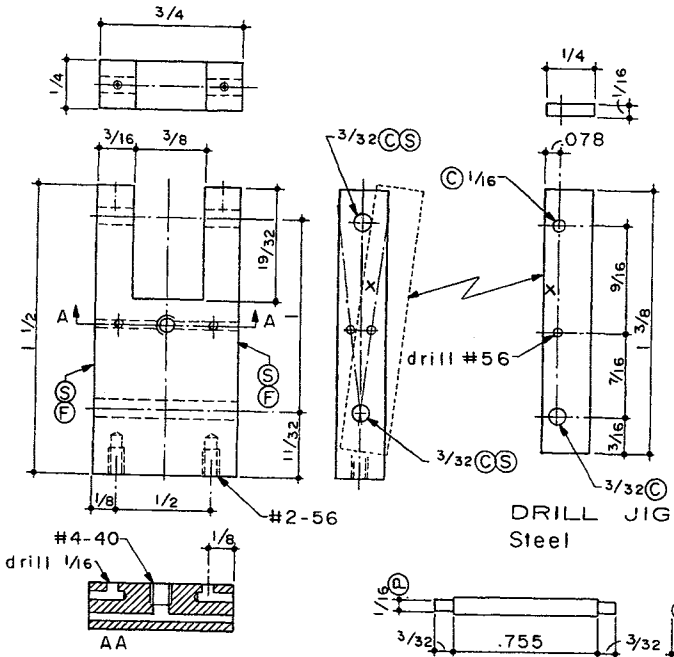
This is a smooth running, high-speed engine, since it has good balance.



V TWIN

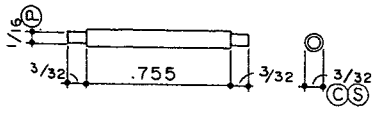


CYLINDER
Hard Aluminum
2 Required

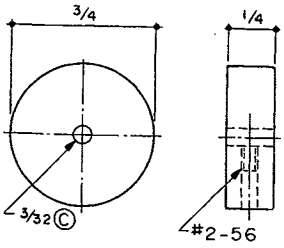


DRILL JIG
Steel

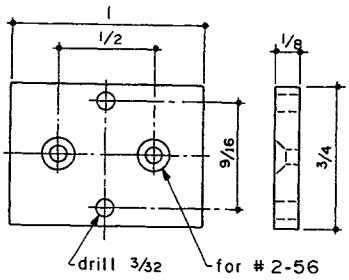
COLUMN
Aluminum



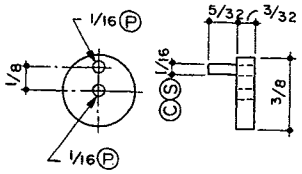
CRANKSHAFT
Steel



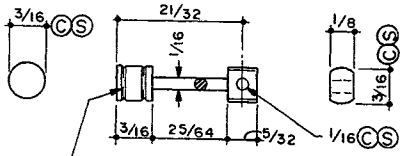
FLYWHEEL
Steel



FOOT
Aluminum

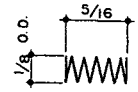


CRANK DISC
Steel
2 Required

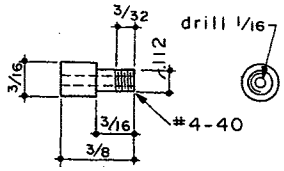


Oil grooves approx.
.010 wide x .005 deep

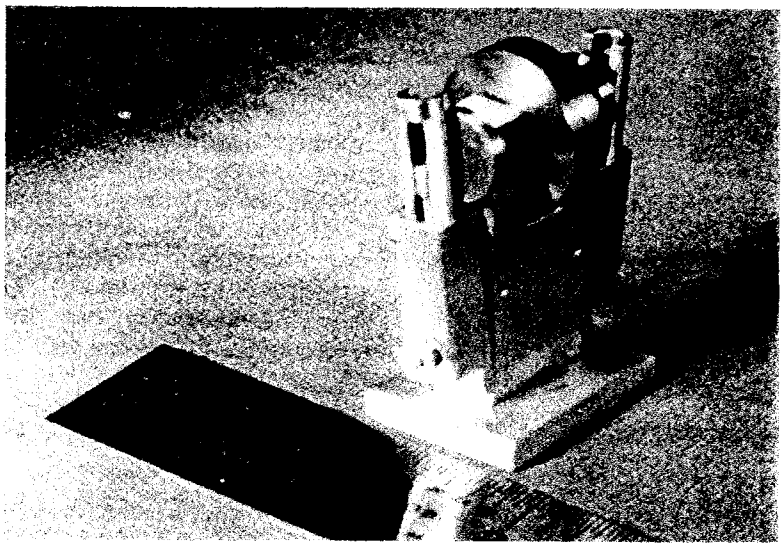
PISTON AND ROD
Brass
2 Required

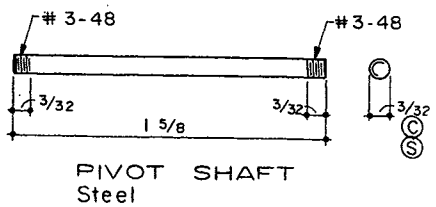


SPRING
.015 Wire
Steel
2 Required



STEAM CON.
Brass





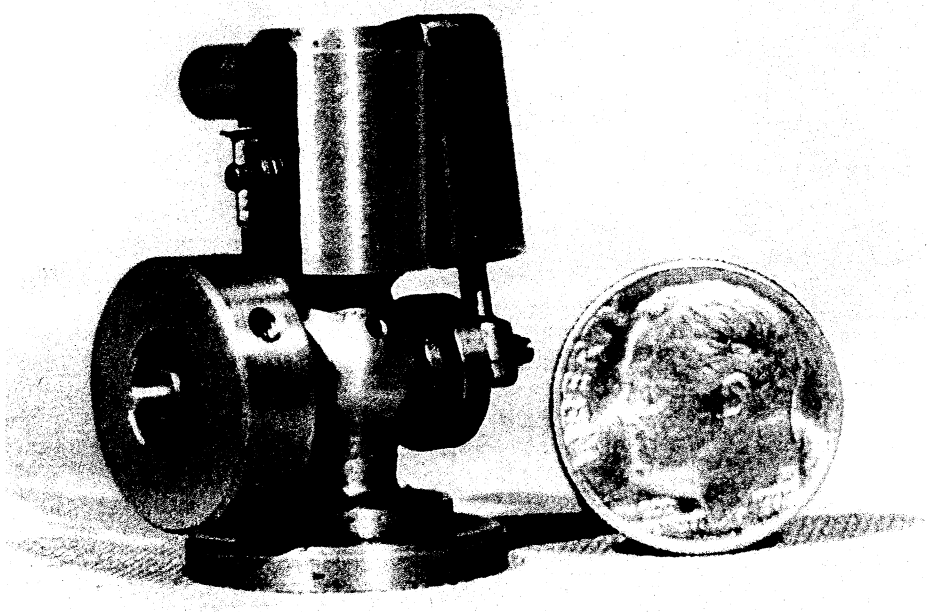
PIVOT SHAFT
Steel

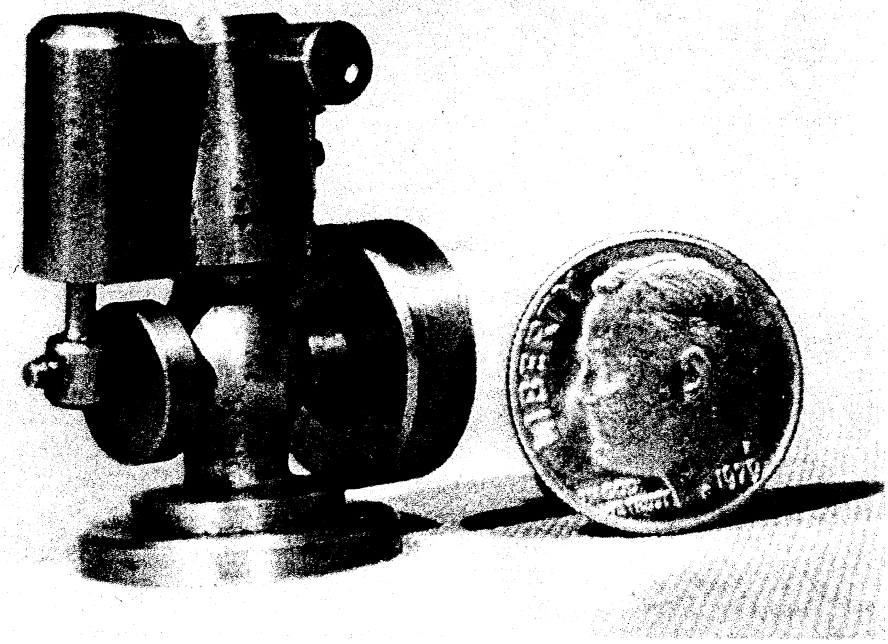
safety first

double-check your set-up

CHAPTER

23 Tiny





This engine is for those who want to try a really small model, but not all the way to tweezer-and-eyeglass size.

The **COLUMN** is made of steel. The best way to start is by chucking a piece of 3/4" diameter x 2" free-machining steel in the three-jaw and turn down to 1/2" diameter for a distance of 1-5/32". The next step is to turn it down to 7/16" diameter for a distance of 1-3/32". Next, cut to 3/8" diameter starting 9/16" from the end and go down to the 1/2" diameter using a round-nose tool bit. Round in the curves, keeping the 3/8" bulge centered 1/4" from the shoulder at the 7/16" diameter. Make a parting cut to length. Make the two flats parallel to each other, lay out and make the Crankshaft hole and the Pivot hole. Make the drill jig and locating pin. Place the jig over a close-fitting pin in the Pivot hole and against the locating pin as shown. Drill a #57 starter hole 1/32" deep and turn the jig over to get the other hole. Remove the jig and anchor the column squarely while completing the port holes. Note — one hole goes through and the other is 1/4" deep.

Transfer the centerline around to the side and make the 5-40 **STEAM CONNECTION**.

Make the **BEARING** out of brass or bronze and set in the Column with Loctite. Add the oil hole and, if you wish, tap up from the bottom for a 2-56 anchor screw.

For the **CYLINDER**, start with a piece of 5/16" x 5/16" x 9/16" brass or bronze. Lay out the bore offset at 3/16" from one edge and prickpunch. Chuck it in the 4-jaw, using a center test indicator, and then use drills and a tiny boring bar to complete the 3/16" bore. Lay out the Pivot center, prickpunch and chuck it in the 4-jaw using a center test indicator and some protection to prevent chuck jaw marks. Make sure the face is parallel

with the face of the chuck. Face, undercut and drill for the brass Pivot Pin. Insert a close-fitting aluminum pin in the 3/16" cylinder bore and solder the Pivot Pin into the Cylinder, using a tiny speck of 430° solder. The solder will not stick to the aluminum.

Rounding the back of the **CYLINDER** is optional. When the Piston and Rod is done, insert the Piston into the Cylinder, place the drill jig over the Pivot Pin and run a close-fitting 1/16 pin through the jig and the hole in the Connecting Rod. Drill the #57 steam port.

The **PISTON AND ROD** is made by chucking a 1/4" diameter x 1-3/8" brass rod in the 3-jaw or collet with about 7/8" projecting. You can make it more if you wish to have tailstock support. This one was made without support by using a long tapered tool bit with about a .010" raidius on the end, honed up keen and by making very light and careful cuts. The Cylinder was used as a gauge. Make the oil grooves with a 90° V-tool and then part to length. Mill the flat and make the 1/16" Crankpin hole.

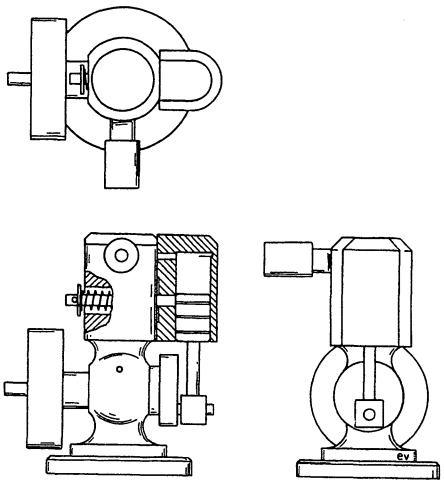
The **CRANKSHAFT** is a simple steel disk and two pieces of drill rod assembled with Loctite.

The **SPRING** is salvage, about the proportions shown, and it seems to do a satisfactory job.

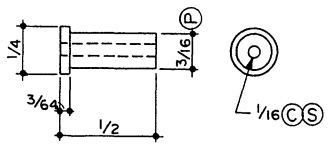
The **STEAM CONNECTION** is brass, made up to take 3/16" plastic tubing. This, also, is optional if you have other plans for attaching an air line.

The **FLYWHEEL** is 5/8" diameter x 3/16" wide of steel fitted with a 2-56 x 1/8" set screw. At assembly, spot the set screw on the same side of the Shaft as the Crank Pin as shown to help counter-balance.

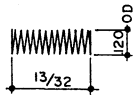
This turned out to be a smooth-running engine. It sounds like a bumble bee on 5 to 10 pounds of air.



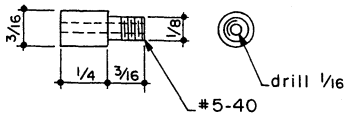
TINY



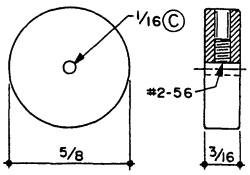
BEARING
Brass



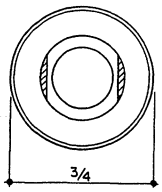
SPRING
Steel
.014" wire
12 coils

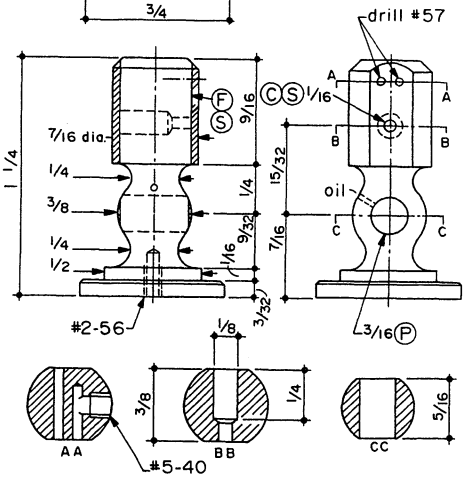


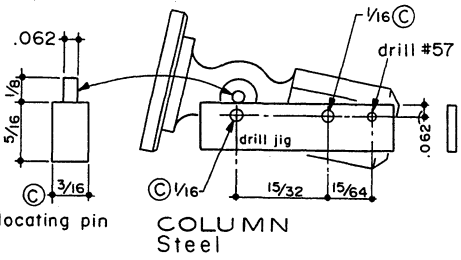
STEAM
CONNECTION
Brass

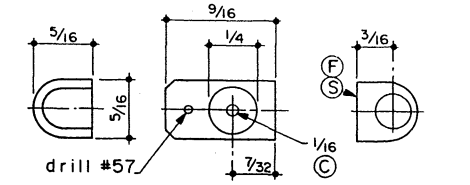


FLYWHEEL
Steel









COLUMN
Steel

locating pin

CHAPTER

24 Beam

This miniature Beam Engine has fair proportions and close resemblance to the original engines. It is quite simplified, though, and some parts are a bit tiny.

On the model shown, the Base and Bearing are steel. The Column, Flywheel andBeam are aluminum. The weight of an iron Flywheel would make it run better. The Column and Beam can be any handy material. TheCrank Shaft and Pin are steel. All the remaining parts are brass or bronze. The Eccentric can be steel or bronze.

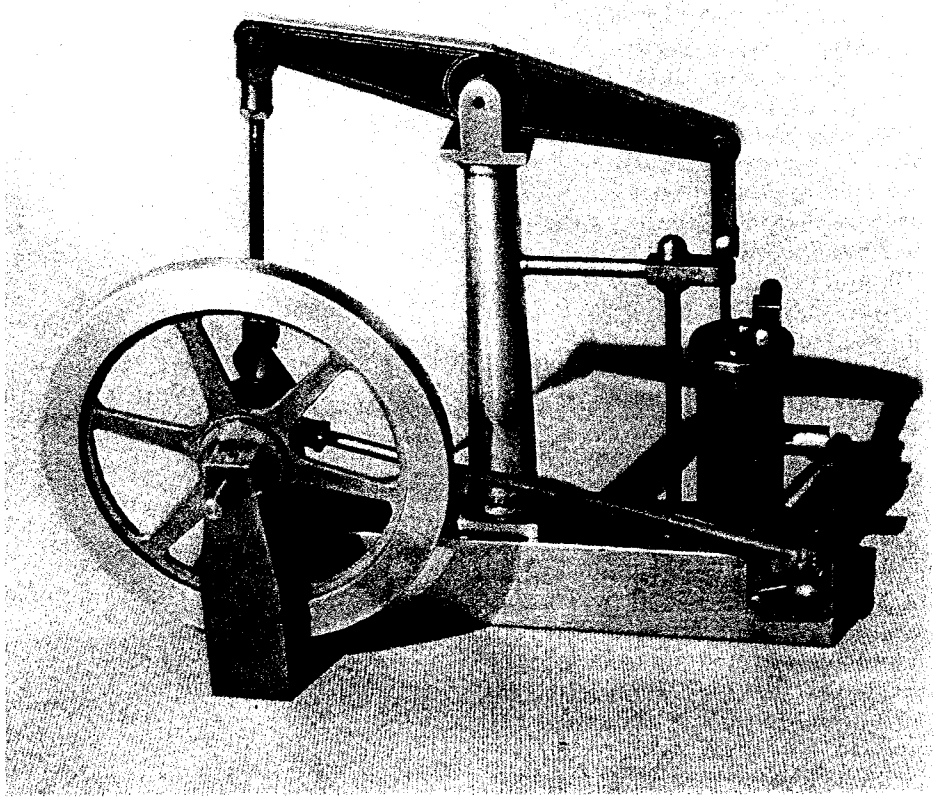
The **BASE** and **BEARING** are simple and straightforward and need no comment.

The **COLUMN** can be made as fancy as you wish. The square part at each end provides gripping and square-up surfaces when drilling and milling.

The **FLYWHEEL** can be a 1/4" or 7/32" thick square or disk to start. From the center, scribe the two circles for the rim. Set a divider to the radius of the inside circle and pace off six equal spaces. Draw three centerlines through opposite marks for the centerlines of the spokes. Run 7/8" and 7/16" radius arcs as shown. Set the dividers at 1/8" and strike off the centers for the twelve 1/8" holes. Use a convenient divider setting and cross the arcs to get the centerlines between spokes for the six 1/4" holes. Centerpunch and drill the twelve 1/8" and six 1/4" holes. Chuck in a four-jaw, centering with a test indicator, gripping on about one-third the thickness of the stock. Turn the O.D., face and web for the spokes. Bore the center 1/4" for a press fit or Loctite on the Eccentric. Reverse in the chuck and turn the opposite side. Coat the web with layout dye and scribe the lines and arcs tangent to the holes and saw out the spokes with a jeweler's saw.

Make the **CYLINDER** of brass or bronze. The Cylinder bore and Valve bore offsets are picked up in a 4-jaw.

The **HEAD** starts out as a 5/8" disk 1/4" thick. Lay out the four holes. Drill the two 3/32" and the 9/64" hole. Chuck in a 4-jaw, offset for the 1/16" hole and turn to a loose 1/4" fit in the Cylinder bore.



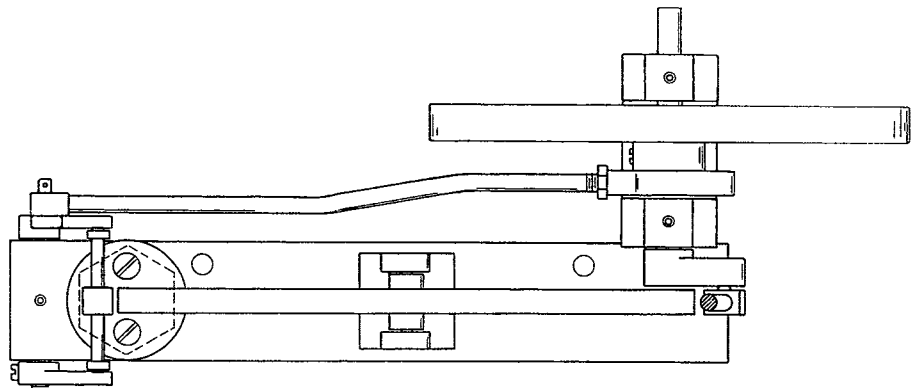
The remainder of the parts are tiny and take patience and time. Soldering is used often here. The ends on the **RODS** are soldered rather than turned from the solid. When soldering, use a holding fixture or some means to hold squareness. To keep from oversoldering, apply the flux to the joint and use the stickiness of the flux to hold a tiny speck of solder cut with shears. In some cases, this speck is no larger than the head of a common pin. Apply heat with a torch. Solder before drilling the crossholes.

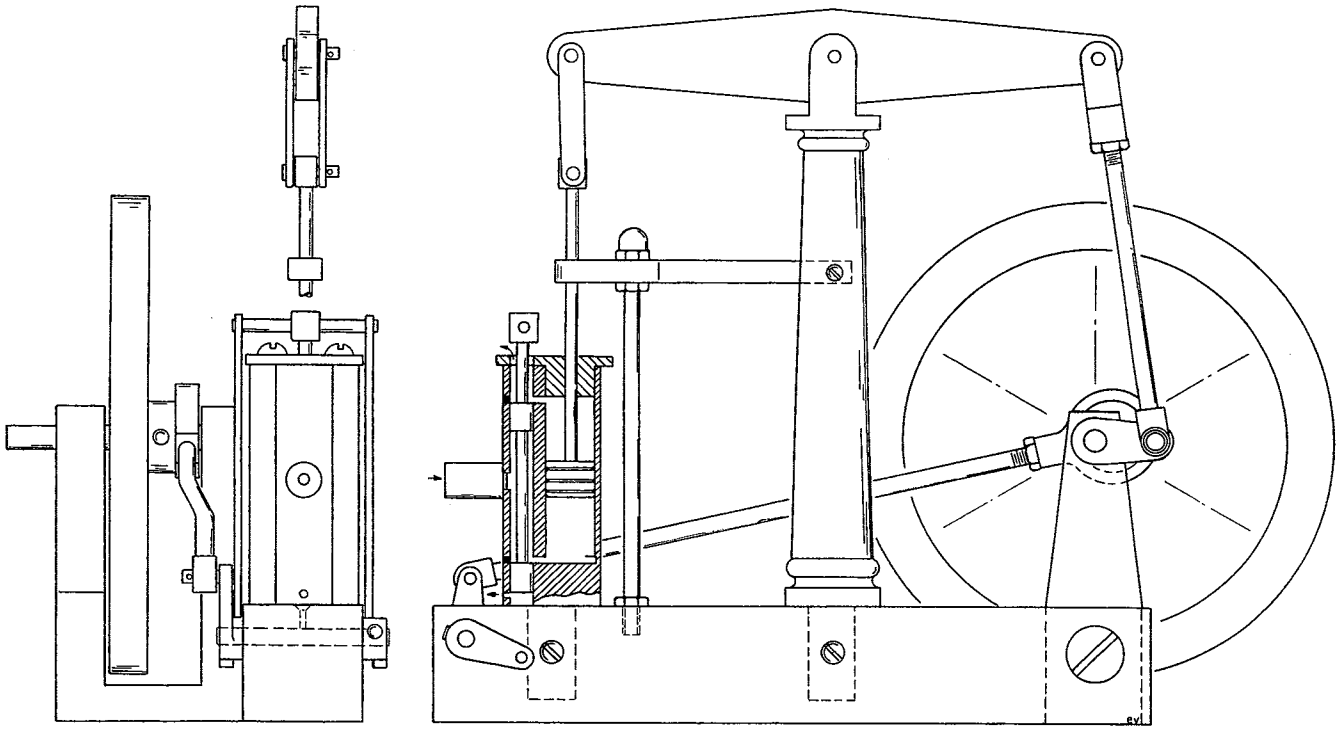
When soldering the **PISTON** and **ROD**, place the Cover and Support Bar before attaching the 1/8" x 5/32" block. The same applies to theValve Linkage.

The Pins without crossholes are held by light prickpunch marks. When setting the Eccentric, the Crank Arm should be horizontal and the Eccentric set for one or the other extreme of travel as shown on the assembly. The drawing shows the Piston at mid-stroke with the Valve full open.

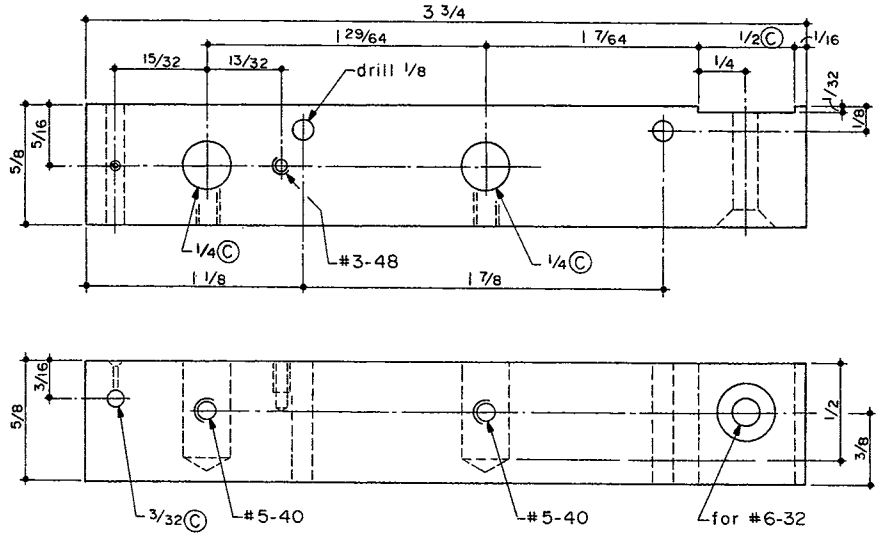
This engine is fitted with a simple support for the Piston Rod to reduce the side thrust at the head. If you are ambitious, you can lay out and fit the famous Watt straight-line motion to this engine instead of this fixed support. It will be a challenge and will require some very small parts.

This is a small model of a giant that ran 50, 60 or so revolutions per minute. You will be lucky if you can make this one run that slow. Try for the smoothest, slowest speed possible. It will make a good showing on as little as 5 psi.

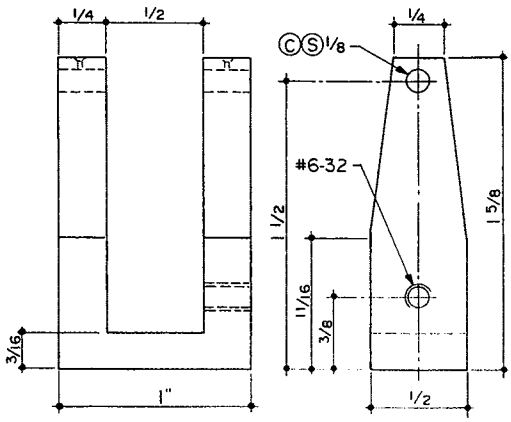




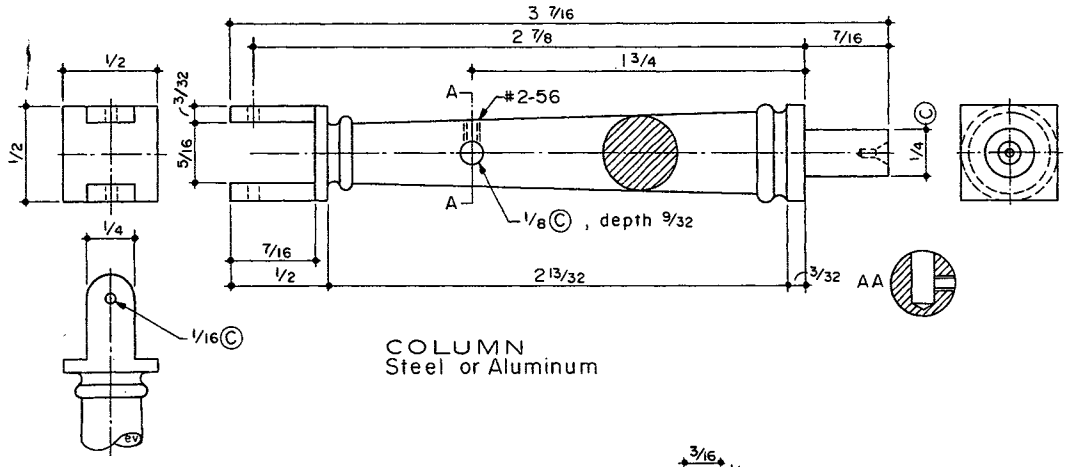
BEAM



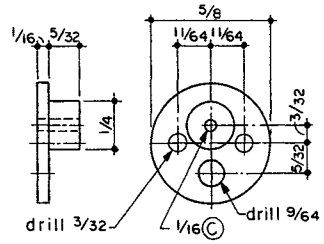
BASE
Steel or Aluminum



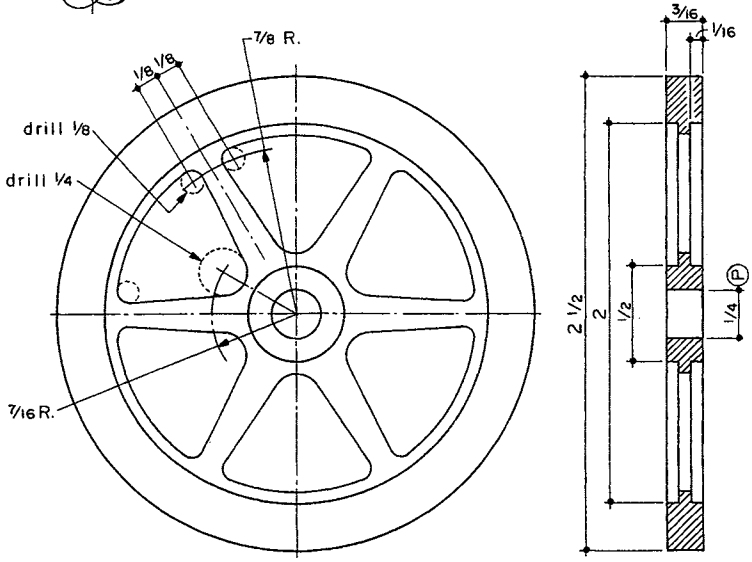
BEARING
Steel or Aluminum



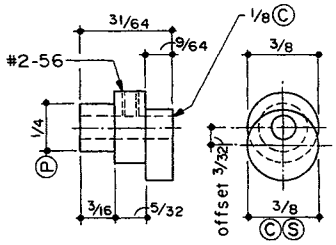
COLUMN
Steel or Aluminum



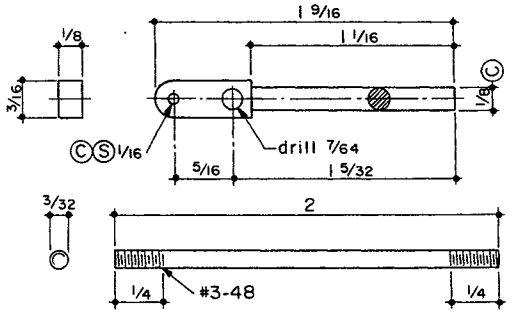
HEAD
Brass



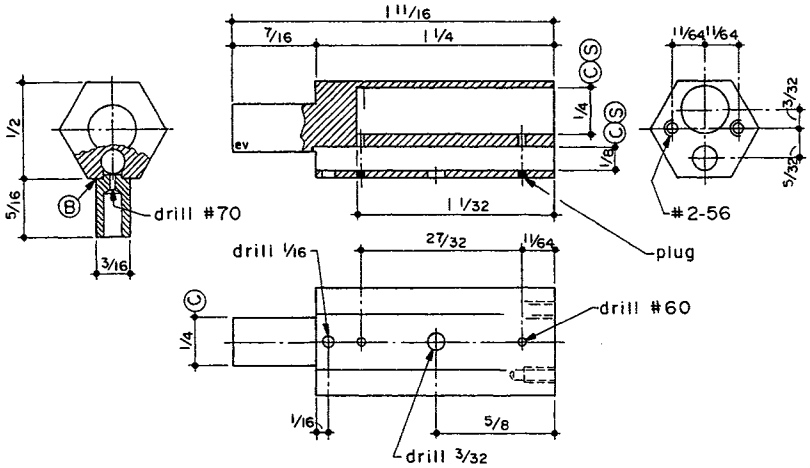
FLYWHEEL
Any Metal



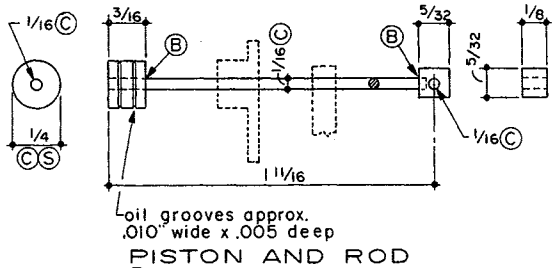
ECCENTRIC HUB
Steel



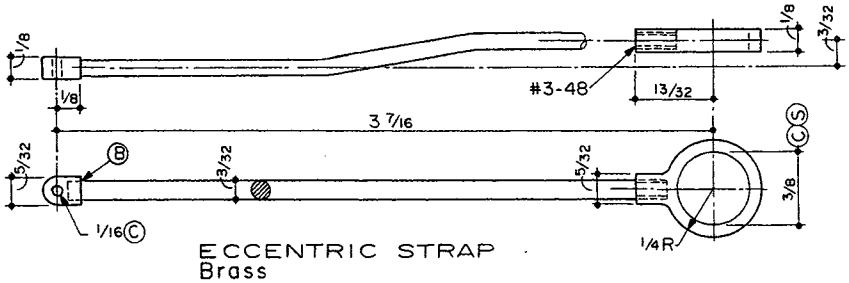
PISTON ROD SUPPORT
Brass



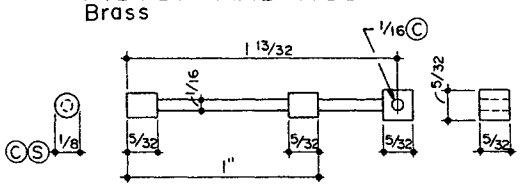
CYLINDER
Brass



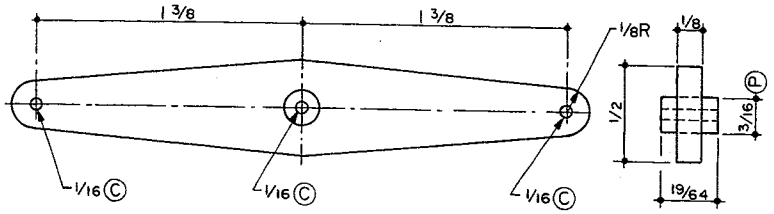
PISTON AND ROD
Brass



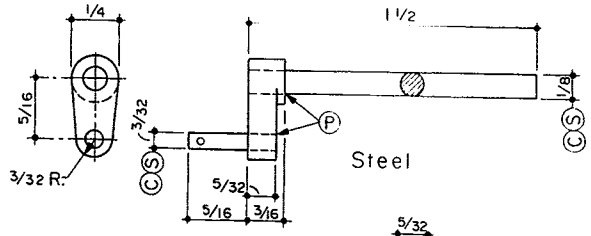
ECCENTRIC STRAP
Brass

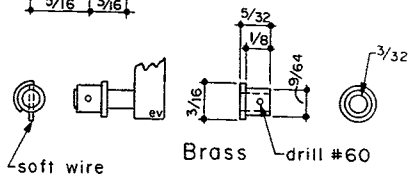


VALVE
Brass

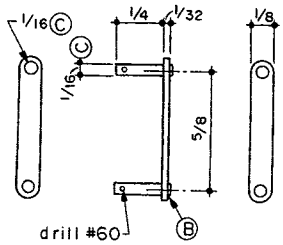


BEAM
Aluminum

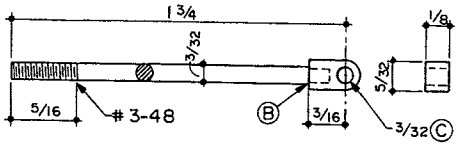


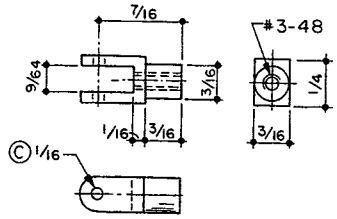


CRANKSHAFT

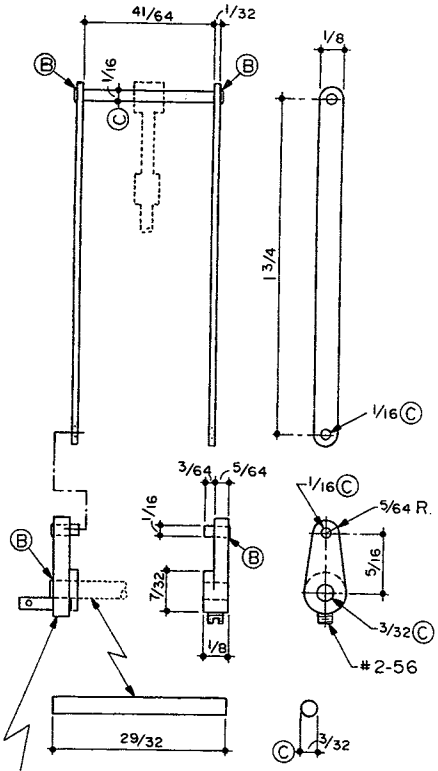


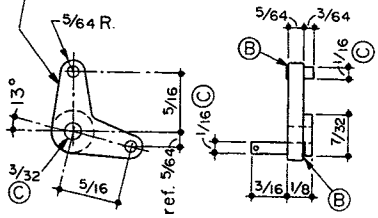
BEAM LINKAGE
Brass



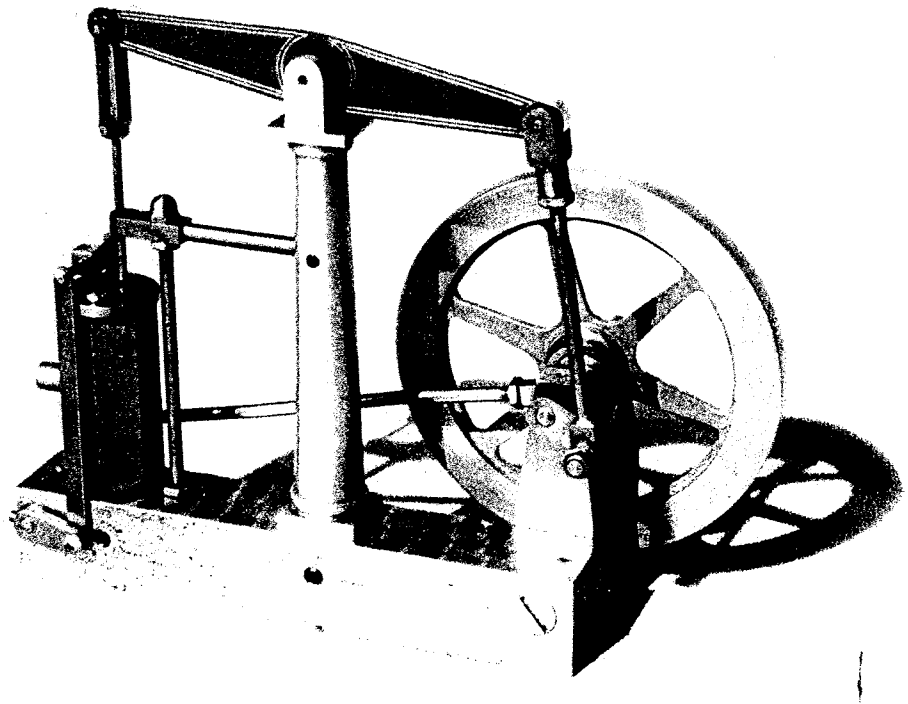


CONNECTING ROD
Brass





VALVE LINKAGE
Brass



SAFETY FIRST

USE PROPER SPEED

CHAPTER

25 Wobbler

A wobbler is usually the first type of engine made by the beginner. The wobbler takes care of the valving without any additional tiny parts. The Frame, Foot and Flywheel are aluminum on the model shown and described here.

Start by making the **FRAME** from an accurate 1/4" x 1" x 2-1/4" piece of metal. Lay out and machine the **FOOT**,Pivot and Crank holes.

Make a jig and **LOCATING PIN** as shown. Run a close-fitting pin through the pivot hole and jig. Drill the 1/16" port opening while holding the side X of the jig against the 3/16" Locating Pin. Turn the jig over to drill the other port. Note — the lower hole goes all the way through. The upper hole is 3/16" deep. Transfer the upper hole centerline around to the end and drill and tap the 5-40 steam connection. Now is the time to check smoothness and flatness where the Cylinder rubs against the Frame. Make the bearing and set with "Loctite". Drill a small oil hole.

The **CYLINDER** is the next part to make. On an accurate and square brass block 1/2" x 5/8" x 1-1/8", lay out and center punch the centers for the 3/8" bore and 1/8" pivot. Chuck in the 4-jaw and center with a center test indicator. Turn and bore and ream 3/8". Before reaming, make an undercut at the bottom for reamer runout. This is done to avoid a shoulder that the Piston would strike. Chuck the Cylinder in the 4-jaw, using a protector over the bore end, centering on the pivot with a center test indicator. Check for squareness in the jaws. Face and undercut as shown and drill for the 1/8" pivot pin.

Make a brass **PIVOT PIN** 11/16" long and thread the end 5-40. In the 3/8" Cylinder bore, insert a close-fitting aluminum pin. Solder the Pivot Pin into the Cylinder using only a tiny bit of low-temperature silver solder. The solder will not stick to the aluminum Pin. Heat is applied to the Cylinder with a propane torch.

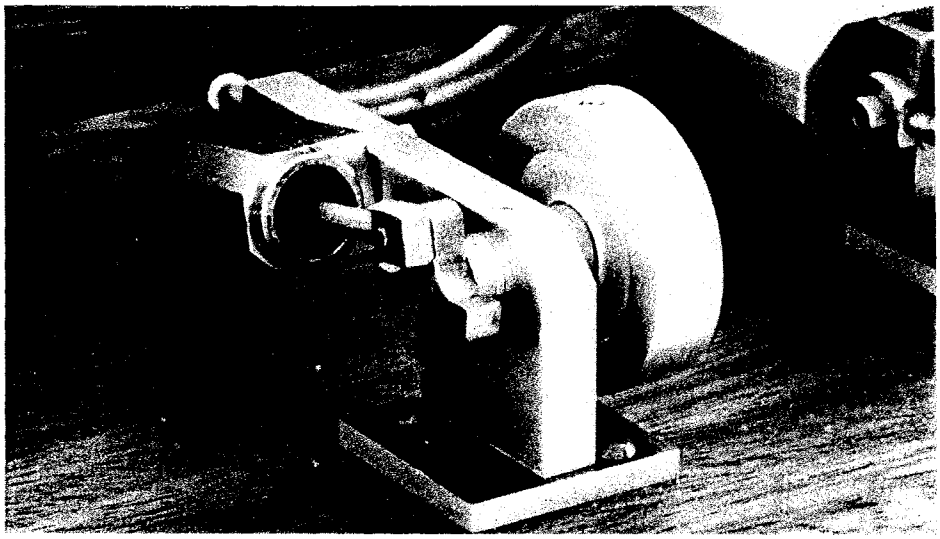
Make the **PISTON** of brass as shown. For the **ROD**, chuck a 1/4" brass rod in the 3-jaw with about 2" projecting. Drill a center hole with a tiny 3/64" center drill and bring the tail center up to support while turning the 1/8" diameter. Turn this long enough to cut away the center hole later. Thread 5-40 using a tailstock die holder. Use parting cuts to bring to final dimensions. Hold the 1/8" diameter in a V-slot in the milling vise and mill to 1/8" thickness. Drill and ream for the **CRANK PIN**. Place the drill jig over thePivotPin. Run a close-fitting 3/32" pin through the jig and the Crank Pin hole after inserting the Piston in the Cylinder. Drill the 1/16" port in the Cylinder.

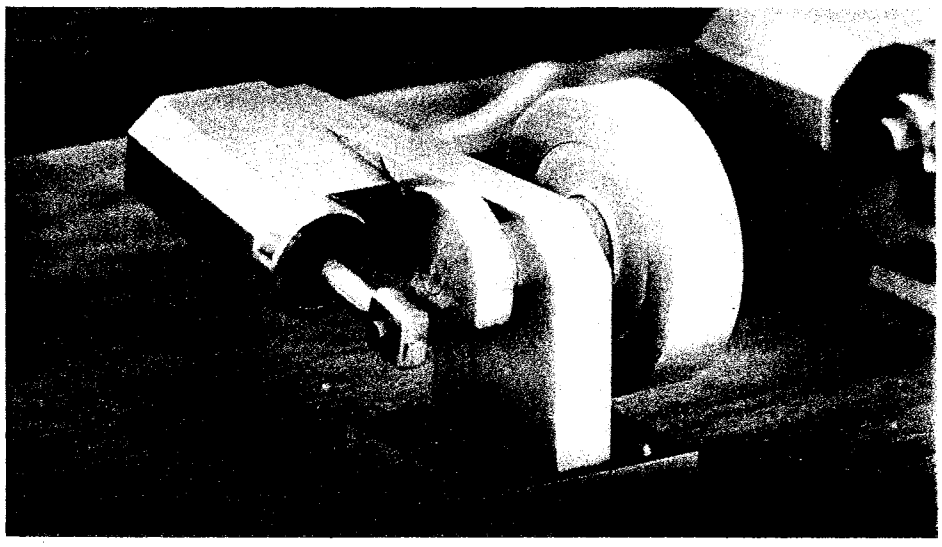
The **CRANKSHAFT**, **FOOT** and **STEAM CONNECTION** don't require much explanation. The CrankShaft is steel. The shoulder on the Shaft helps square up the Crank Disk at assembly. The "steam" connection is made to take 3/16" plastic aquarium tubing on compressed air.

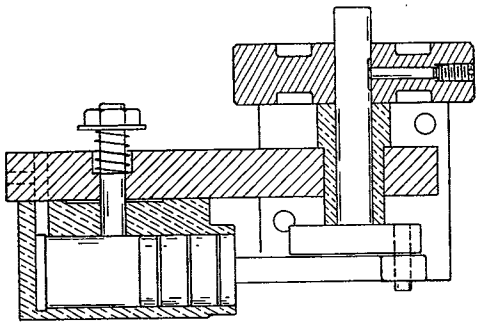
SPRING proportions shown are those of a spring found in the odds-and-ends department.

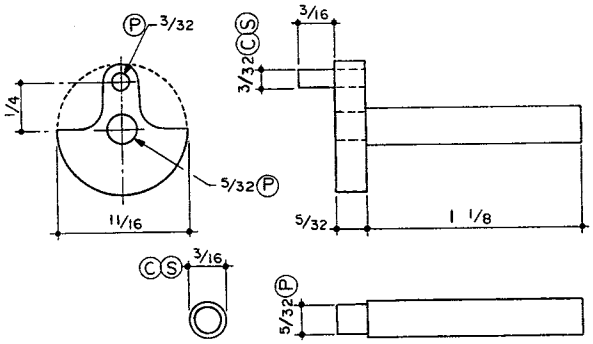
The **FLYWHEEL** is 1-1/4" diameter x 5/16" wide with a set screw. In this case, a set screw is near the surface and a free-fitting pin in the tap drill hole applies the pressure to the Shaft.

It's all done, now so you can ssemble, lubricate and give a test run on 5 to 10 pounds of air.

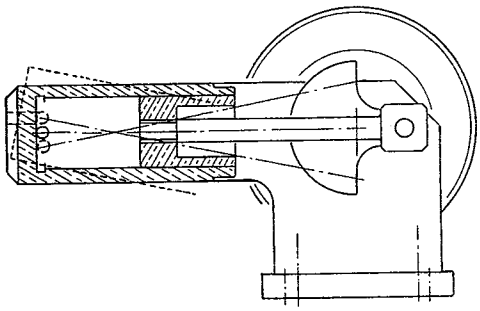


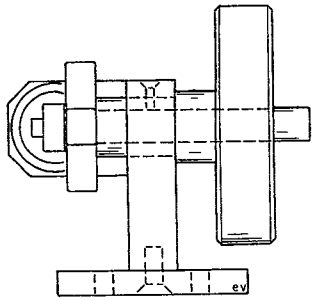




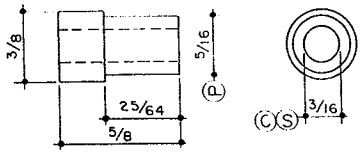


CRANKSHAFT
Steel

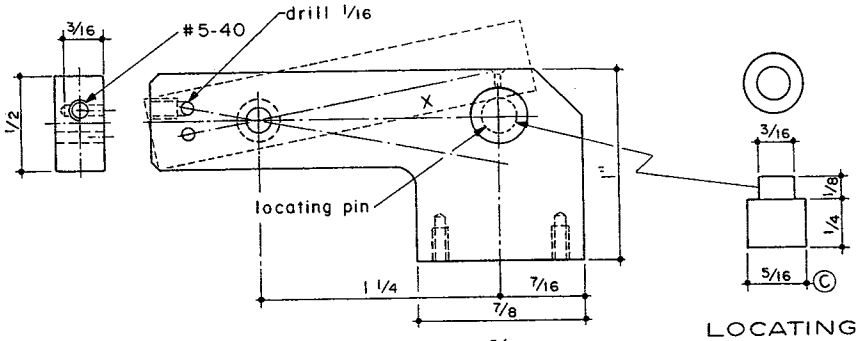




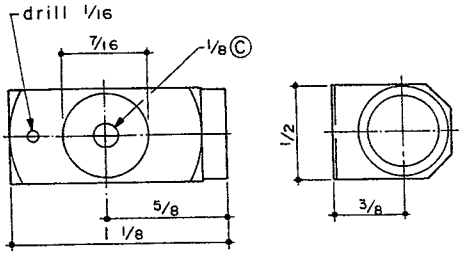
WOBBLER

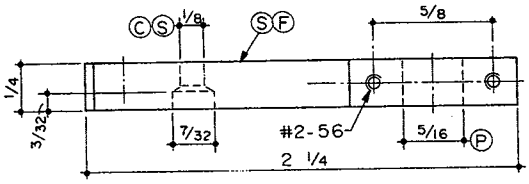


BEARING
Brass

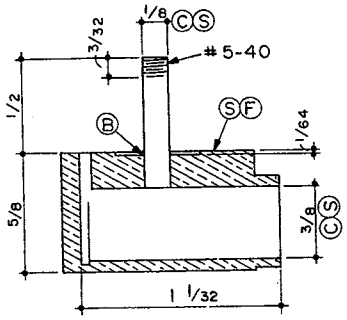


LOCATING
PIN
Steel

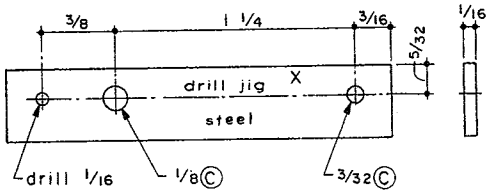


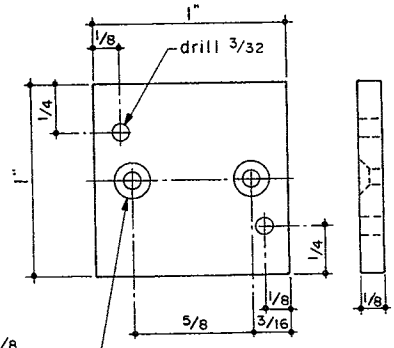


FRAME
Aluminum

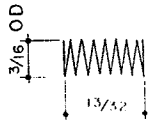


CYLINDER
Brass

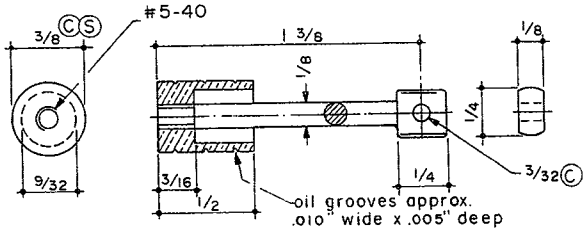




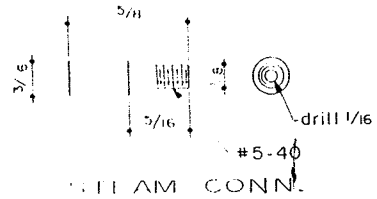
FOOT
Aluminum



SPRING
.022" Steel Wire



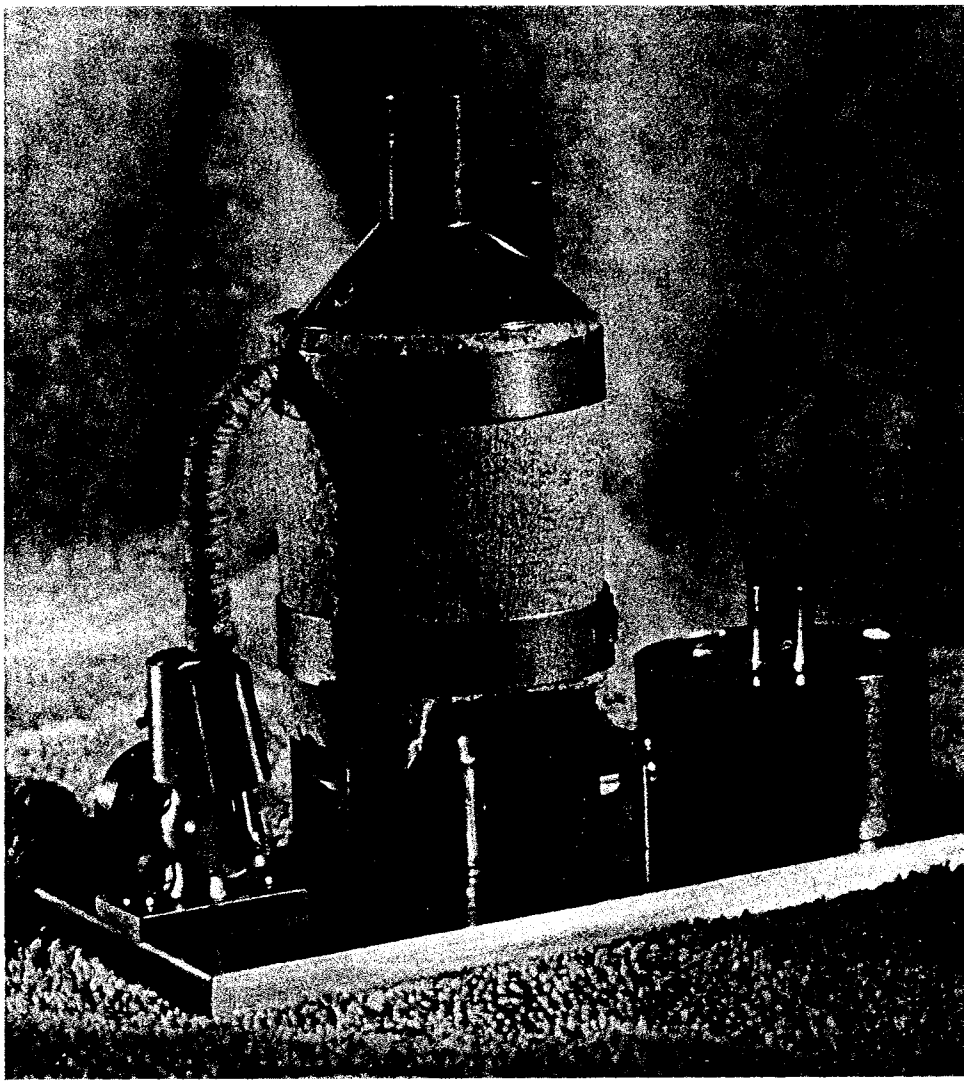
PISTON AND ROD
Brass



...TEAM CONN.
Brass

CHAPTER

26 Live Steam Boiler and Engine



It is fun to complete an engine and see it run on compressed air, but it is more fun to run it on steam. The engine and boiler described here are good starters on your Live Steam projects. They are within the capacity of a model lathe and made of quite common materials.

The **BOILER** and **BURNER** are of copper and brass construction for easy soldering. The model shown was soldered with 430° solder. After firing up a half-dozen or so times, there is no sign of failure. The 1-1/2" tubing is common sink drain pipe. The **FLUE** is 1/2" O.D. copper. The two **FILL TUBES** are 5/16" I.D. x 11/32" O.D. brass sold as telescoping tubing. An assortment package of corks from the corner hardware store had four corks that fit the 5/16" tubing.

The **LAGGING** here is sheet asbestos. It is really needed. The brass carries away the heat so fast the burner can barely keep up. Optional Lagging could be 1/28" wood veneer stock of your choice. Run the grain vertical and moisten the outside so it will bend easily and wrap around the Boiler.

While making the parts for the Boiler and Burner, try for a push fit at all solder points. The assembly will hold its shape better while soldering. The cone-shaped **TOP** makes a dead air space for insulation and makes the Boiler appear slightly more authentic. Use an escutchen pin for a rivet in this cone. Try for a lose free fit on the Boiler. It is not soldered to the Boiler.

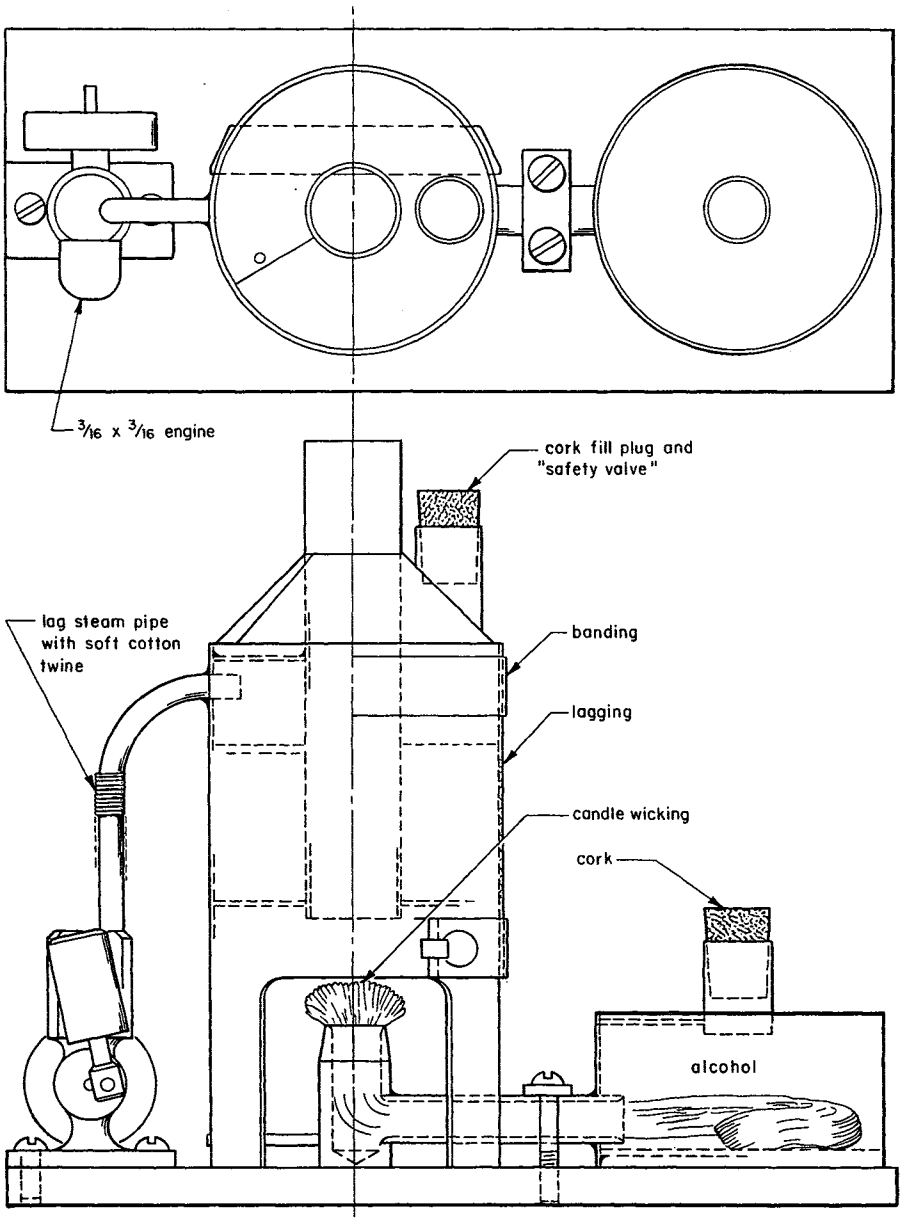
About 12" of fine wire was folded in the center and started in the Wick end of the Burner. With a bit of patience, it can be worked through until it shows under the fill tube. Hook it up out of the fill tube and thread the candle wicking through the wire loop. Draw it back through the tube until 3/8" of Wick is showing above the Burner. The size of this Wick bouquet determines the size of the flame.

The **ENGINE** is fairly simple and not too much will be said about the construction. The rubbing face of the **CYLINDER** must be flat and smooth. Make the 1/16 Shaft a close fit so it will be sqaure with the face when soldered. Chamfer the Cylinder slightly for the solder. Apply flux and a very tiny chip of solder and heat the Cylinder with a propane torch. By inserting a close-fitting aluminum rod in the bore, the Shaft and solder will not enter the bore or stick to the aluminum.

Try various **SPRINGS** from your collection. The one used here had the dimensions shown.

Do not run the **STEAM PIPE** in so far that it shuts off the steam passage. Thread the end #5-40 while the metal is rigid or "half hard". Mount the threaded end in a small vise and place a piece of larger tubing over the projecting end. Play the propane torch flame on one side of the tube and slowly apply pressure, bending away from the torch. You can feel the moment the heat has removed the work-hardened condition of the tube. Take it easy and bend at a right angle. If the heat is spread evenly on the stretch side of the bend, it will hardly collapse the tube at all. At final assembly, the bent end must aim at the Boiler when it runs tight in the thread. Apply pipe joint compound to the thread. Assemble the Engine and Boiler on the Base and solder the pipe into the Boiler.

The ports in the column are made with a jig as shown. Use the shoul-



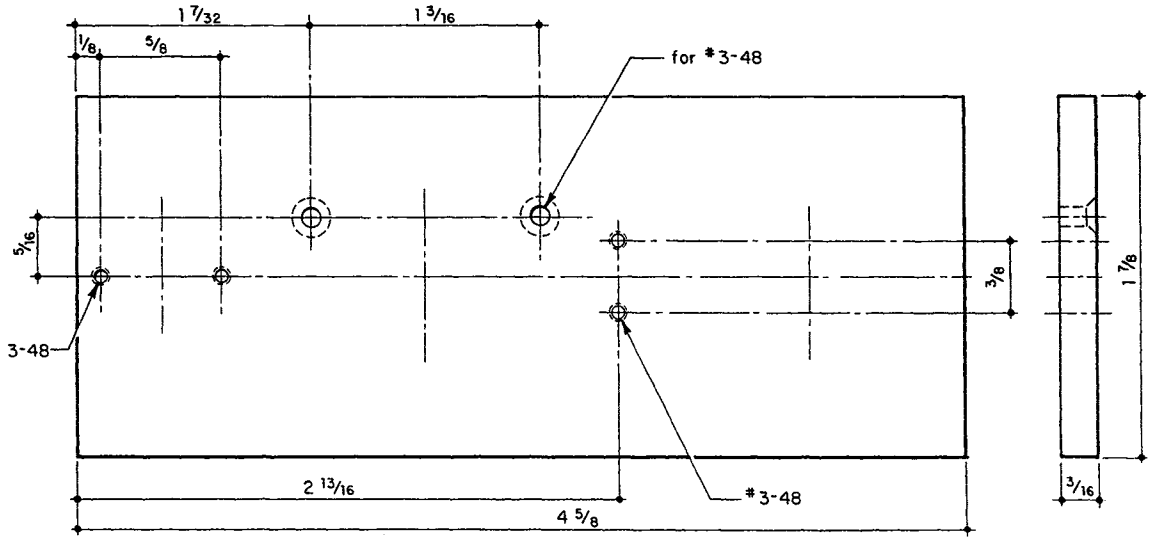
dered locating pin and a 1/16" straight pin in the column. Hold the jig against the locating pin while drilling. Turn the jig over the second hole.

Use the same jig to drill the port in the Cylinder. Insert the Piston in the Cylinder. Place jig over the shaft and a 1/16" pin through the jig and Connecting Rod.

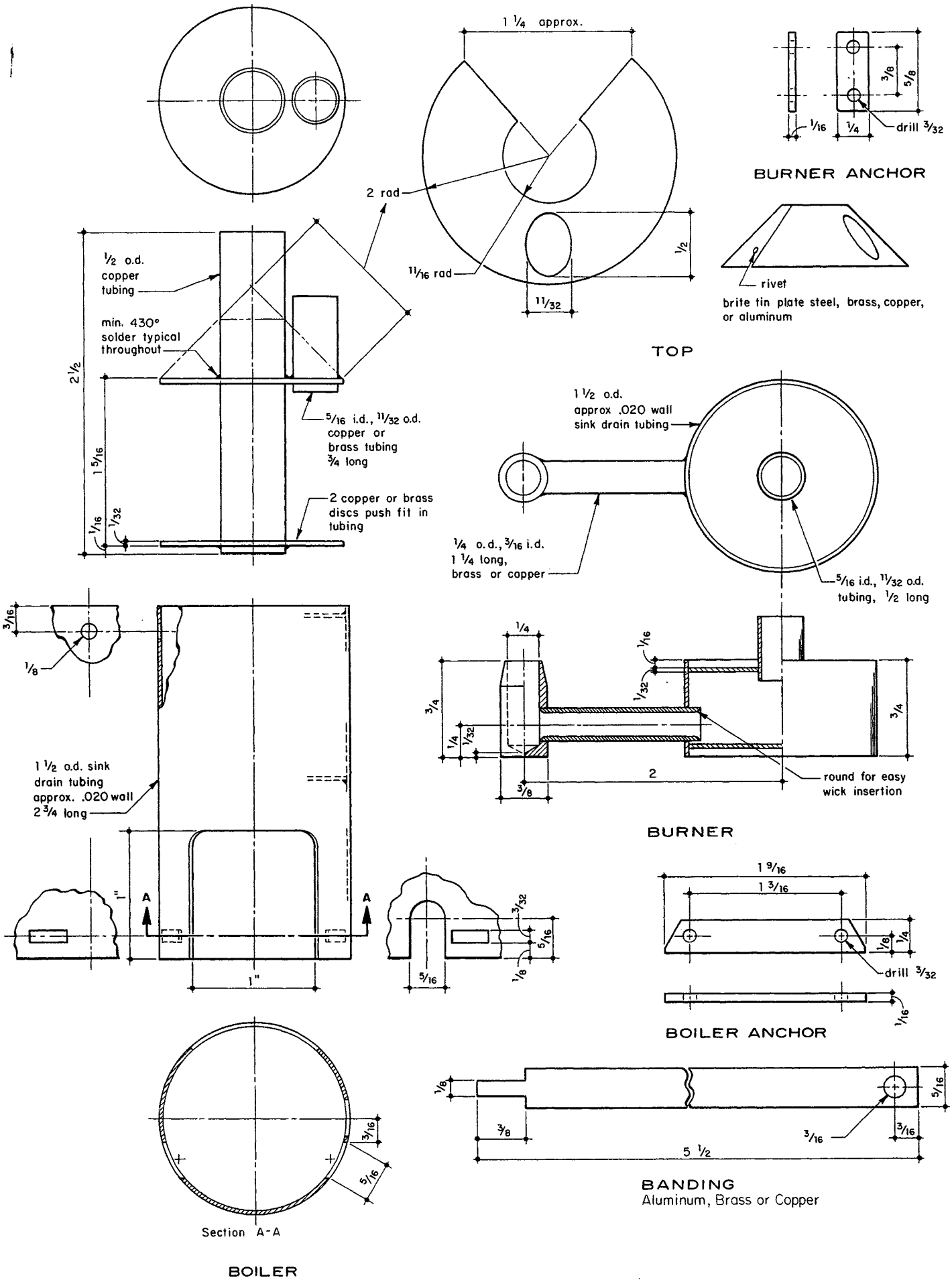
Do not seal this Boiler any tighter than provided by the cork. It will hold the 5 to 10 pounds of pressure needed and easily blow out if higher pressure develops. Do not have your face above the Boiler when operating. **Remember, you are dealing with flammable liquid, fire, hot water and steam. If you made this for your grandson, supervise his operation of this model.**

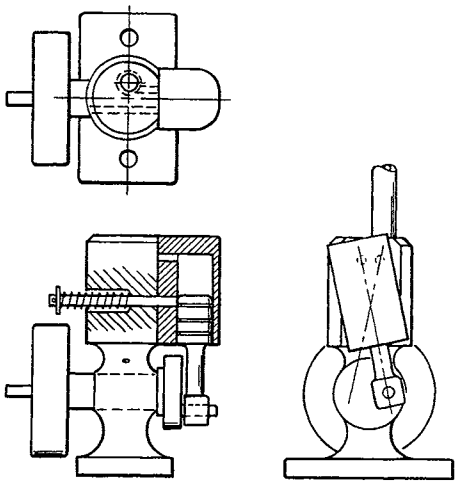
A hypodermic syringe is great for measuring the water and alcohol. The Boiler should be only about 2/3 full of water. If the Boiler runs out of water (the engine stops) blow out the flame immediately

This is a good educational project with lots of operational action.

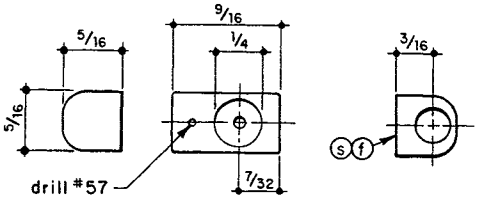


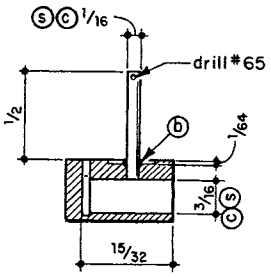
BASE


1 1/4 approx.
2 rad
11/16 rad
1/2
11/32
TOP
1/2 o.d. copper tubing
min. 430° solder typical throughout
2 1/2
1 5/16
1/16
1/32
5/16 i.d., 11/32 o.d. copper or brass tubing 3/4 long
2 copper or brass discs push fit in tubing
3/16
1/8
1 1/2 o.d. sink drain tubing approx. .020 wall 2 3/4 long
A
A
1"
1"
5/16
3/32
5/16
1/8
1 1/2 o.d. approx .020 wall sink drain tubing
1/4 o.d., 3/16 i.d. 1 1/4 long, brass or copper
5/16 i.d., 11/32 o.d. tubing, 1/2 long
1/4
1/16
1/32
3/4
1/4
1/32
3/4
2
3/8
round for easy wick insertion
BURNER
3/8
5/8
1/16
1/4
drill 3/32
BURNER ANCHOR
rivet
brite tin plate steel, brass, copper, or aluminum
1 9/16
1 3/16
1/8
1/4
drill 3/32
1/16
BOILER ANCHOR
1/8
5/16
3/8
3/16
3/16
5 1/2
BANDING
Aluminum, Brass or Copper
3/16
5/16
Section A-A
BOILER

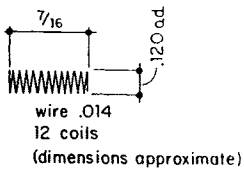


3/16 x 3/16 WOBBLER ENGINE

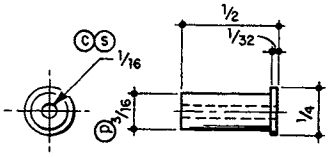




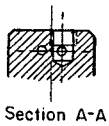
CYLINDER
Brass

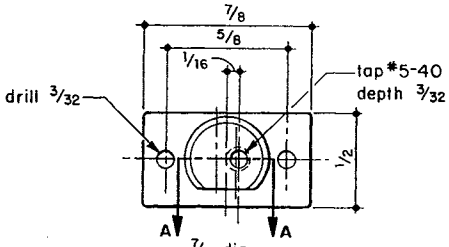


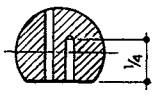
SPRING
Bronze or Stainless Steel



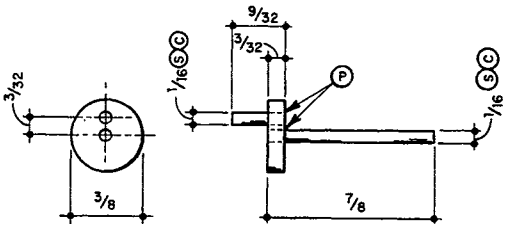
BEARING
Brass or Bronze


Section A-A

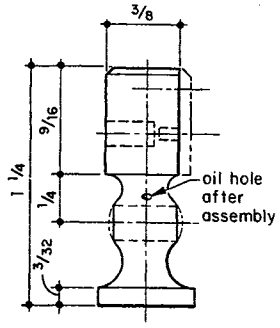


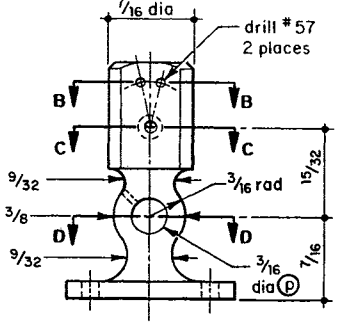


Section B-B

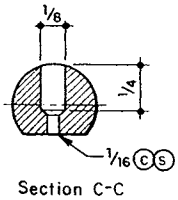


CRANKSHAFT
Brass

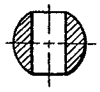


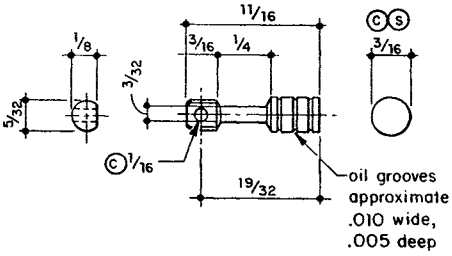


COLUMN
Aluminum or Brass

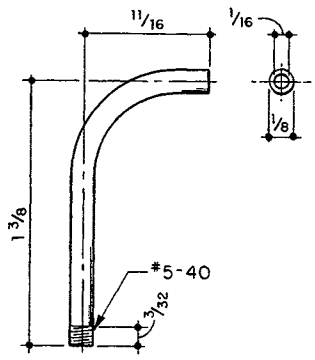


Section C-C

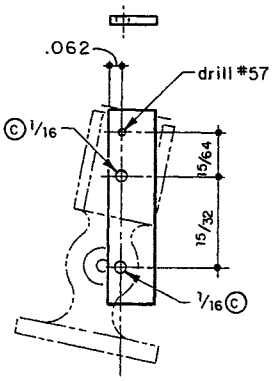

Section D-D



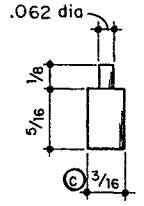
PISTON AND ROD
Aluminum



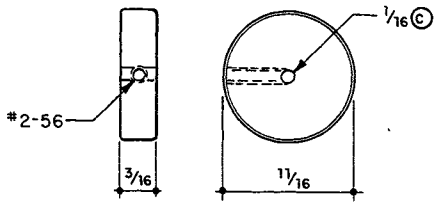
STEAM PIPE
Copper or Brass
(Half Hard)



DRILL JIG



LOCATING PIN

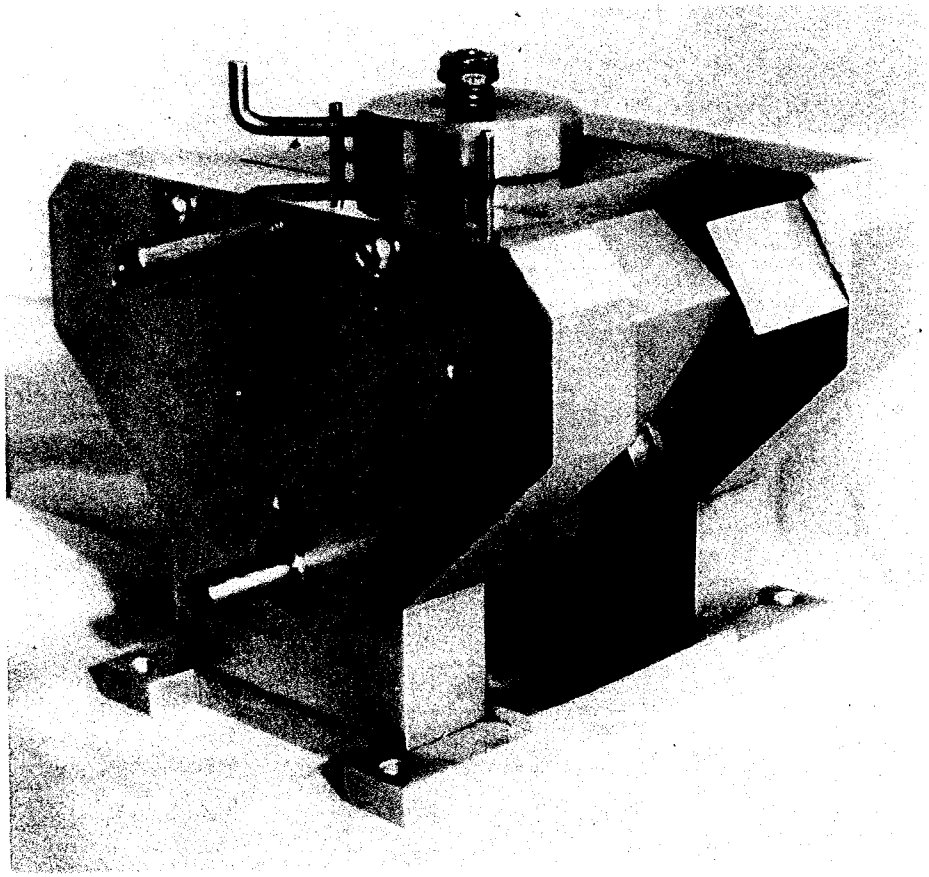


FLYWHEEL
Brass

C close fit	P press fit or loctite
S smooth	b braze or solder
f flat	

CHAPTER

27 V4 Wobbler



This engine was inspired by Jan Gunnarson's V4. I would say Jan's engine using cast iron, steel and bronze would make a more durable engine and, under steam, can take a lot more than this aluminum engine. I offer my apologies to Jan. This is just another approach to his basic design.

Scribe the "V" outline and all the centerlines on the 2-1/4" x 3-1/8" **END PLATES**. Chuck in the 4-jaw and center for the Crankshaft Bearing and 1-1/16" recess. Make **BUSHINGS** and press in flush with the back side so the Plates will lie flat on the drill press for other operations. Oilite was used for the Crankshaft Bearings. Bushings were chosen for the Cylinder pivots. Do not break into the steam passage in Section **G**.

Make the **DRILL JIG**. Insert a short-close fitting 3/16" pin **Y** in the pivot hole and place the Jig over it with **X** side against another short 3/16" pin **Z** in the Crankshaft hole as shown. Drill the 1/16" steam hole only 1/64" to 1/32" deep in the Plate. Turn the jig over and drill the other hole. These holes are shallow now for locating purposes only. If drilled deeper they might deflect the crosshole drill.

Pick up and transfer the centerline of these holes to the edges of the Plate. The crossholes require some careful study and layout. Note they are at 3/32", 7/32" and 11/32" from the face and are drilled to different depths. These were drilled 1/16" but they could be 5/64" for better steam flow. Lay out and drill the four holes in the top edge at 1/4" and 7/16" spacing. They intersect the cross holes. Now do the same with four holes from the face at 1/4" and 7/16", intersecting the vertical holes you just made. Go back to the shallow 1/16" holes made with the jig and drill them into the crossholes.

Drill the screw holes for the Valve Plate and drill and tap for the foot screws. Cut these **END PLATES** to the "V" shape. Press the Bushings in against their shoulders and drill the three oil holes starting with a 1/16" end mill. Don't break into the crosshole shown at section **D**.

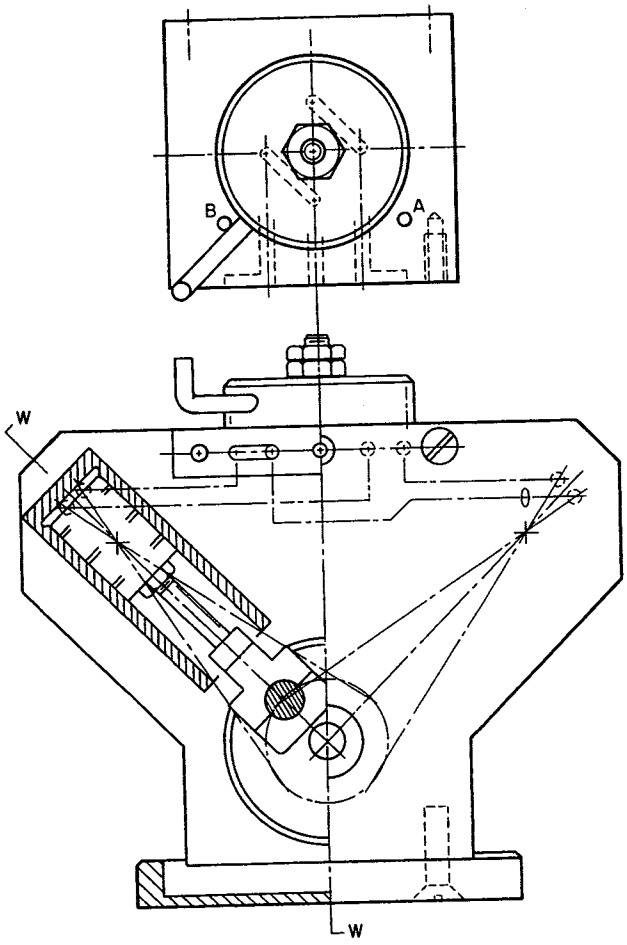
Clean out all chips. The steam passages are now done except for plugging. The stock for plugging should be about .002" larger than the drilled holes. File a slight taper on the plug that will allow the plug to enter the hole about 1/32". Apply a tiny dab of Loctite and drive in until firm; cut off and dress flush. Do not drive deep enough to close off a steam passage. These passages do not have streamline flow for the steam but the steam does get to the Cylinders.

The holes in the **VALVE PLATE** require careful layout and machining that must match the above End Plates and the Valve, so no steam passages will be partially closed off at assembly. Insert a close-fitting pin in each End Plate center steam hole and corresponding hole in the Valve Plate. Line up and clamp the two End Plates and Valve Plate together. Insert a piece of 3/16" drill rod through the shaft holes. It should rotate freely. Spot the 4-40 holes in the Valve Plate. Remove and complete drilling and tapping.

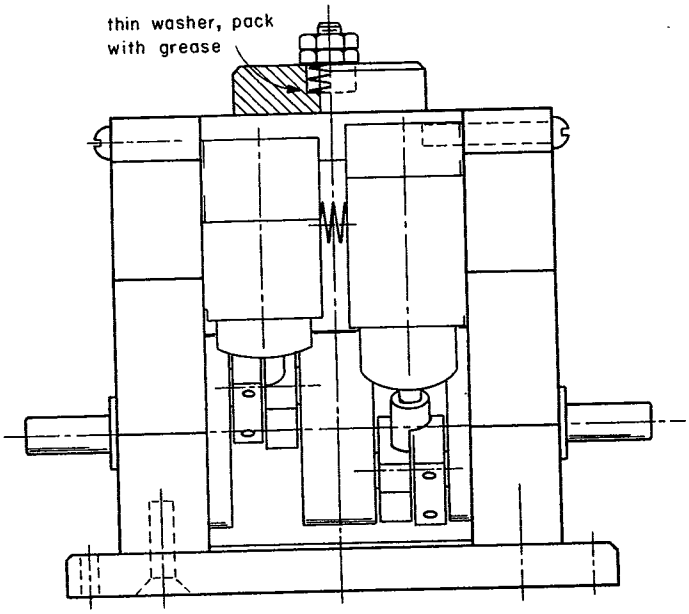
Afer completing the Valve Plate and Valve, insert the 5-40 stud. Make a close-fitting pin about 5/32" long and insert it in one of the four Valve holes in the Plate and lower the Valve over it, engaging one end of the valve slot and clamp. Spot a 1/16" hole at **A** with the drill just touching the lever. Lift the Valve and repeat for the other Valve position at **B**.

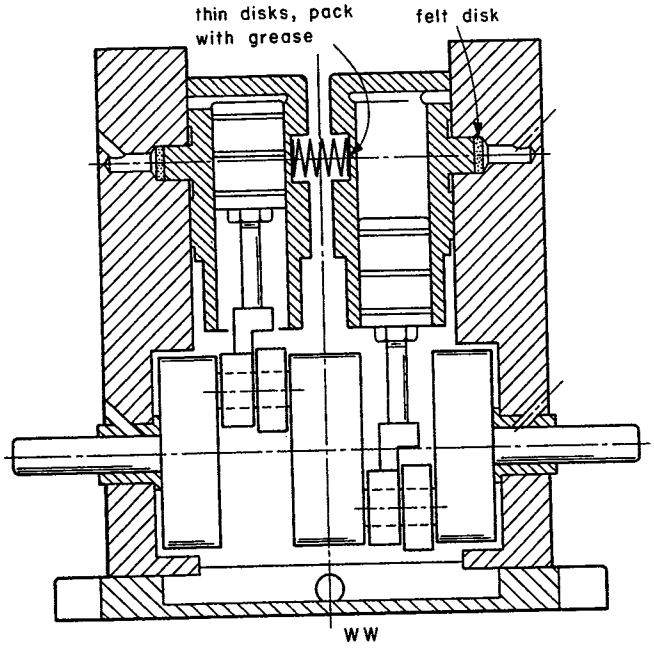
Make the **FOOT**. The important dimension is across the shoulders. It should match the ValvePlate.

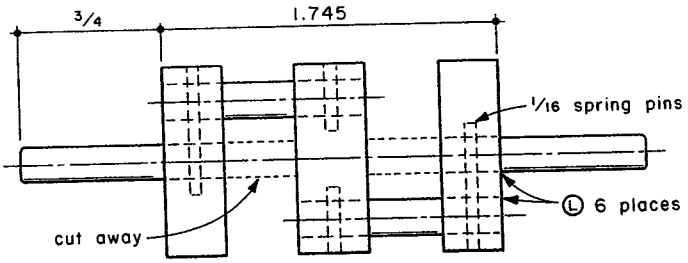
The **CYLINDERS** start with four accurate pieces 1/2" x 3/4" x 1-5/16". Lay out and center punch for the bore,Pivot and Spring hole. Use the four-jaw chuck and center up and

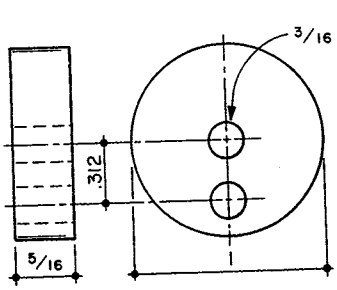


Ⓒ close fit
Ⓢ smooth
Ⓟ press fit
Ⓛ "loctite"
Ⓕ flat

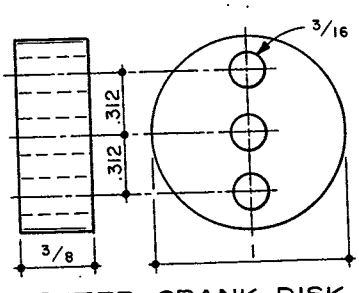




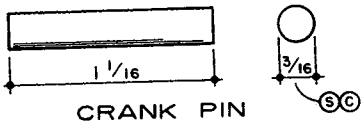




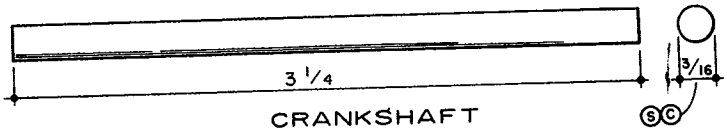
END CRANK DISK
Steel, 2 Required



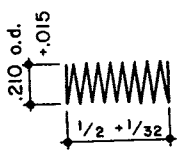
CENTER CRANK DISK
Steel



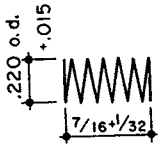
CRANK PIN
Steel, 2 Required



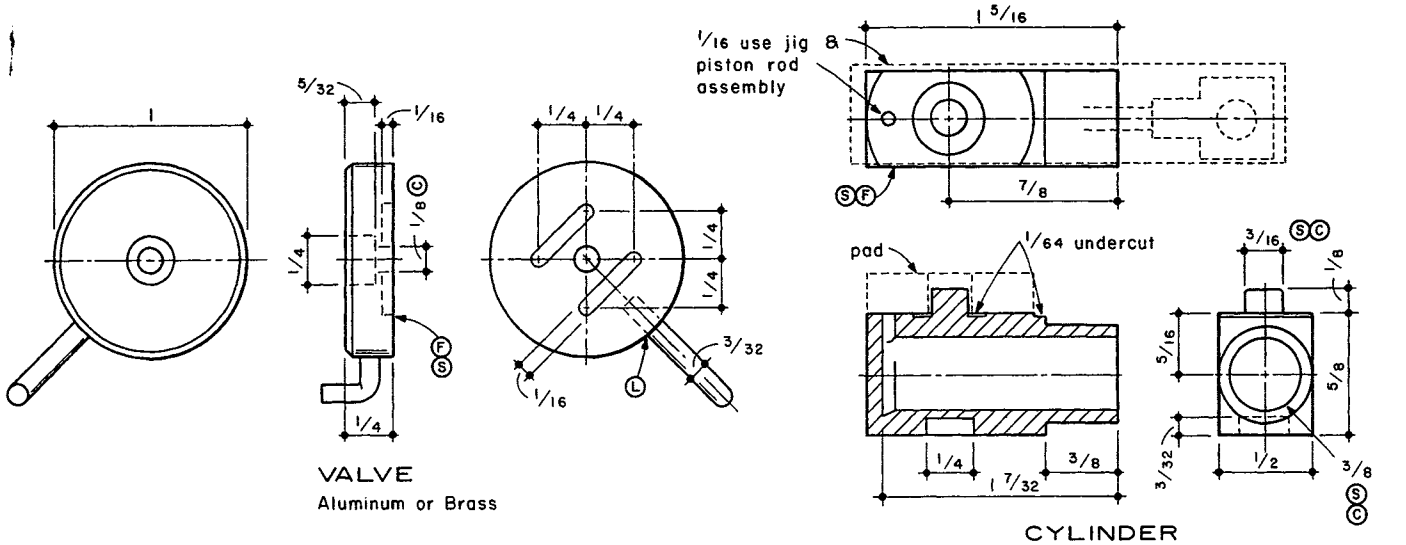
CRANKSHAFT
Steel

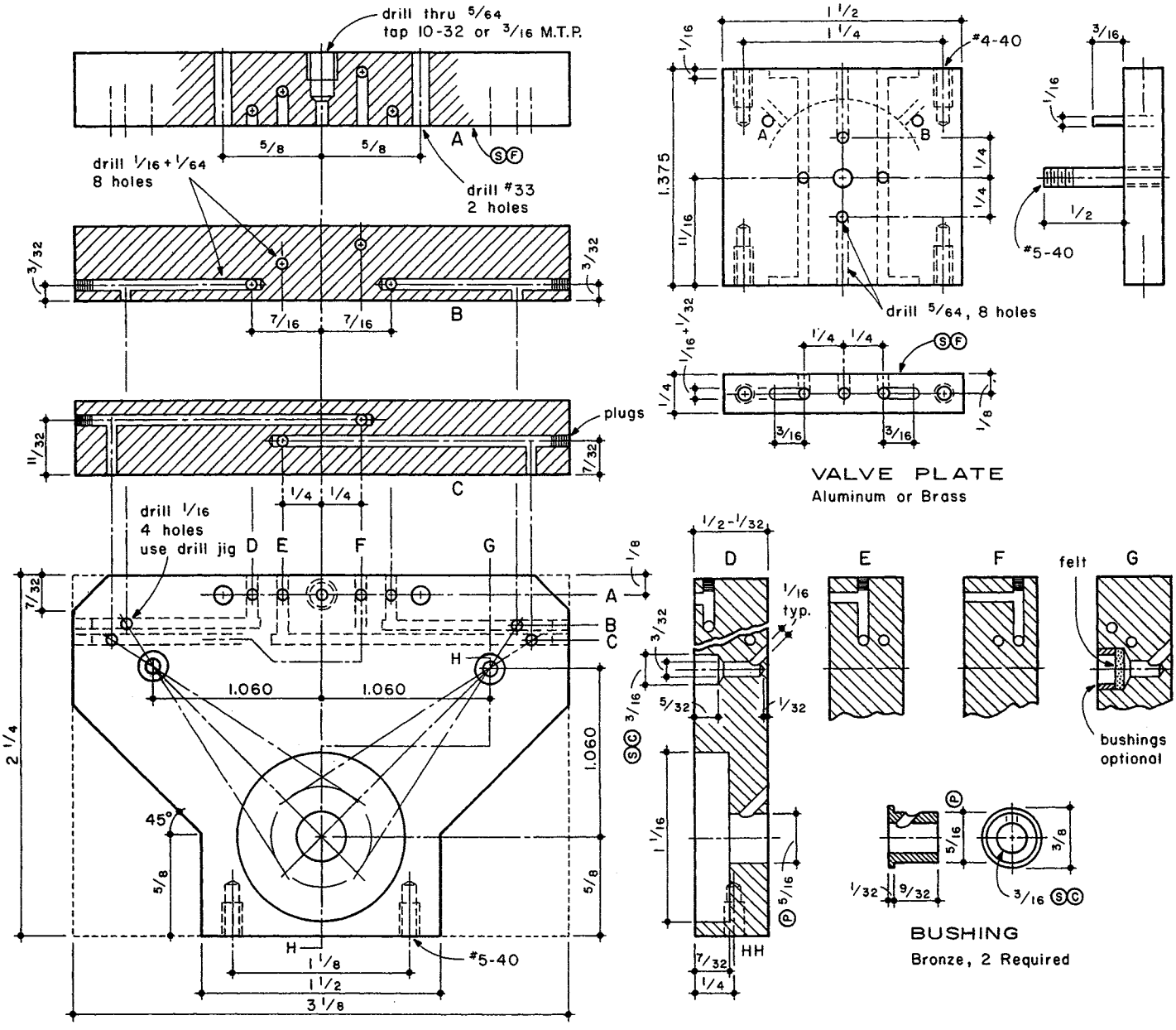


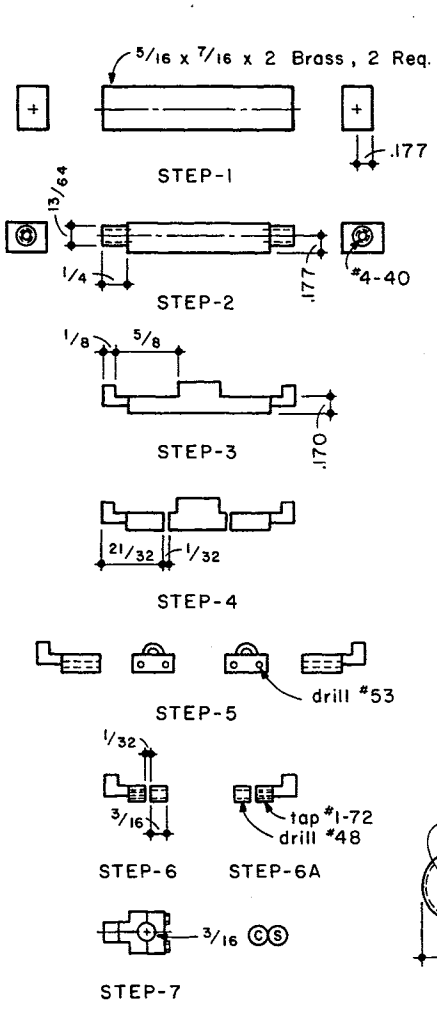
VALVE SPRING
Steel
.030 wire appr. 7 active coils



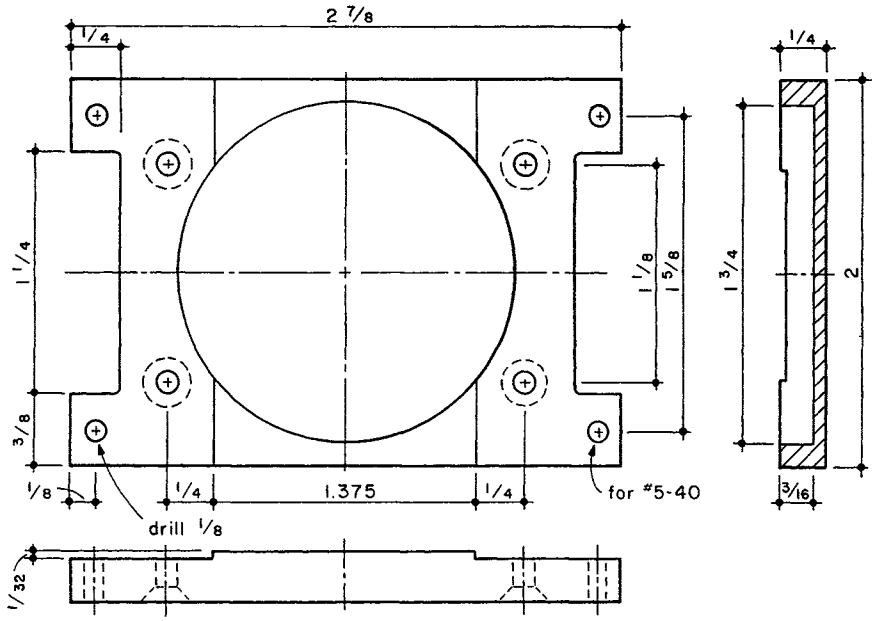
PIVOT SPRING
Steel, 2 Required
.025 wire appr. 5 active coils


1
5/32
1/16
1/8
1/4
F
S
1/4 1/4
1/4
1/4
3/32
L
1/16
VALVE
Aluminum or Brass
1 5/16
1/16 use jig & piston rod assembly
S F
7/8
pad
1/64 undercut
1/4
3/8
1 7/32
3/16 S C
1/8
5/16
5/8
3/32
1/2
3/8
S C
CYLINDER
Aluminum or Brass, 4 Required

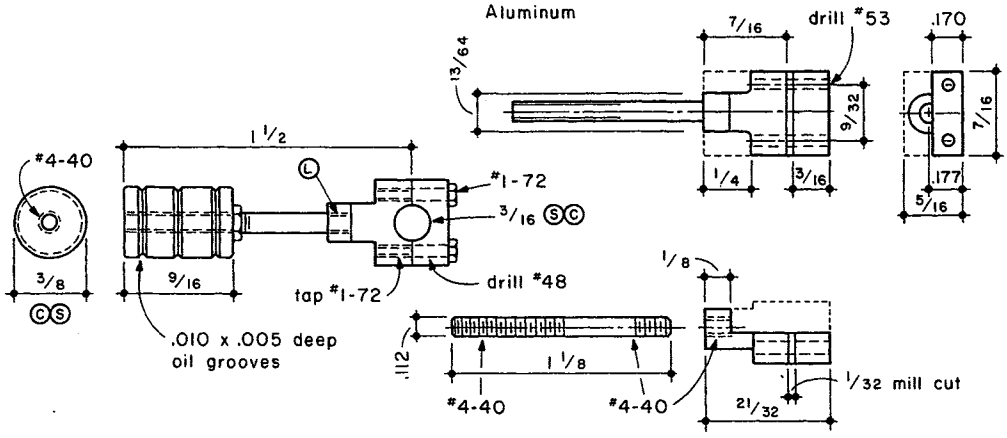

drill thru 5/64
tap 10-32 or 3/16 M.T.P.
5/8
5/8
A
S F
drill 1/16 + 1/64
8 holes
drill #33
2 holes
3/32
3/32
7/16
7/16
B
11/32
plugs
7/32
C
1/4 1/4
drill 1/16
4 holes
use drill jig
D
E
F
G
7/32
1/8
A
B
C
H
1.060
1.060
2 1/4
45°
5/8
5/8
H
1 1/8
1 1/2
3 1/8
#5-40
END PLATE
Aluminum, 2 Required
1 1/2
1 1/4
#4-40
1/16
3/16
1/16
A
B
1.375
1/4
1/4
11/16
1/2
#5-40
drill 5/64, 8 holes
1/16 + 1/32
1/4 1/4
S F
1/4
3/16
3/16
1/8
VALVE PLATE
Aluminum or Brass
1/2 - 1/32
D
E
F
felt
G
1/16 typ.
3/32
3/16
S C
5/32
1/32
1 1/16
P
5/16
HH
7/32
1/4
bushings optional
P
5/16
3/8
1/32
9/32
3/16 S C
BUSHING
Bronze, 2 Required



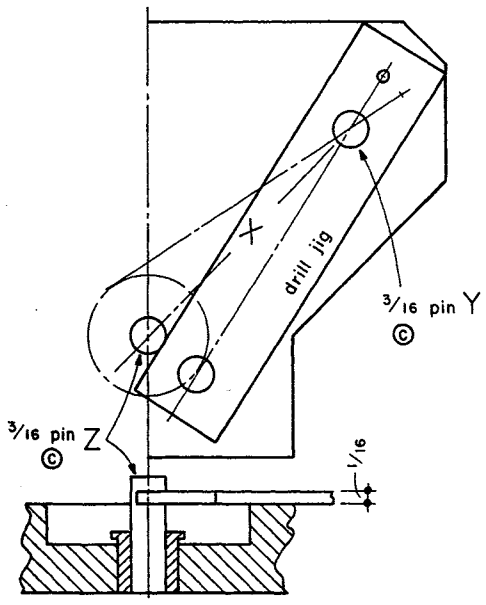
PISTON ROD BEARING
4 Required

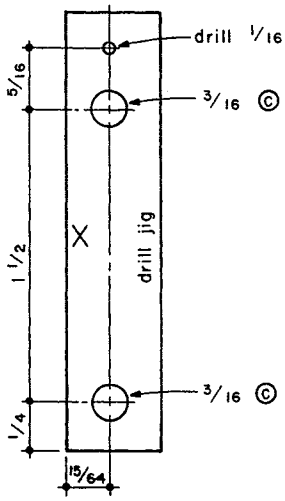


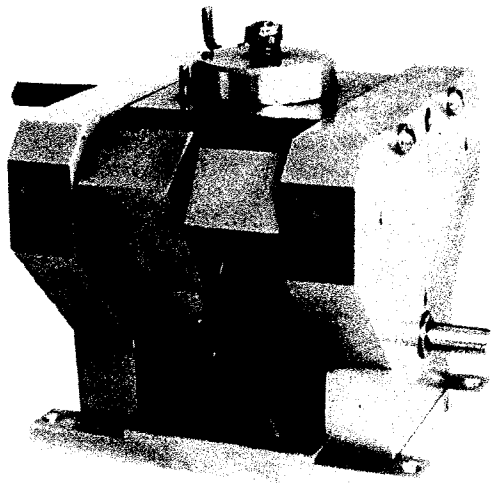
FOOT
Aluminum



PISTON & ROD
Brass, 4 Required
See 7 Steps







turn the spring recesses. Turn over in the chuck and turn the pivot side of the Cylinder. Use an indicator or parallels to square up in the chuck. Make a chucking pad about 3/16" x 1/2" x 7/8" with a 1/4" hole in the center. Cut a piece of thin cardboard to match with a 1/4" hole. Mount the Cylinder in the 4-jaw with these two pieces protecting the finished Valve face. Center, using a center test indicator and make the 3/8" bore. Back up the boring tool at the bottom of the cut to give the reamer some runout clearance. Turn the 1/2" diameter back 3/8". Drill the steam hole later.

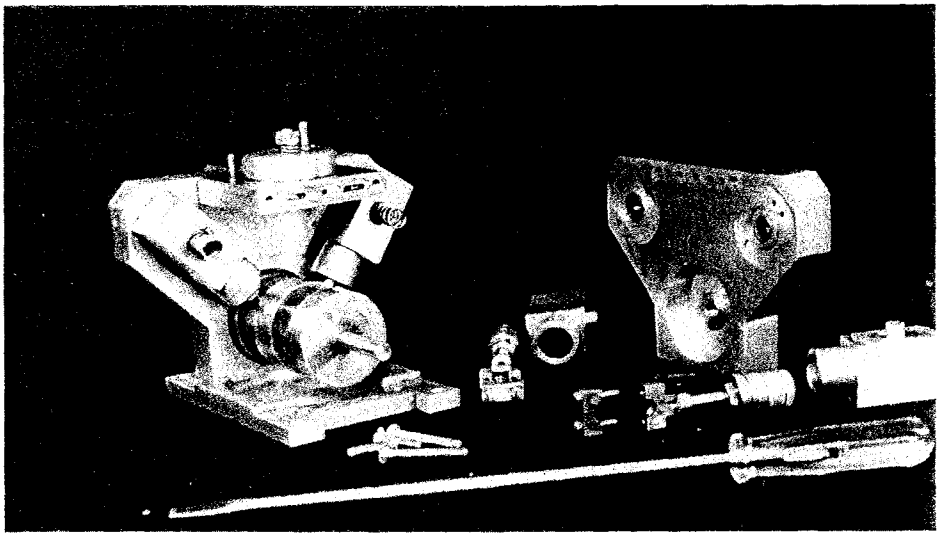
Turn the **PISTONS** and, while still in the lathe, tap the 4-40 hole. Use the Cylinders as gauges and keep each Piston with its own Cylinder from now on. Make the 1-1/8" **ROD** also, threading in the lathe.

The **CONNECTING ROD BEARINGS** are made from two pieces of 5/16" x 7/16" x 2" stock. Apply layout dye over about 3/4" of both ends. Lay out the rod center .177" from one face as in **Step 1**. Chuck, turn and tap both ends as in **Step 2** and then make the 5/8" cut down to .170 thickness as in **Step 3**. The purpose of the .170" and .177" dimensions is to guarantee clearance at the Crank Pin as seen on the assembly drawing. The Bearings should float on the Crank Pin and not touch each other or the CrankDisks, a condition which could tilt a Cylinder off its seat. In **Step 4**, use a 1/32" slitting saw and cut at 21/32". Drill the two holes in each piece in **Step 5**. Again, using the 1/32" saw, cut at 3/16" in **Step 6**. Drill and tap **Step 6A**. Assemble with #1-72 screws, center punch and bore 3/16" for the Crank Pin in **Step 7**.

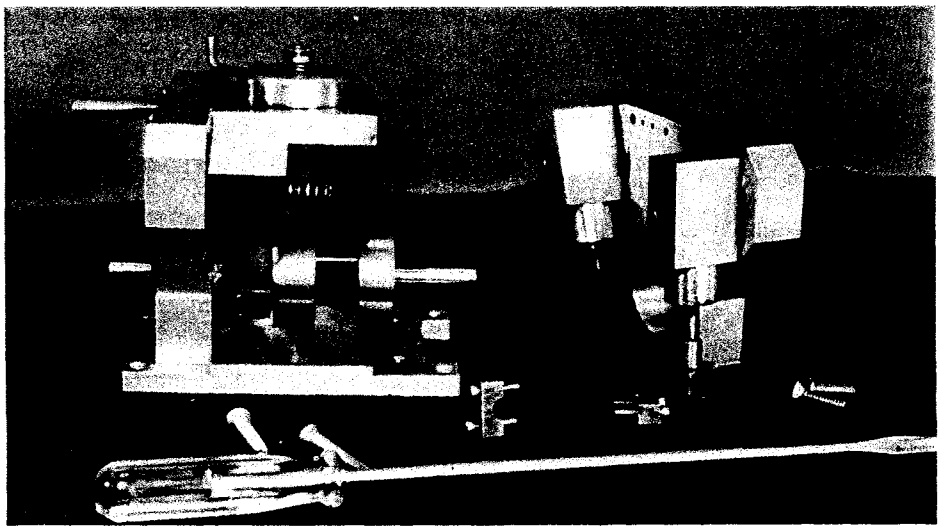
Now is a good time to make tiny marks on the Caps and Bearings so each Cap can be brought back to its own Bearing to the position at which it was machined.

Insert a Piston in its Cylinder and place the drill jig over the Pivot and insert a short, close-fitting pin through the jig and Connecting Rod hole. Drill the 1/16" steam port.

The **CRANKSHAFT** is made the way Jan laid it out. Turn, bore and ream all three Disks. Drill and ream for the Crank Pins using the 3-jaw chuck on an indexing fixture. Chuck a piece of 3/16" drill rod in the spindle and bring the Disk on center so the rod will freely enter the center bore. "Zero" the collar and feed in .312". Drill and ream at this position for all three Disks. For the center Disk, rotate 180° for the second hole.



Partial assembly of the V4 Wobbler.



Bringing the sub-assemblies together for final assembly.

Assemble the two completed End Plates, Valve Plate and Foot. Measure across face to face between the Crank Bushings with an inside caliper. Transfer this setting to a slide caliper and lock the slide.

Loosely assemble the entire Crank Shaft. Apply Loctite **only** at the center disk **Crank Pin holes.** Set aside to cure. When set, assemble the two end Disks and Shaft and the center Disk assembly with Loctite. Hold the distance across the end Disks .005" less than the slide calipers.

Work out a marking system so all the parts can be reassembled the way they were fitted and worn-in.

The dimensions of the **SPRINGS** shown are based on the salvage springs used. Actually, the least amount of spring pressure to hold a seal is all you need, keeping the friction as low as possible. At assembly, add thin steel disks in the Cylinder Spring holes, bedded in grease.

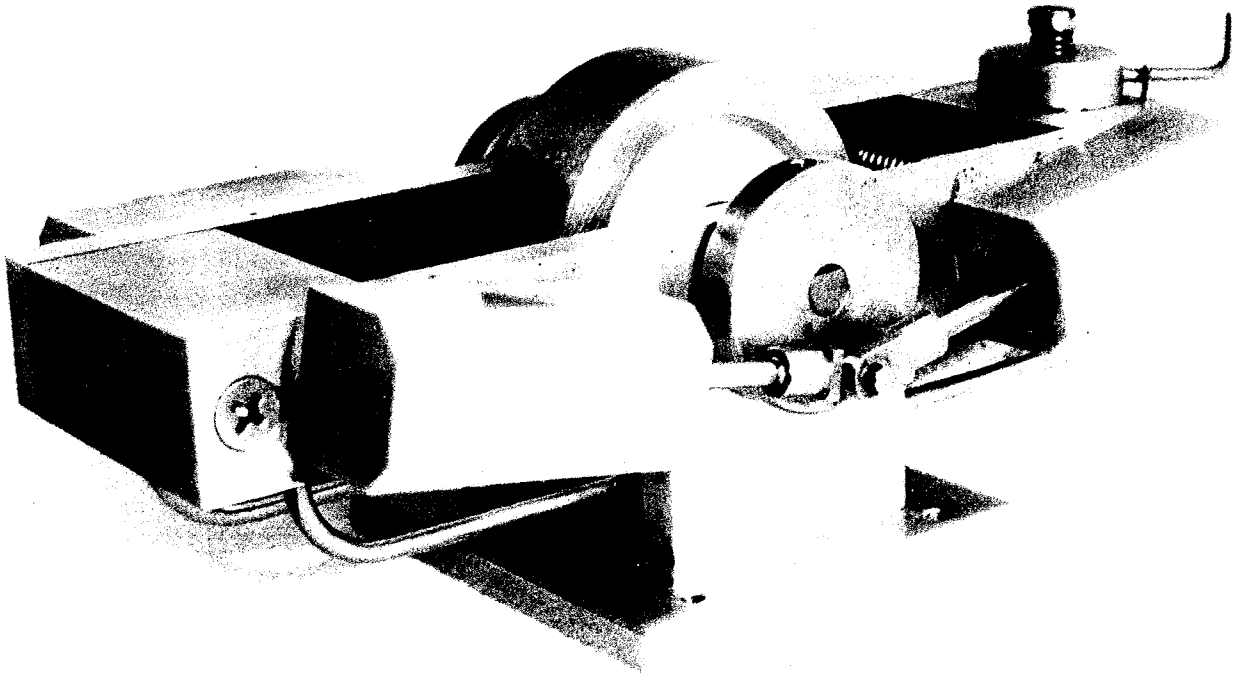
Assemble one End Plate, the Valve Plate, Crankshaft and two sets of Cylinders and Connecting Rods. Insert the Pivot Springs. Hold the other End Plate and two Cylinders together and bring them to this assembly, engaging the Pivot Springs. Hold together and insert the Valve Plate screws. Now insert the Pistons into their own Cylinders, rock around until the Connecting Rod Bearings engage the Crankshaft and fit the Caps in place.

Attach the Foot and the Valve and start your "fiddlin', fussin', filin' and fittin'." It takes a bit of this to make it run free and easy.

Even though there is the friction of four wobbling Cylinders, it takes only about 10 psi of air to spin this engine at a good speed after it is once broken in a bit.

CHAPTER

28 H-Quad Engine



In 1981, this writer built a small twin wobbler engine and drawings were published. The overall length was about 2-1/4", the bore was 1/4" and it had a 1-1/4" flywheel. Ralph Weidman in Wooster, Ohio, didn't like to work to that small size so he doubled it and added two more cylinders and a reverse. His engine is shown below, next to the original H-Twin.

The drawings presented here cover his engine with a few slight variations since his engine is mostly brass while this one is mostly aluminum.

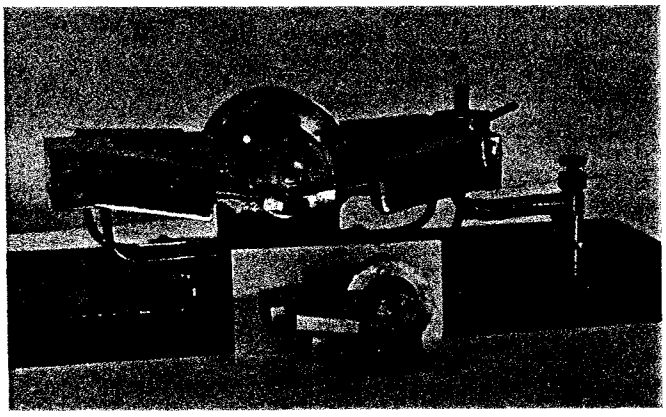
The Side Frames and End Blocks are worked up together in Steps 1 through 11.

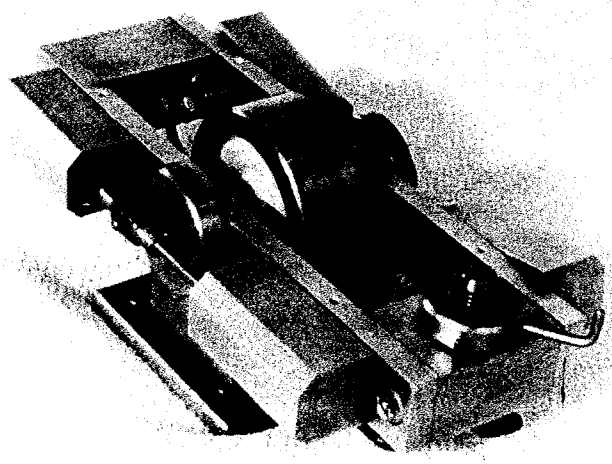
STEP 1. Make the two **SIDE FRAMES** alike. One side has 1/16" dowels to keep the End Blocks from rotation. Lay out the one Frame, clamp the two Frames together and drill and countersink for #8-32 screws. Bolt the two together with flat head screws so one side will lie flat while drilling and reaming the 5/16" Crankshaft hole and 3/16" Pivot holes.

STEP 2. Make the two **END BLOCKS,** tapped for the #8-32 screws.

STEP 3. The **DRILL JIG** is a simple steel strip drilled

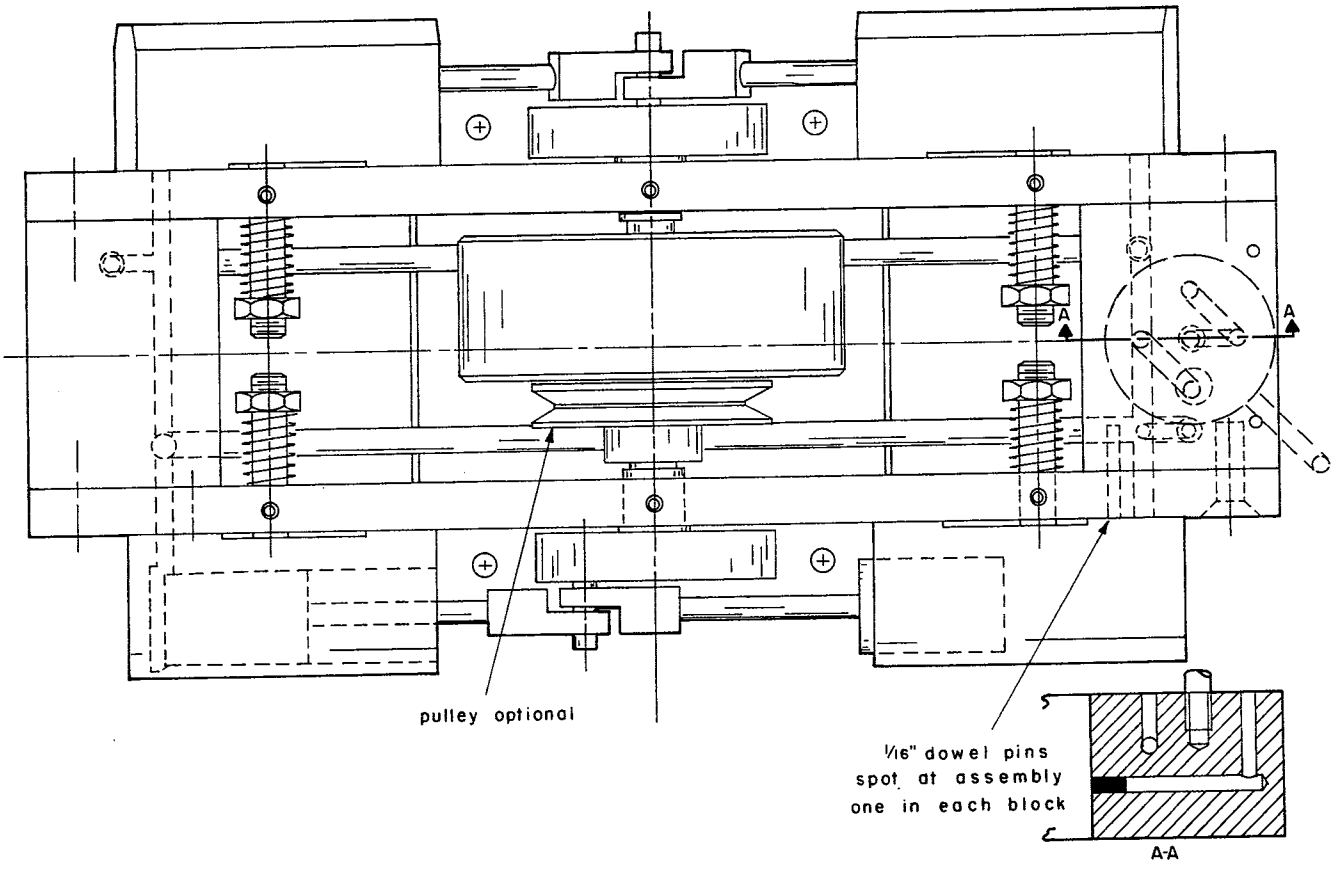
Below: Ralph Weldman's 4-cylinder wobbler alongside the original H-Twin.
Right: The H-Quad is an interesting engine which shows a lot of action.

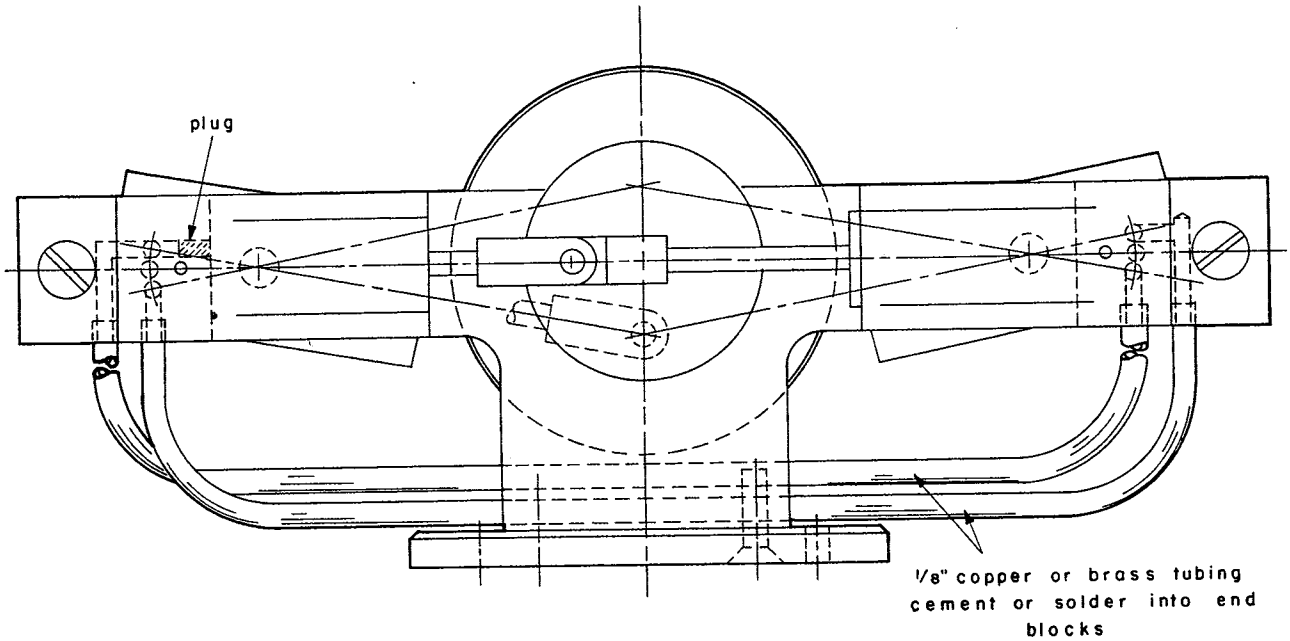


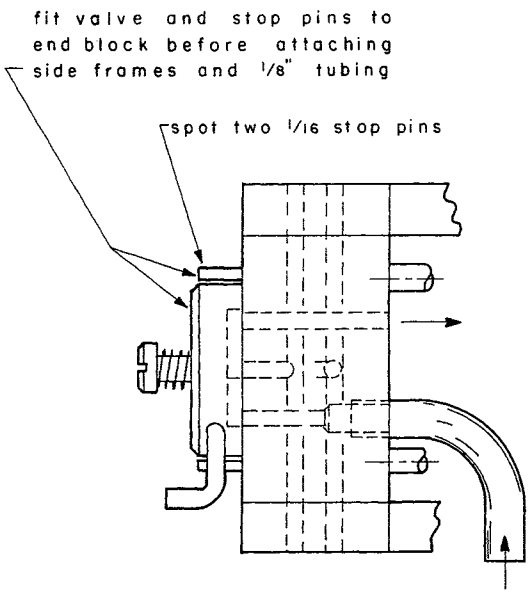


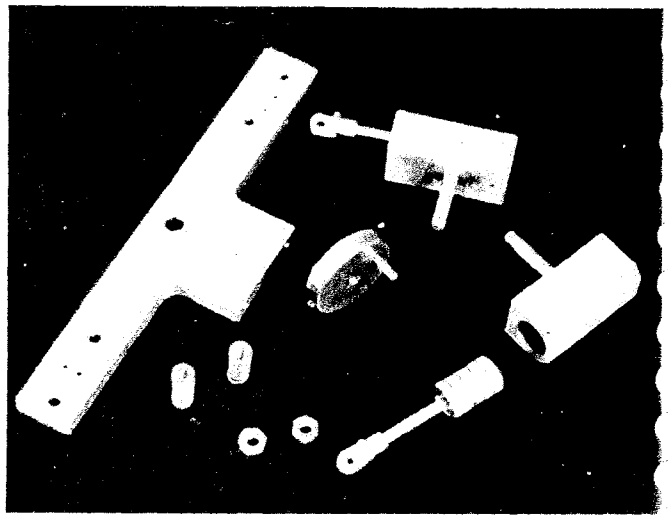
H-QUAD with reversing gear

Developed by Ralph Weidman from H-TWIN

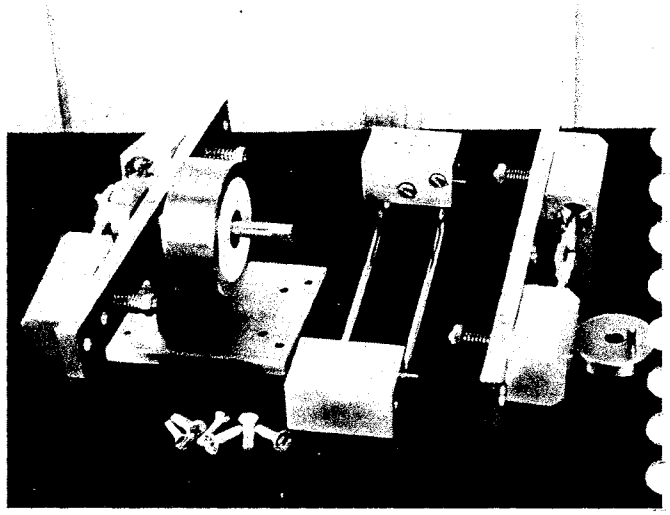




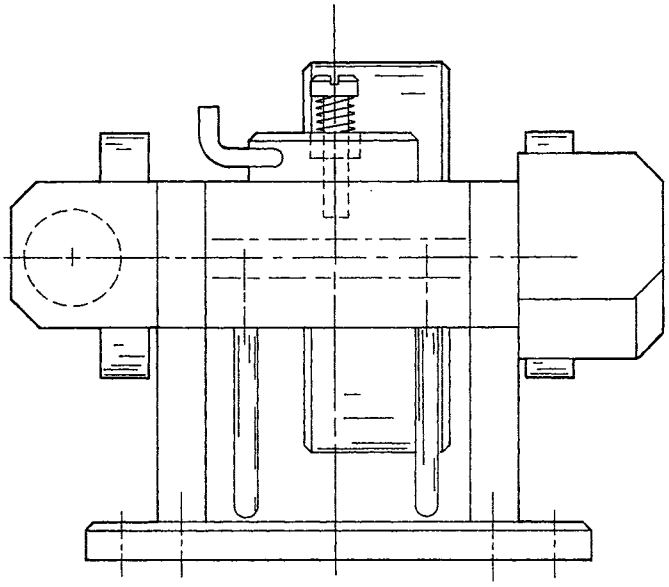


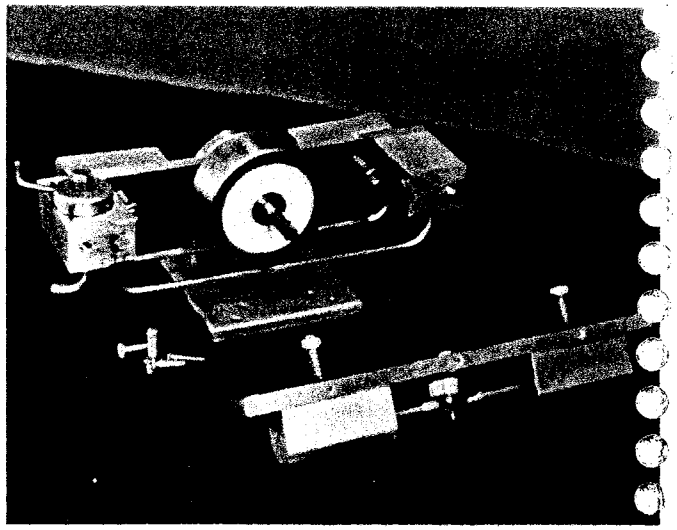


One Side Frame, Crank Disk, Cylinders, Pistons and springs.

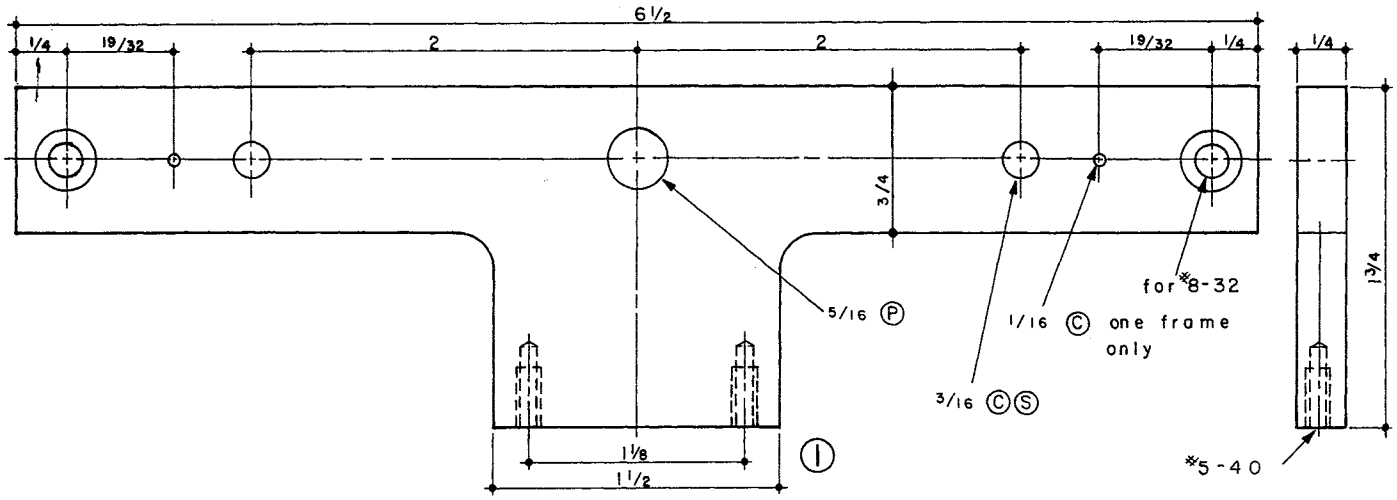


The three major assemblies.

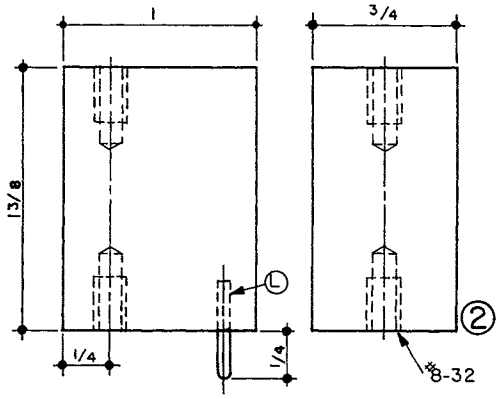




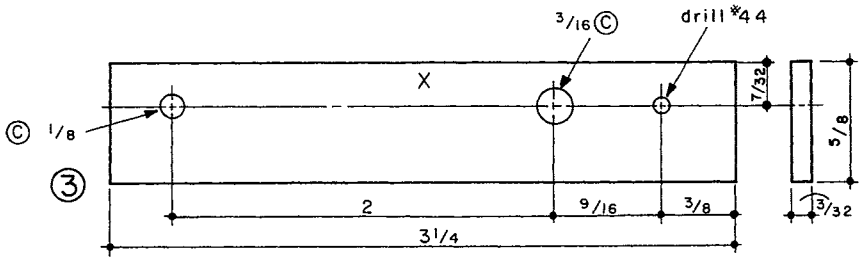
Two sub-assemblies bolted together and ready for the third.



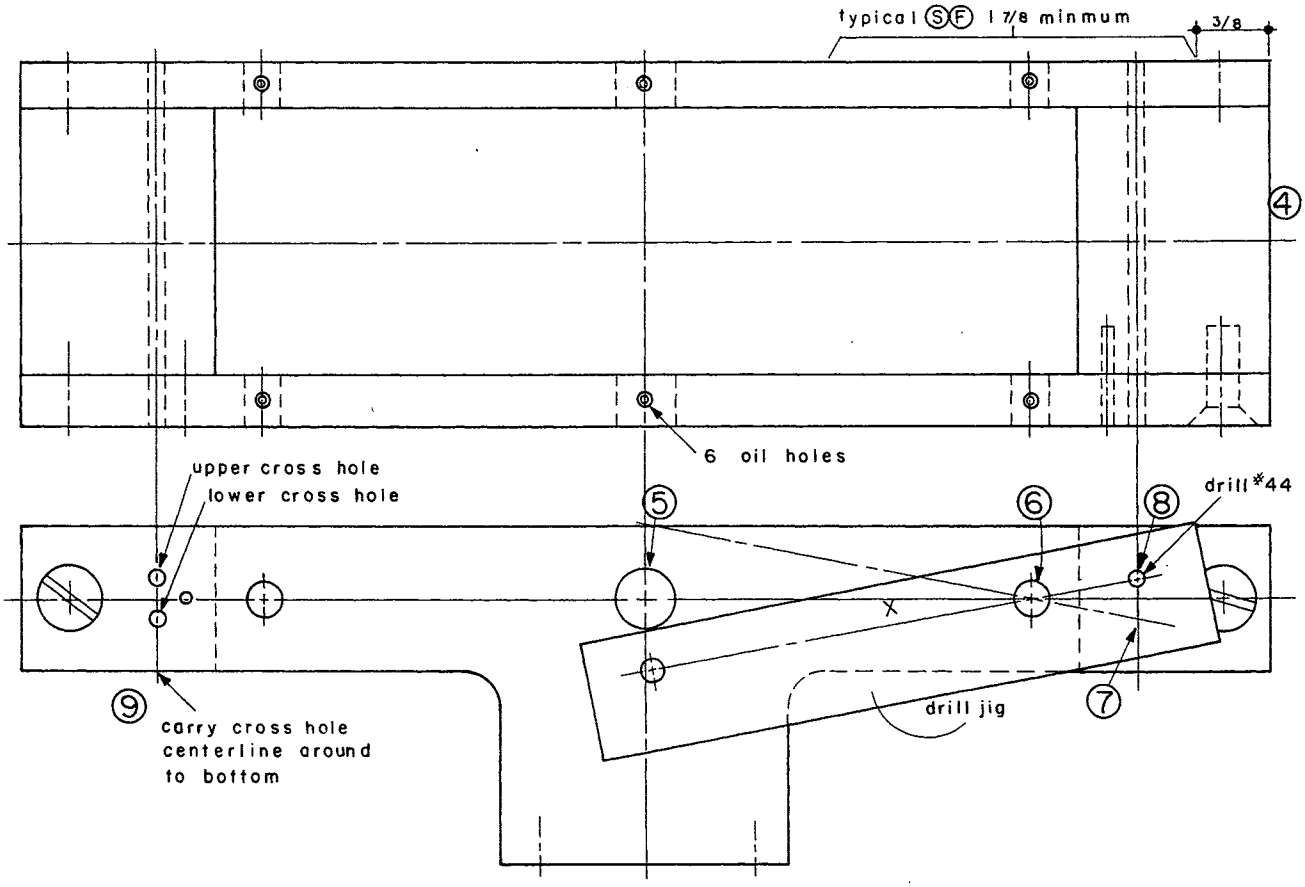
SIDE FRAME
Aluminum or Brass, 2 Required
Must be straight and flat

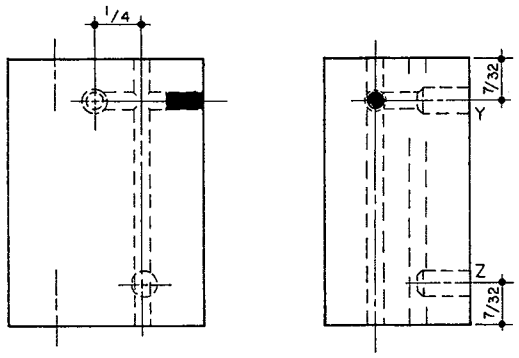


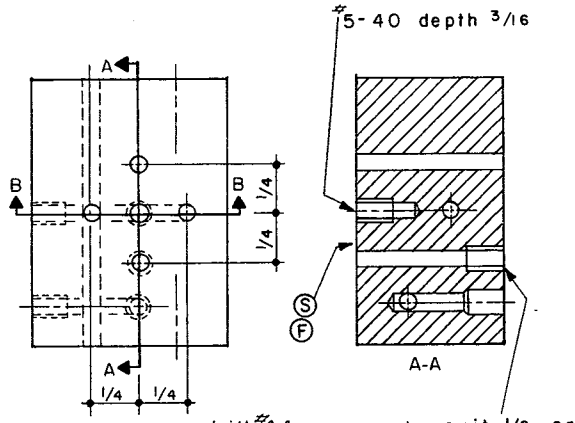
END BLOCK
Aluminum or Brass, 2 Required

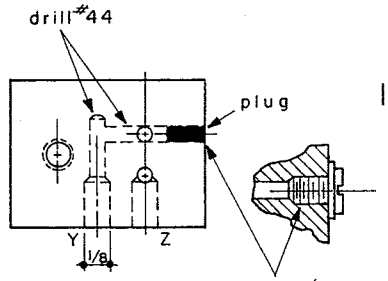


DRILL JIG
Steel

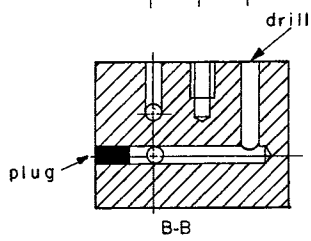




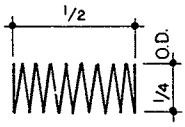




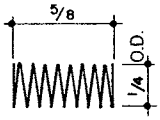
10



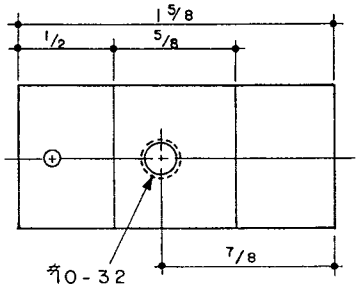
11

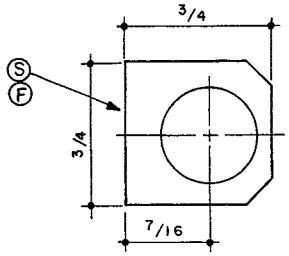


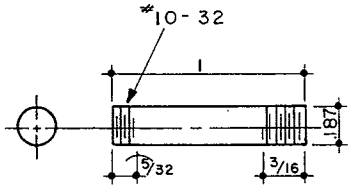
VALVE SPRING
Steel, .030" wire
approximately 6 coils



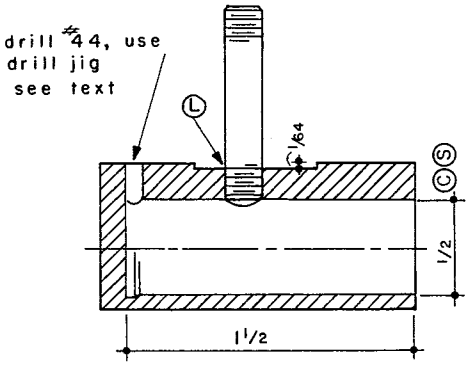
PIVOT SPRING
Steel, .030" wire
approximately 8 coils



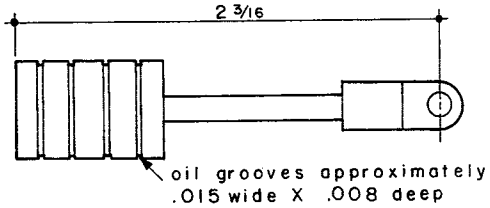


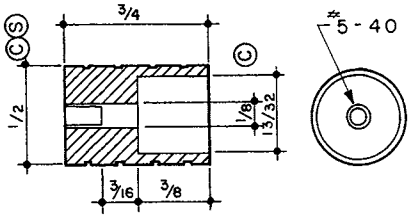


PIVOT
Brass or Steel
4 Required

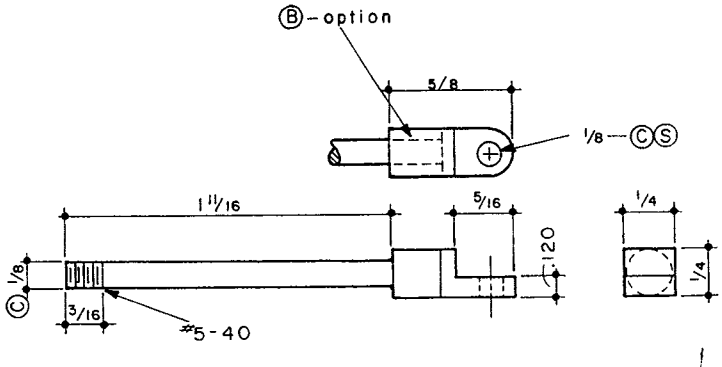


CYLINDER
Brass or Aluminum
4 Required

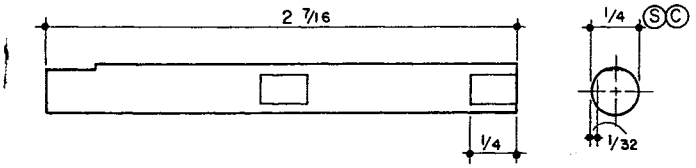




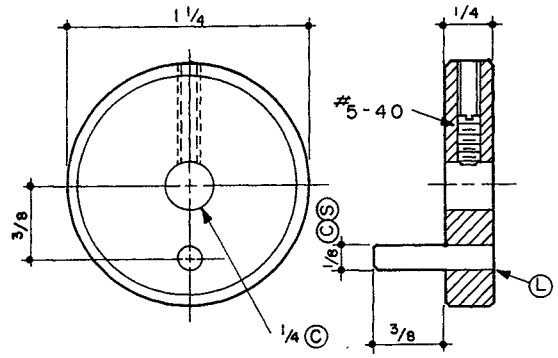
PISTON
Brass or Steel, 4 Required



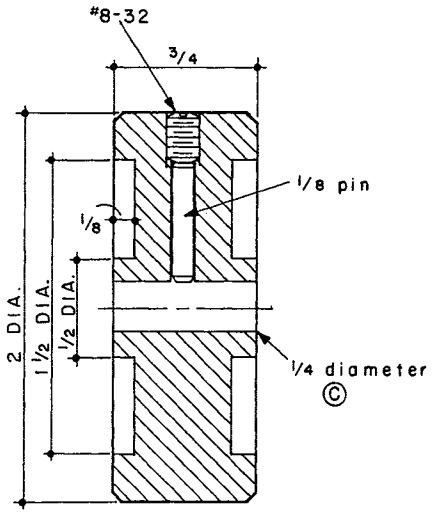
PISTON ROD
Brass or Steel, 4 Required



CRANKSHAFT
Steel

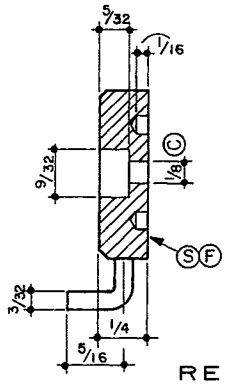


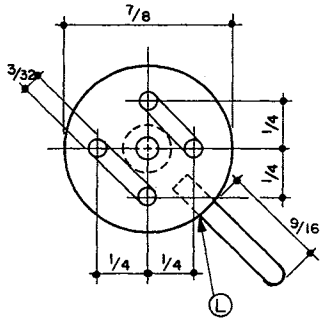
CRANK DISK
Brass or Steel, 2 Required



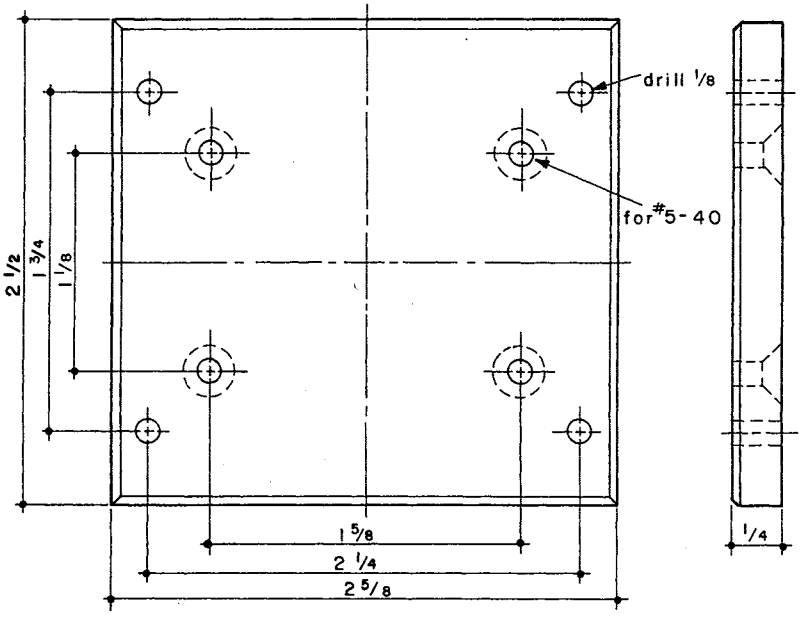
FLY WHEEL
Any Metal

Ⓒ close fit
Ⓢ smooth
Ⓕ flat
Ⓟ press fit or "loctite"
Ⓛ "loctite"
Ⓑ braze or solder

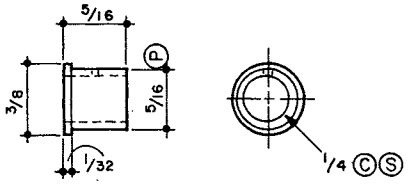




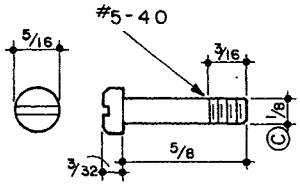
REVERSING VALVE
Brass or Aluminum



BASE
Aluminum or Steel



CRANKSHAFT BEARING
Bronze, 2 Required



VALVE PIVOT SCREW
Brass or Steel

and reamed for the 1/8" Crank Pin and 3/16" Cylinder Pivot Pin. Stamp the side **X** for locating purposes.

STEP 4. Assemble the two Side Frames and End Blocks, well aligned and tight. Run a 1/16" drill through the Side Frame hole into the End Blocks and remove that Side Frame. Set the two 1/16" dowels in the End Blocks with Loctite. Wait for it to cure and wipe away any on the outside so it won't set up in the Side Frame. Attach the Side Frame. Number each corner 1 through 4 and stamp the bottom of the Side Frames and End Blocks so it is easy to reassemble in the way it was machined.

STEP 5. Insert a close-fitting rod in the 5/16" Crankshaft holes and a 3/16" rod in the Cylinder Pivot holes.

STEP 6. Place Jig over the 3/16" rod and hold Jig against 5/16" rod as shown. Drill #44 about 1/8" deep.

STEP 7. Turn Jig over and repeat for other port hole.

STEP 8. Drill eight holes in this manner. Next, remove pins and drill #44 carefully and squarely halfway through from one side and turn the assembly over and drill until the holes meet in the center of the End Blocks. Do not drill all the way through from one side.

STEP 9. Carry the center of these cross holes around to the bottom.

STEP 10. Remove the End Blocks, lay out and drill up from the bottom at **Y** and **Z**. Counterbore for 1/8" tubing. Carry the center of the upper cross hole to the face and drill as shown. Make both blocks alike. When they are assembled to the Side Frames, they will be set for the tubing which must connect the lower cross hole at one end to the upper cross hole at the other end. This is shown in the lower lefthand assembly view. In operation, one tube is **INTAKE** and the other is **EXHAUST**. The reverse changes these to opposite — intake becomes exhaust, etc. As you can see, when the Crank is down, one Cylinder is "taking steam" and the other Cylinder on that same side is exhausting.

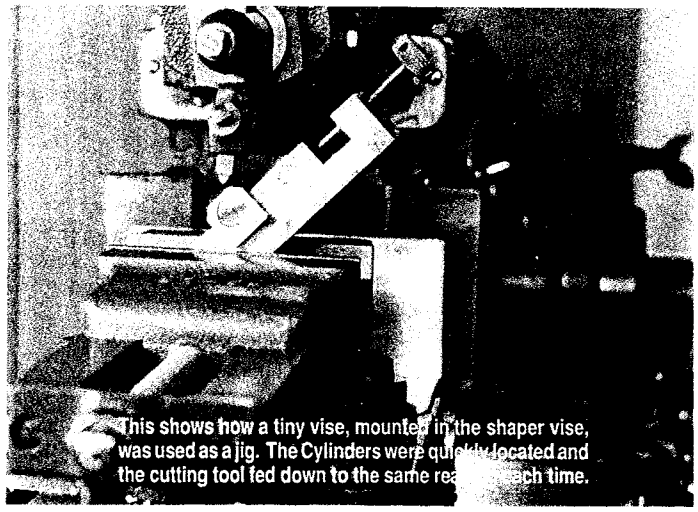
STEP 11. On one block only, which becomes the reverse control, drill from the inside face as in section **B—B** through the lower cross hole. Drill four Valve holes at 1/4" distance as shown. Two holes go way through the block and become the engine intake and exhaust. One or both can be tapped to take a tubing fitting. A third goes down and enters the upper cross hole. The fourth goes down to meet the hole that passes through the lower cross hole. Drill and tap 5-40 for the Valve Pivot Screw. The top of the block must be flat and smooth to seal against the Valve.

You can now polish all the parts with fine emery on a flat surface. Note the "flat" areas needed at the Cylinder locations. Make and press fit or Loctite the two Crankshaft Bearings into the Side Frames. Drill six oil holes. When all machining is done, blow out all passages and plug as shown. Short screws and gaskets are optional.

The **CYLINDER** and **PIVOT** are straight layout and machine work. Make some relief at the bottom of the bore for reamer run-out. Don't leave a ridge that the Piston will strike. Try to make the Pivot as square as possible to the rubbing face of the Cylinder. This rubbing face must be flat and smooth for a good seal.

Make the **PISTONS** and **RODS**, fitting each to a Cylinder. Stamp each Cylinder and Rod with the number of the Frame corner at which it is mounted.

Insert the Piston in its Cylinder and place the drill jig over the Pivot. Run a close-fitting 1/8" pin through the jig and Rod Bearing. Drill #44 for the Cylinder port.



This shows how a tiny vise, mounted in the shaper vise, was used as a jig. The Cylinders were quickly located and the cutting tool fed down to the same re[illegible]ch time.

You will probably search your spring collection and try to find something near the dimensions shown for this model.

The **REVERSE VALVE** is made from a short length of 7/8" stock chucked in the 3-jaw. Face the end smooth and make a center dimple with a tiny center drill. Paint the face with layout dye and scribe the 1/2" circle. Make the 1/8" center hole and part-off at 1/4" thickness. Reverse the piece in the chuck and take a skin cut off the face and counterbore for the Spring. Divide the 1/2" circle into four equal spaces and drill four 3/32" holes 1/16" deep. Clamp the piece to the milling machine table and make the 3/32" end mill cuts as shown. Add a 3/32" lever.

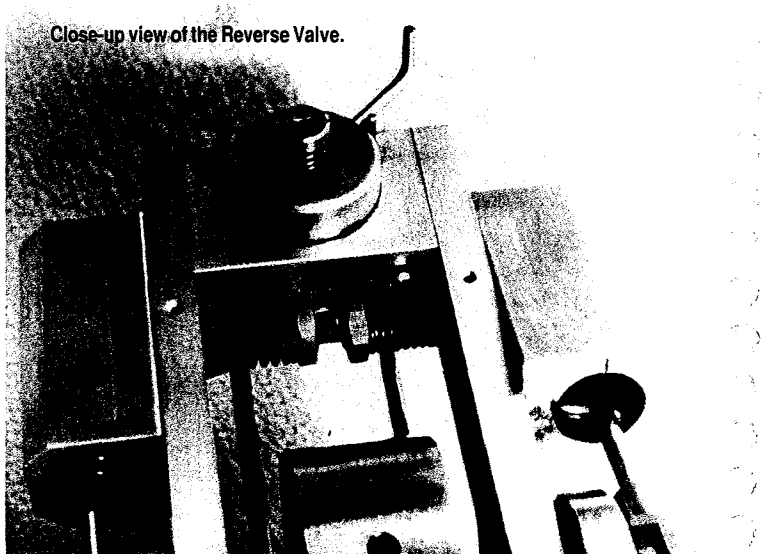
The **CRANK DISKS** are plain machining. They are held on the **CRANKSHAFT** by set screws bearing against flats that are 90° apart. This 90° makes the engine self-starting and requires the set screws to be on the same centerline as the Crank Pin.

The **FLYWHEEL** can be your own idea as to size and style. If you mount it off-center to make room for a pulley, make the flat on the Shaft accordingly, as well as a flat for the pulley set screw.

Make the **TUBING** to match the assembled Frame. If you use brass tubing and brass blocks they can be soldered. On the aluminum material for the model shown, the tubes were set with epoxy. Form the Tubing so it is down near the Base and will not interfere with the Flywheel. On the model shown they were run too high and the Flywheel had to be centered in the Frame.

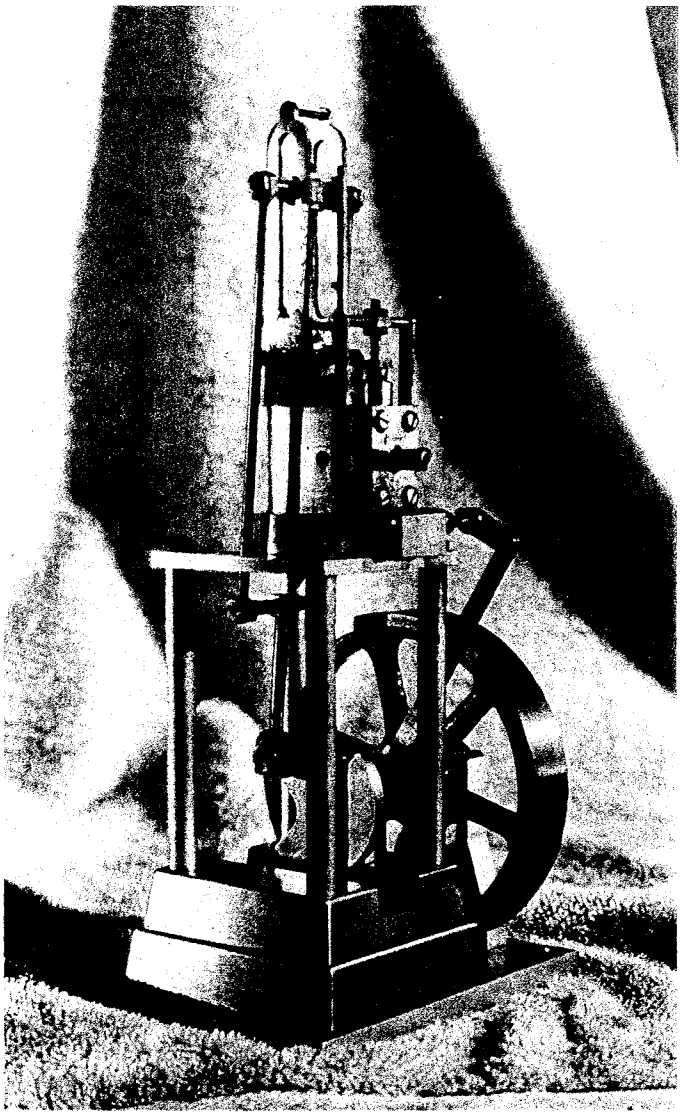
This is an interesting engine and it shows a lot of action. It runs easy on 5 to 10 pounds of air. There are several variations that can be made from this basic design such as two cylinders only on one side opposed, or two cylinders diagonally opposed, and a double-size H-Twin.

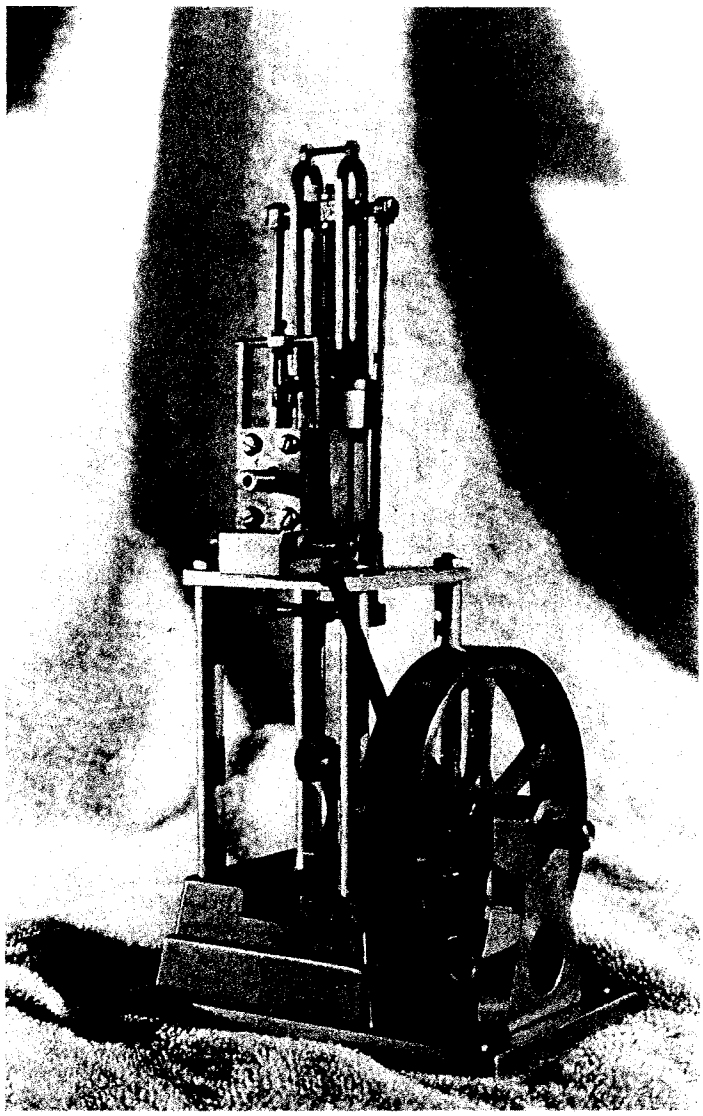
Close-up view of the Reverse Valve.



CHAPTER

29 Mine Engine





This model is patterned after an old mine engine. It has an interesting Connecting Rod and Crosshead Guide. A Rocker Shaft and linkage operate the Valve.

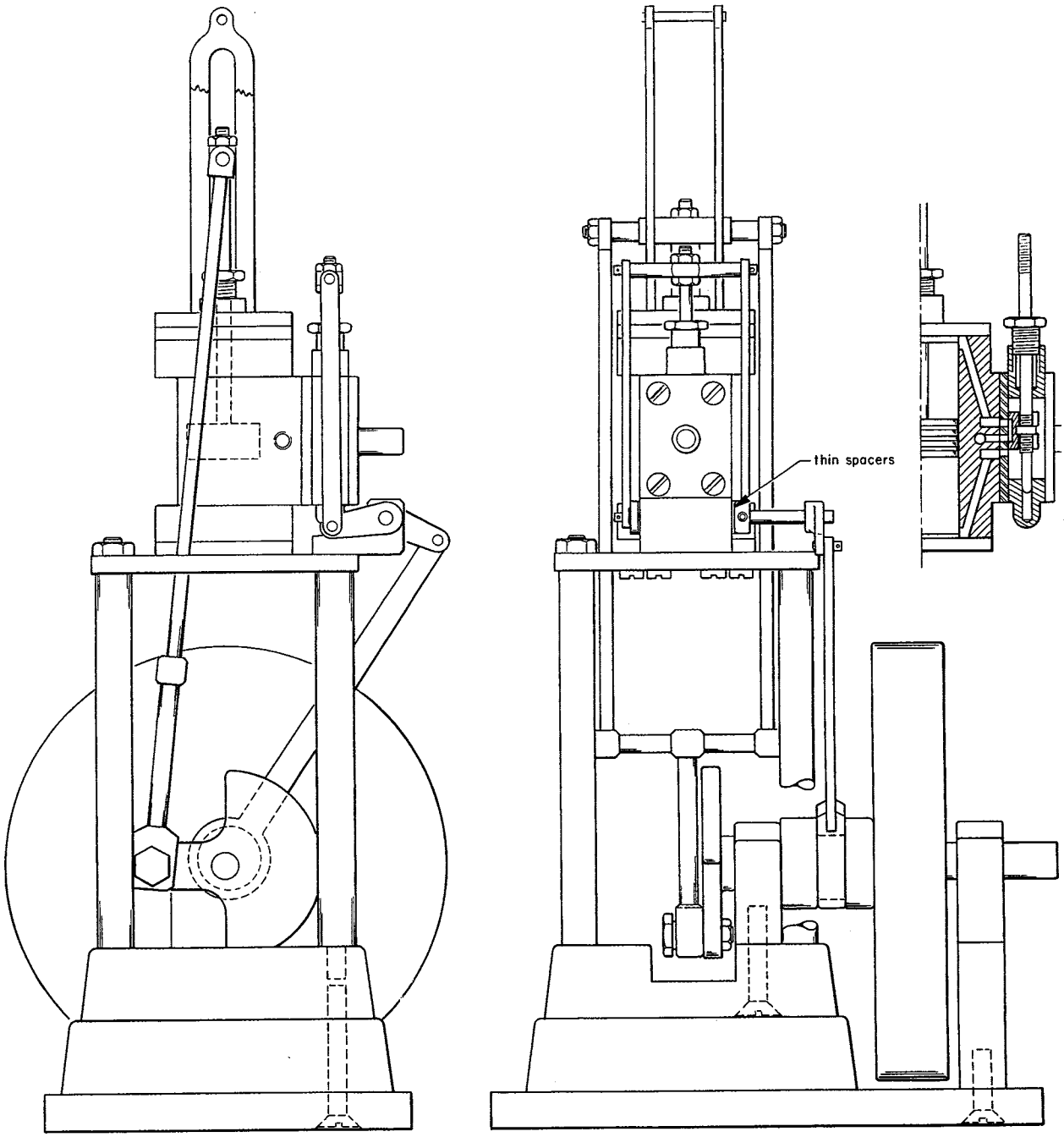
No castings are required for this engine. A lot of the parts can be made from odds and ends.

For the **BEARINGS**, start out with an accurate 5/16" x 3/4" x 27/32" and 5/16" x 1-1/4" x 1-27/32" blocks. Scribe the outlines on the face of each Bearing. Drill and tap for anchor holes. Lay out the center of the shaft hole on the Tall Bearing and mill both to the outline. Assemble the Bearings to the Floor, Base and Sub-Base, all tight and well aligned.

On the model shown, the assembly was mounted in the cross-slide milling attachment. The Shaft center was picked up with a wiggler and the Shaft holes line-drilled and reamed in easy steps. Now you have a choice of 1/4" reamed holes in the Bearings or enlarge to 3/8" for Bushings. "Oilite" bushings were pressed in on the model shown. A 1" long screw and thick nut were used as a jack between the Tall Bearing and the Base to take some of the drill thrust. This operation might be done in a drill press.

The **CROSSHEAD GUIDE** consists of carefully milled or filed parts, soldered together. Make an accurate block (preferably aluminum since solder won't stick to it) to clamp between the guides, squarely against the flange to hold the parts in place while soldering.

Chuck 5/8" diameter stock in the 4-jaw for the **ECCENTRIC**. Brighten the O.D. and bore 1/4". Offset .050" and turn the 7/16" diameter. Mount a square-ended bar in the tool post



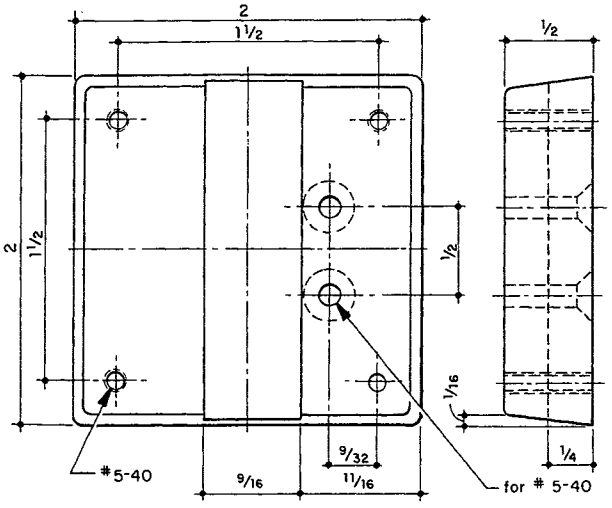
and bring it up against the stock. "Zero" the cross-slide collar. Turn the chuck so two jaws are horizontal. Ease off the vertical jaws slightly and back up the rear jaw about 1/16". Push the stock back, using the front jaw. Advance the cross-slide .050" and ease the stock back against the bar, using the rear jaw. Snug up all jaws. Now, when the high spot just kisses the bar and then the chuck is rotated 180 degrees, a .100" bar should just pass between the bar and the stock in the chuck. Spot the setscrew on the centerline through the offset. It helps when timing the Valve.

The **CONNECTING ROD** is a soldered assembly. Solder the Crank end squarely to the crossbar and solder the two eyes to the 3/32" rods. Run a piece of 3/32" stock through the eyes and the 3/32" rods into the crossbar. Clamp this assembly squarely to a plate while soldering.

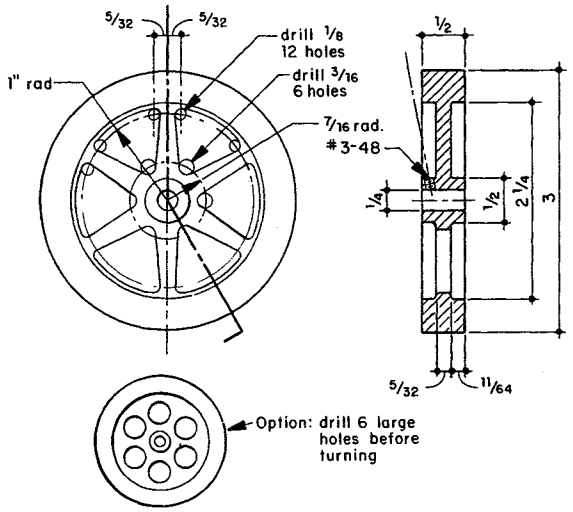
If you choose to bevel the **BASE** and **SUB-BASE**, make the beveling the last operation. All the operations are laid out and made from square surfaces.

The **STEAM CONNECTION** on the Steam Chest Cover is for 3/16" tubing. Make your Cover to suit.

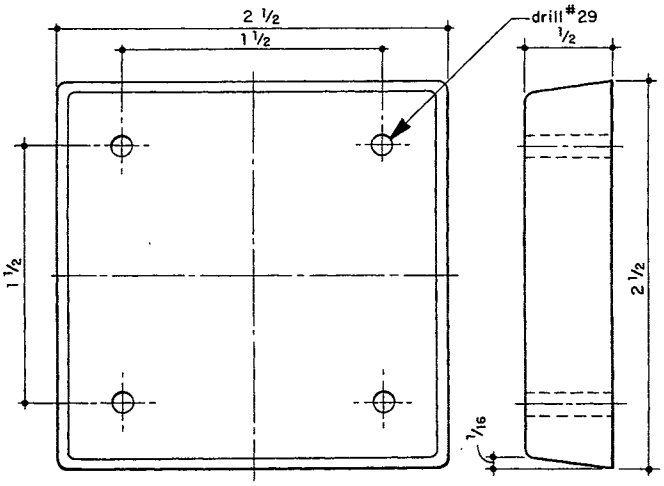
At **ASSEMBLY**, adjust the Piston Rod so the Piston is centered between the heads. Clamp the Steam Chest temporarily with the Cover removed. With the Piston at mid-stroke as shown in the Left Hand Assembly view, spot the centerline through the Eccentric in line with the Link as shown. This should put the Valve at the lowest end of its travel, giving full steam flow. You have three adjustments you can make to center the Valve properly. If you watch the



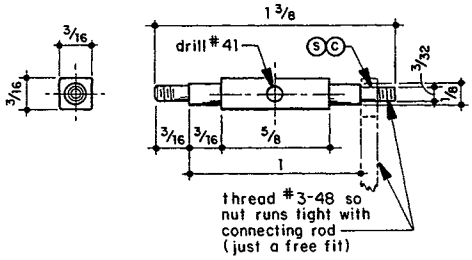
BASE



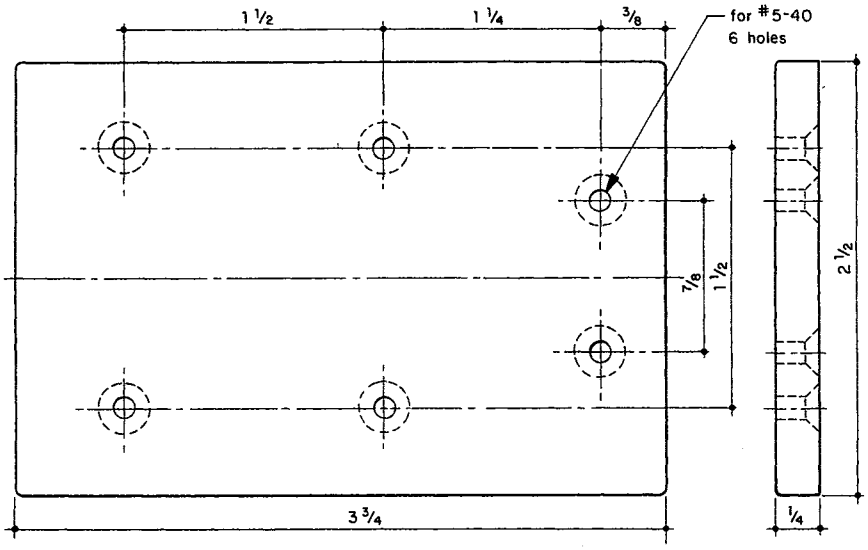
FLYWHEEL



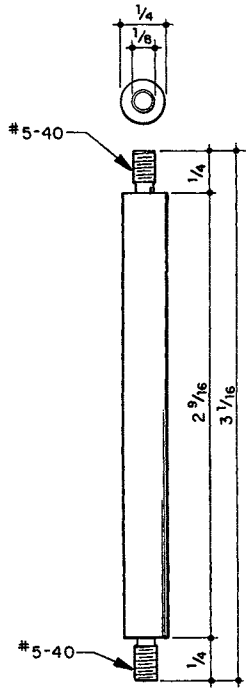
SUB-BASE



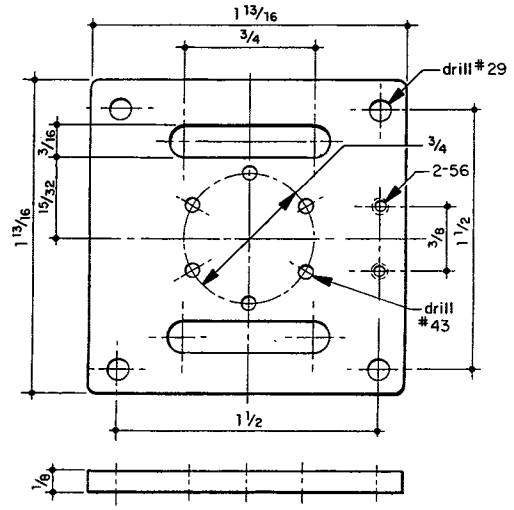
CROSS HEAD

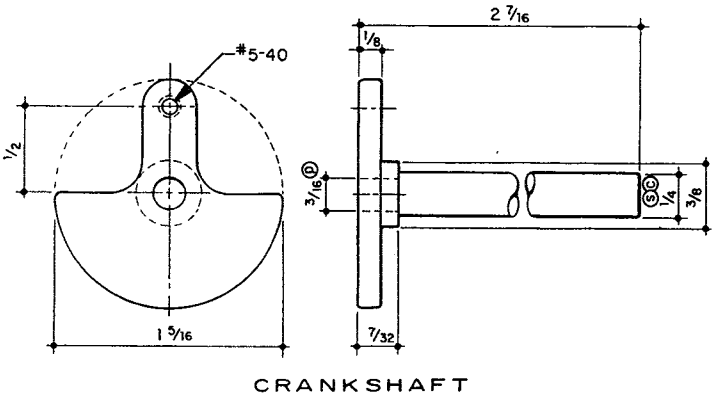


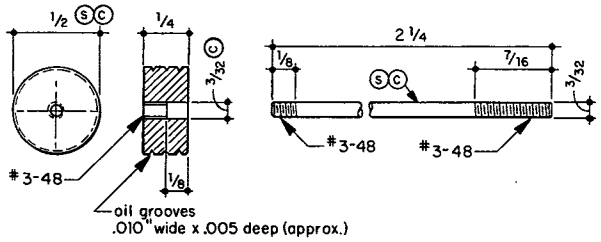
FLOOR

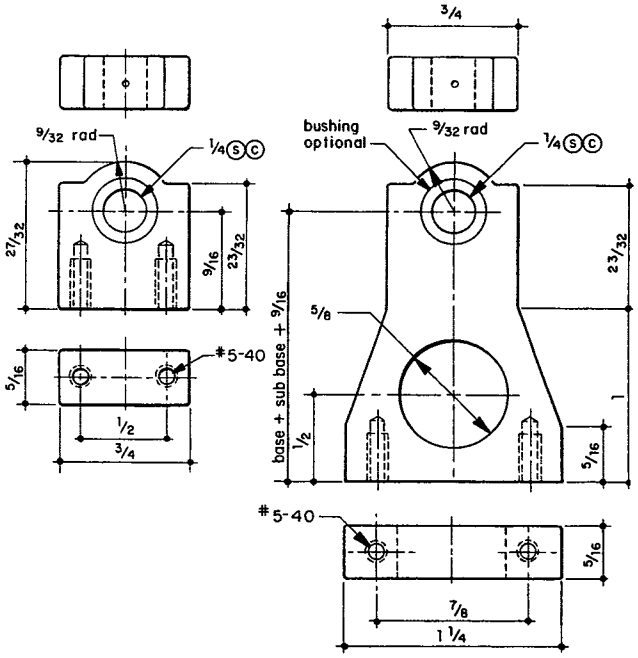


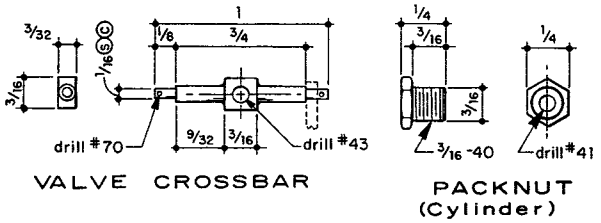
COLUMN

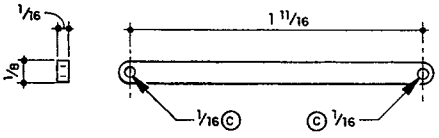

1 13/16
3/4
drill #29
3/4
2-56
drill #43
1 1/2
TABLE

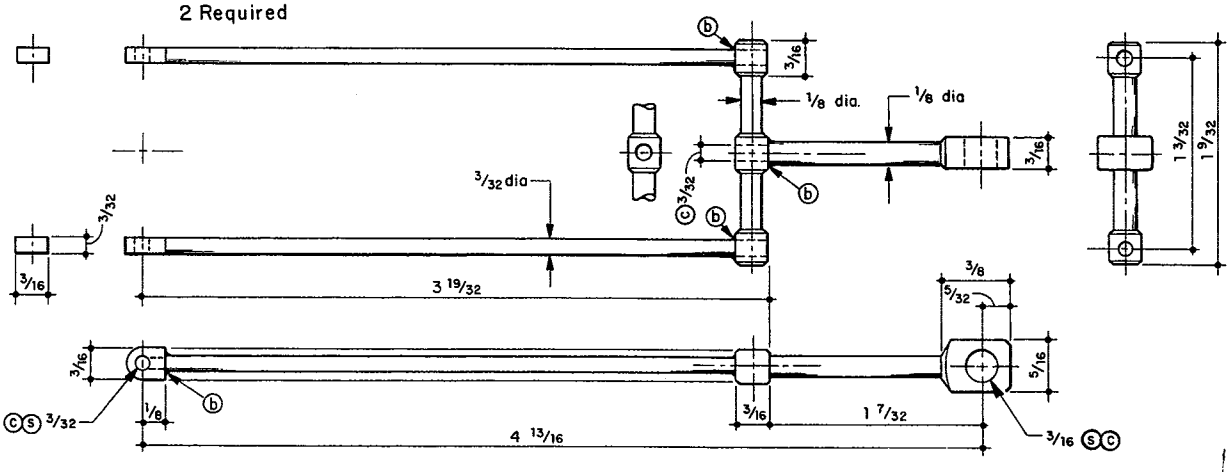

#5-40
1/2
1 5/16
2 7/16
1/8
3/16
1/4
3/8
7/32
CRANKSHAFT

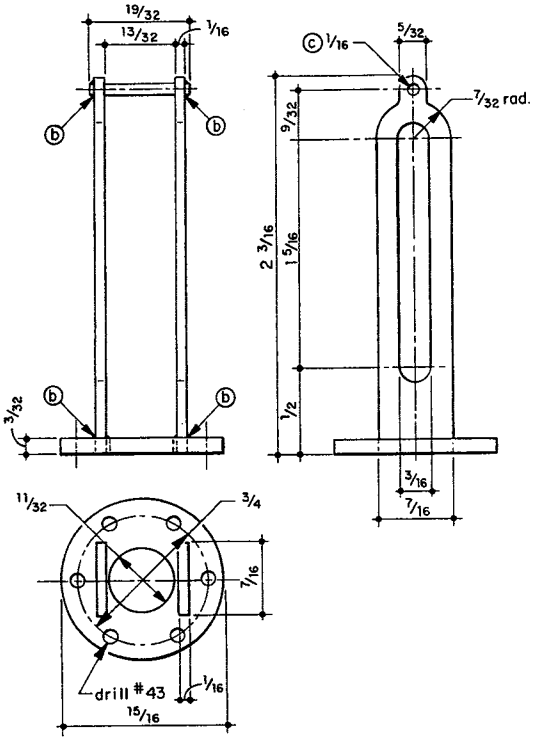

1/2
1/4
3/32
#3-48
1/8
oil grooves
.010" wide x .005 deep (approx.)
2 1/4
7/16
3/32
#3-48
#3-48
PISTON AND ROD


3/4
9/32 rad
1/4
bushing optional
9/32 rad
1/4
27/32
9/16
23/32
23/32
5/8
base + sub base + 9/16
1/2
1
5/16
5/16
#5-40
1/2
3/4
#5-40
5/16
7/8
1 1/4
BEARINGS

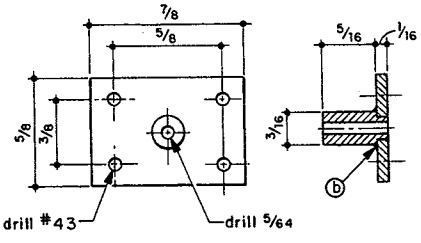

3/32
3/16
1/16
1
1/8
3/4
drill #70
9/32
3/16
drill #43
VALVE CROSSBAR
1/4
3/16
3/16 -40
1/4
drill #41
PACKNUT
(Cylinder)


1/16
1/8
1 11/16
1/16
1/16
LINK
2 Required

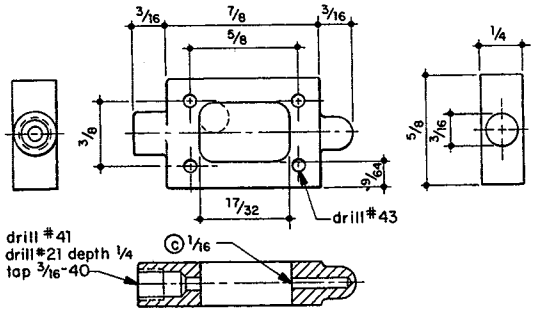

3/16
1/8 dia.
1/8 dia
3/16
3/32 dia
3/32
3/32
3/16
3 19/32
3/8
5/32
5/16
3/16
1/8
3/32
3/16
1 7/32
4 13/16
3/16
1 3/32
1 9/32
CONNECTING ROD



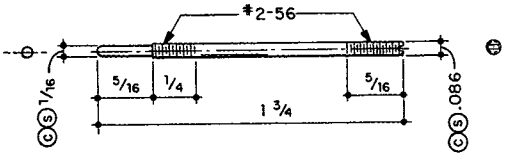
CROSSHEAD GUIDE



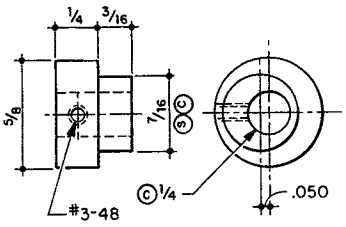
COVER



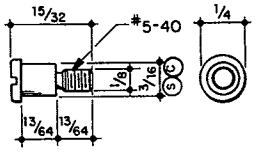
STEAM CHEST



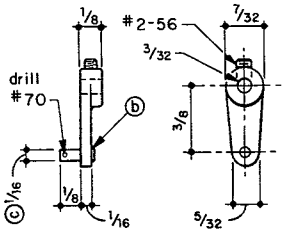
VALVE ROD



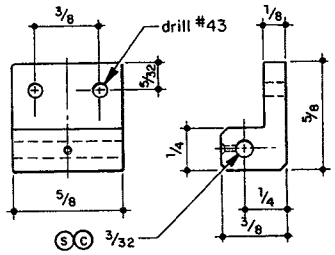
ECCENTRIC



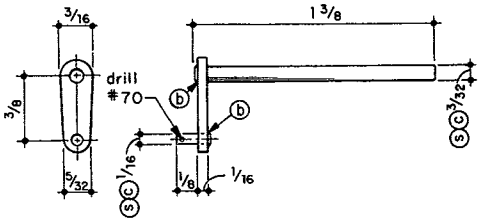
CRANK SCREW



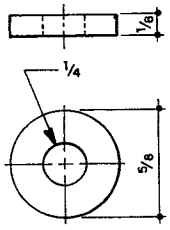
ROCKER ARM
2 Required



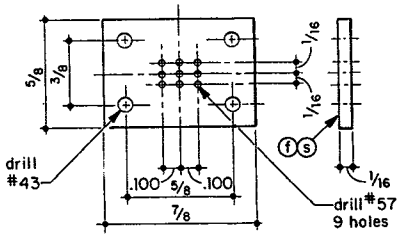
ROCKER BEARING



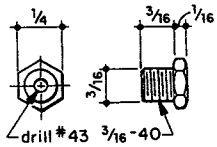
ROCKSHAFT



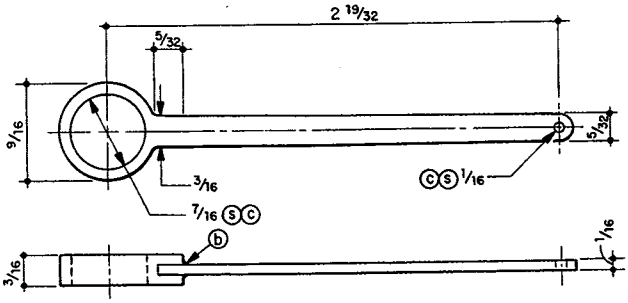
SPACER



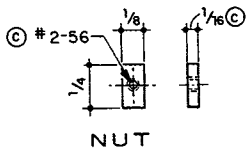
VALVE PLATE



PACKNUT
(Steam Chest)

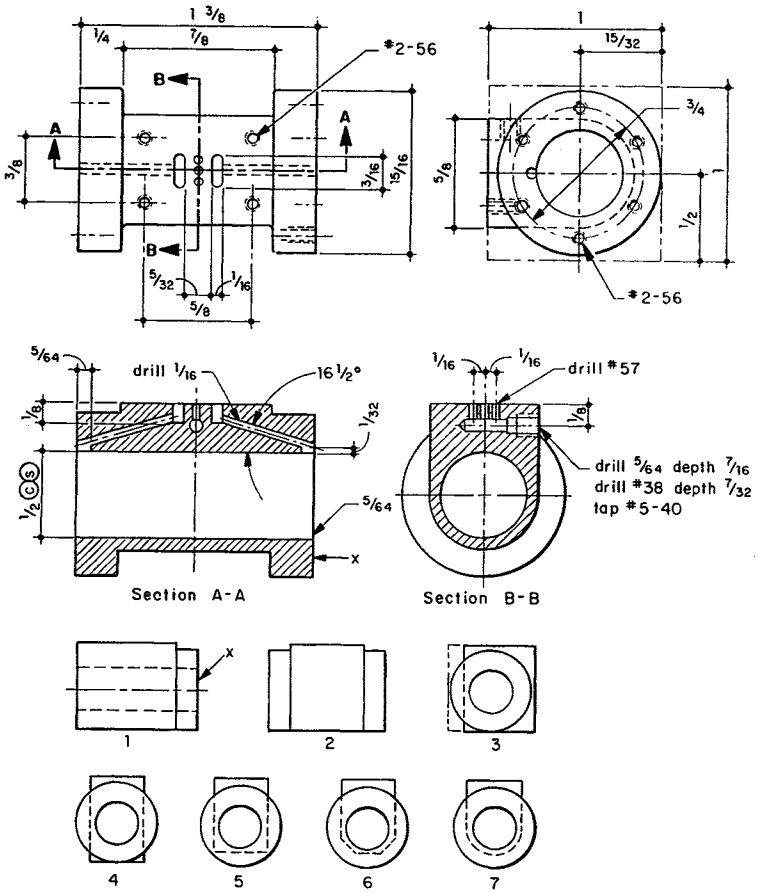


ECCENTRIC STRAP

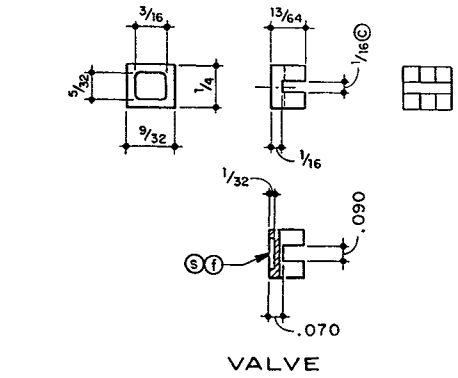


NUT

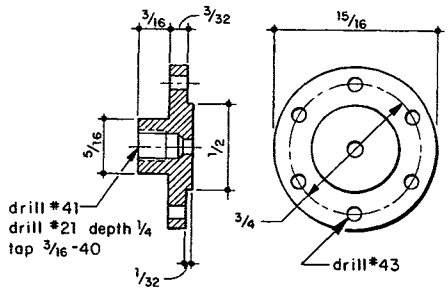
c close fit	b braze or solder
s smooth	p press fit or loctite
f flat	



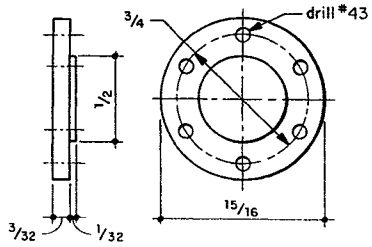
CYLINDER



VALVE



UPPER HEAD



LOWER HEAD

action of the Valve in relation to the Piston, you will soon get the drift of what is needed. The Valve should equally expose the Valve holes at each end of its stroke. When the Piston is at one extreme of its travel, no steam should enter the Cylinder.

The **PACKING** is 1/16" strands, unravelled from braided asbestos graphite packing. Do not snug up the packing nuts too tight. Turn them in lightly with the fingers. It is not strictly necessary to use this type packing. Some short pieces of fine copper wire in the #70 holes will keep the Links in their place.

It is an interesting engine to watch and the one shown ran fine on as little as 5 psi air.

Now's the time to start your own Vertical Mine Engine and get in on the enjoyment!

Why not head for your shop right now and get started?

Be sure you always practice

SAFETY FIRST

USE YOUR GOGGLES — WEAR PROPER CLOTHING
DOUBLE-CHECK YOUR SET-UP — USE PROPER SPEED
USE PROPER COUNTERBALANCE
DO NOT USE DULL TOOLS — USE PROPER LIGHT
KEEP FLOOR CLEAN

CHAPTER

30 Opposed Piston Steam Engine

In the December, 1977, issue of *Popular Science*, a radical new diesel engine design caught my eye. It was an opposed piston, swing-beam engine being developed by the English firm of Armstrong Whitworth & Company, Ltd., of Slough, near London. The model presented here is an adaptation of this principle to a steam-powered engine which is simple to build and provides an answer to the Amateur Machinist asking for designs of small stationary engines which do not require castings.

I am unable to go into the fine points of determining stress and horsepower but feel that, for a simple engine, it does have several interesting features. It appears to be a balanced engine, but the weight of the Arms and Pistons and the speed do cause some vibration. The short throw at the Cranks requires a high speed. The Pistons travel twice as far as the Connecting Rods do at the Cranks.

Also, there is room for some experimenting. The engine was first made with the exhaust only through the Shaft, but it did not seem to run quite right. Two exhaust holes were then added to make a una-flow type exhaust. These, plus the other exhaust passage, lets it run like mad! If either of the two exhaust systems is closed off, the engine slows down, so both are needed.

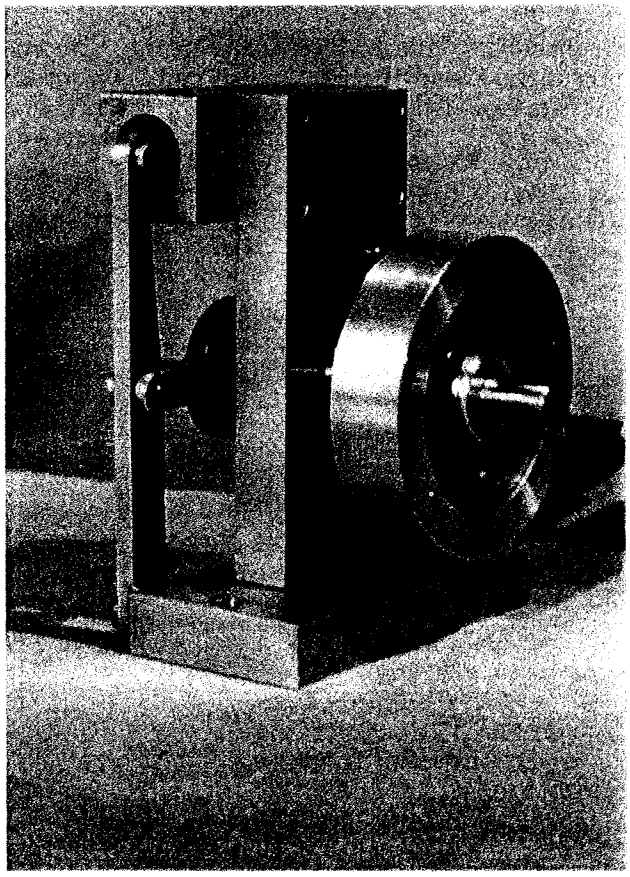
Another question involves the direction of rotation. There is a similarity in porting and it appears that the engine should rotate either way, but it will run only one way. The problem must lie in setting the Eccentrics in the right relationship to the flat Valve surface on the Shaft. It is hard to do this right down to a fine point.

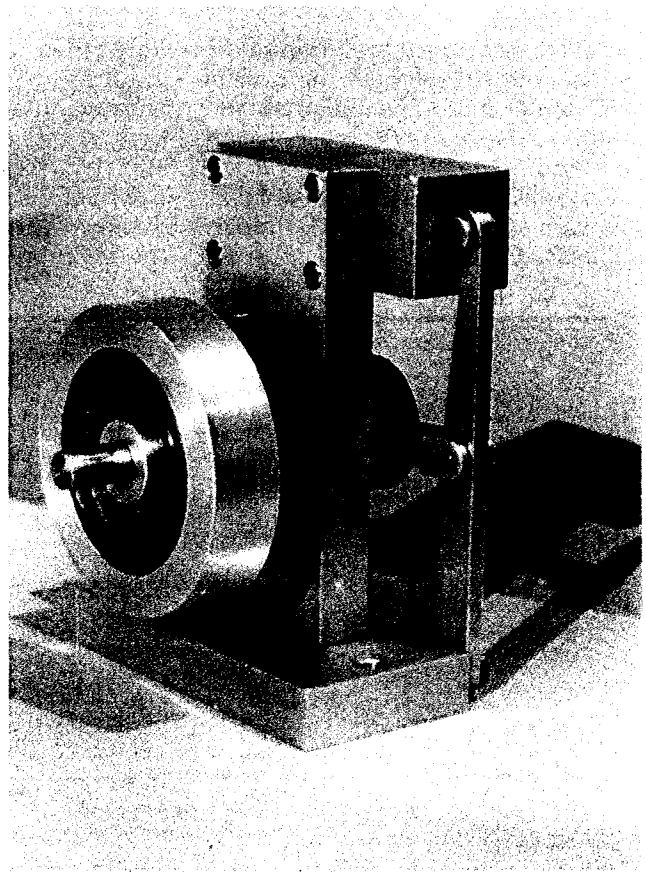
Something else to experiment with is the width and location of the flats on the Shaft, to change the timing and cutoff.

The material for this engine can be most any of the common metals. Since this was to be a display and conversation piece and not run very much, it was made of a fairly hard aluminum that was on hand. The Pistons, Bearings, Eccentrics and screws are brass, the flat washers at the Eccentrics are steel and the Piston pin is drill rod.

The **FOOT**, **COLUMN** and **CYLINDER** are simple, straight pieces requiring squareness and accurate layout. Insert a short, 3/32" pin in the steam passages in Column and Cylinder as a guide, then square up and clamp together for spotting the four 2-56 tapped holes.

Make the **ROCKER ARMS**, shoulder **SCREWS**, **SHAFT** and **BEARING**. Assemble the Bearing into the Column with the 3/16" hole on the vertical centerline, then drill through 3/32" for the steam passage. Solder a short length of 3/16" tubing in the





Bearing for a steam hose connection, as shown. I often run the engine on compressed air at 15 psi, so plastic tubing clings tight enough. For a more durable and steamtight joint, the tube can be longer and threaded.

When making the **PISTONS**, spot four oil grooves as shown, about .010" wide and .005" deep. After Piston, Connnecting Rod and Pin are assembled, very lightly prick-punch the pin hole rim over the ends of the Pin to retain it. One very light punch per end is enough.

The **ECCENTRICS** can be made in a four-jaw chuck. First, turn to an accurate 9/16" diameter, about 1/2" wide, then loosen the jaws slightly and, using the cross-slide for measuring, move the workpiece 1/8" off center. Ream 3/16" for the Shaft. Return the workpiece to center (or near center) and make parting cuts for two .130" thick Eccentrics. Mount the two Eccentrics on a close-fitting 3/16" Pin. Rest this Pin on two more 3/16" Pins on a flat surface, as shown. With the two Eccentrics also touching the surface, clamp together with a small machinists clamp and drill the 1/16" pin hole. Mark with a stamp the two faces that touch, so the Eccentrics can be reassembled in the same relationship in which they were drilled.

Make three **DISKS**. Use one of the Eccentrics to spot the pinhole in the center Disk only. This 1/16" pin, about 9/32" long, is retained by the two outer Disks as shown. The O.D. of the Disks can be finished by chucking the Shaft to run true, then mounting the three Disks and two Eccentrics in place and hold them with a 10-32 nut.

There are several ways to make the four **CONNECTING RODS**. These range from plain hacksaw-and-file work to gang-milling the way Kozo Hiraoka does it. For accuracy and finish, the 9/16" bore is a lathe job, using a center test indicator and fine cuts.

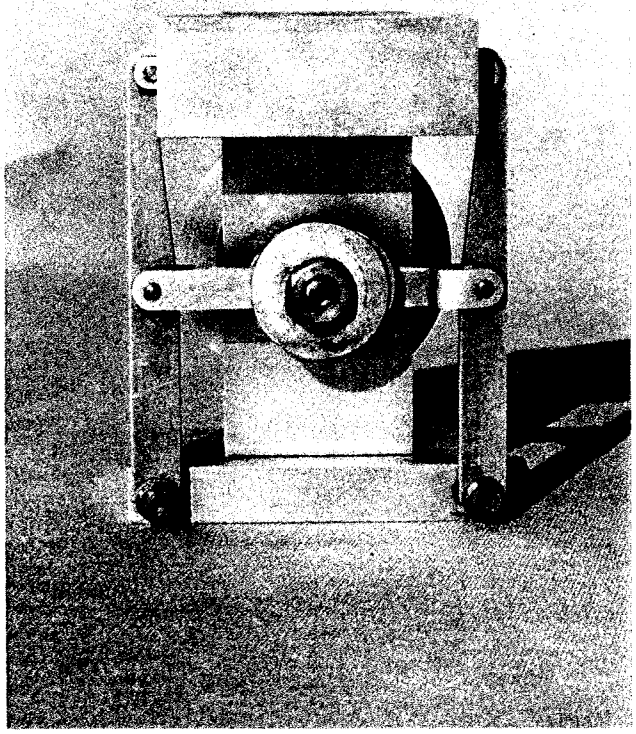
The four 3/32" pins in the Rocker Arms may be made in several ways. Here again, it isn't very good engineering, but a small prick punch near the rim of the pin will keep them in place. Tiny nuts and bolts can be made or make the pins long enough to take tiny cotter pins.

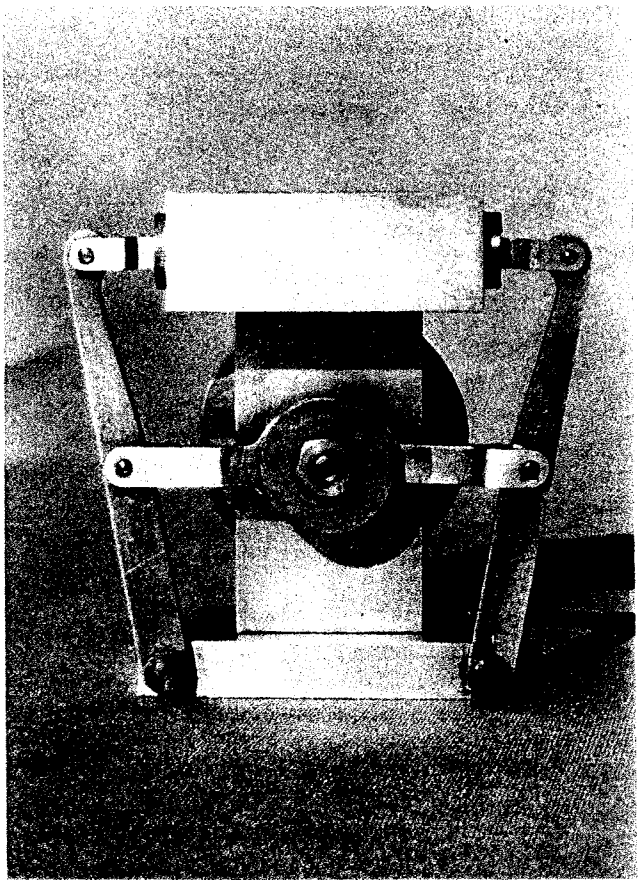
The **FLYWHEEL** should be about 2" in diameter and 1/2" wide, with a setscrew, to fit the 1/4" Shaft.

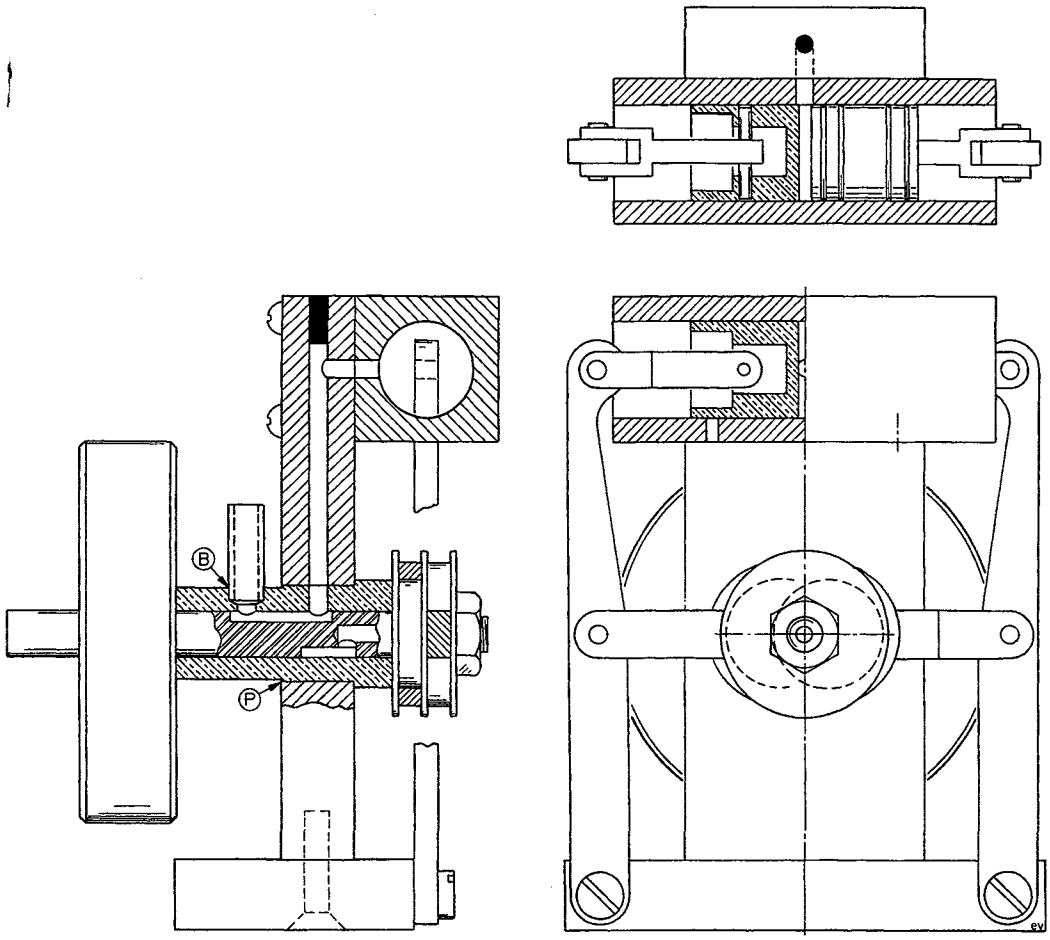
At final assembly, be certain that the relationship of the Eccentrics to the Valve surfaces on the Shaft are correct. They are shown in the Eccentric Mounting Detail drawing.

This simple and unusual engine should provide you with several hours worth of enjoyment in building and operation.

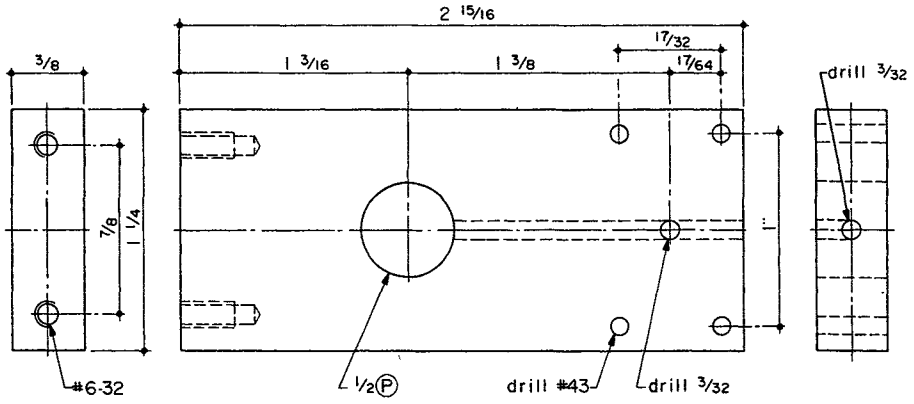
It will be a most interesting addition to your collection of fine steam engines.



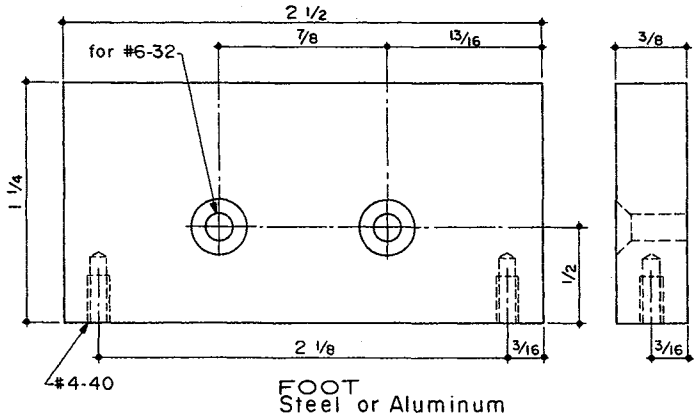




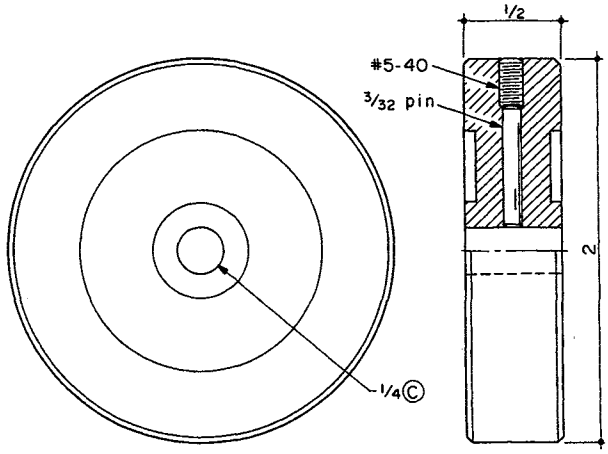
OPPOSED-PISTON ENGINE



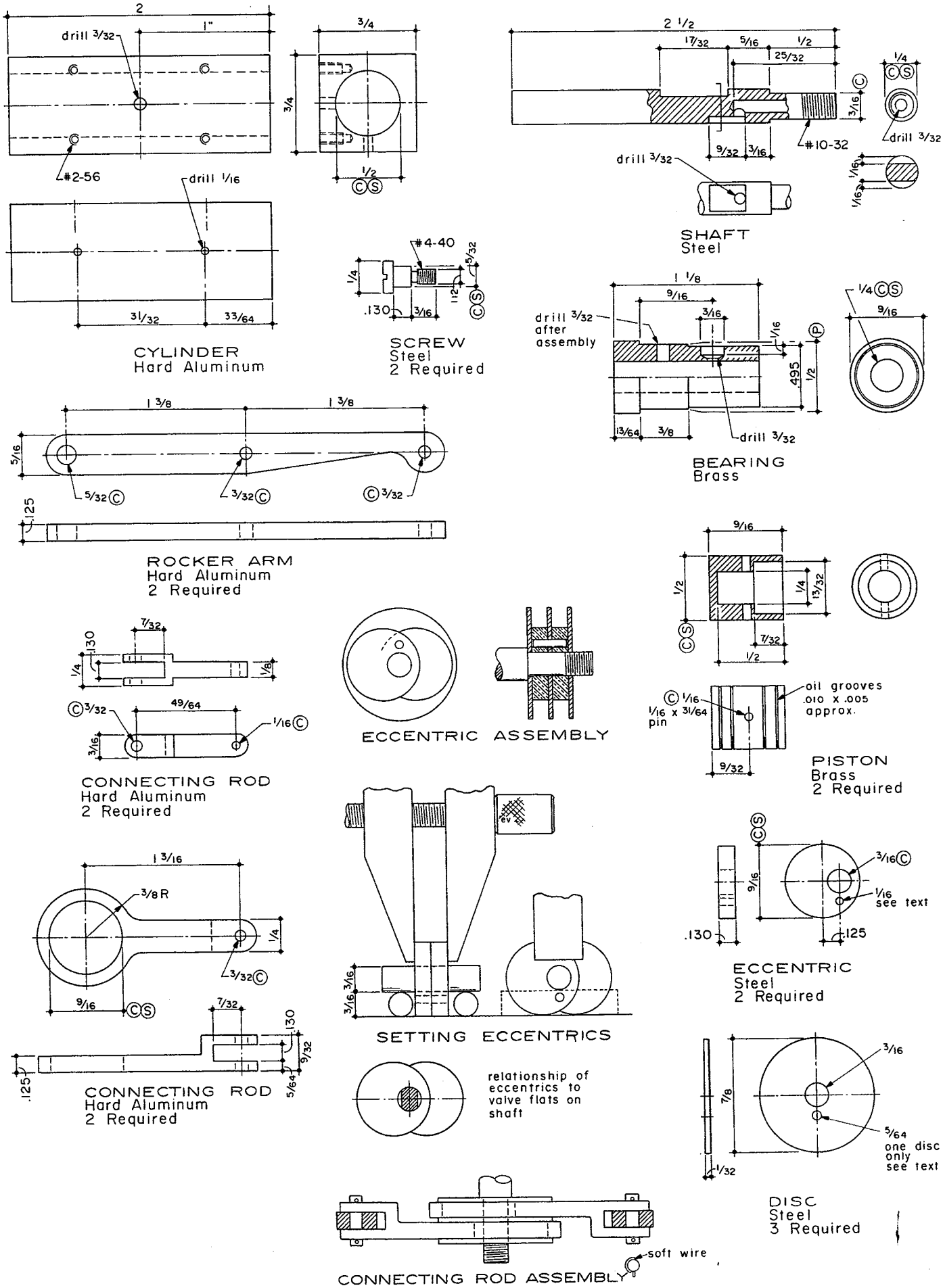
COLUMN
Steel or Aluminum



FOOT
Steel or Aluminum



FLYWHEEL
Any Metal

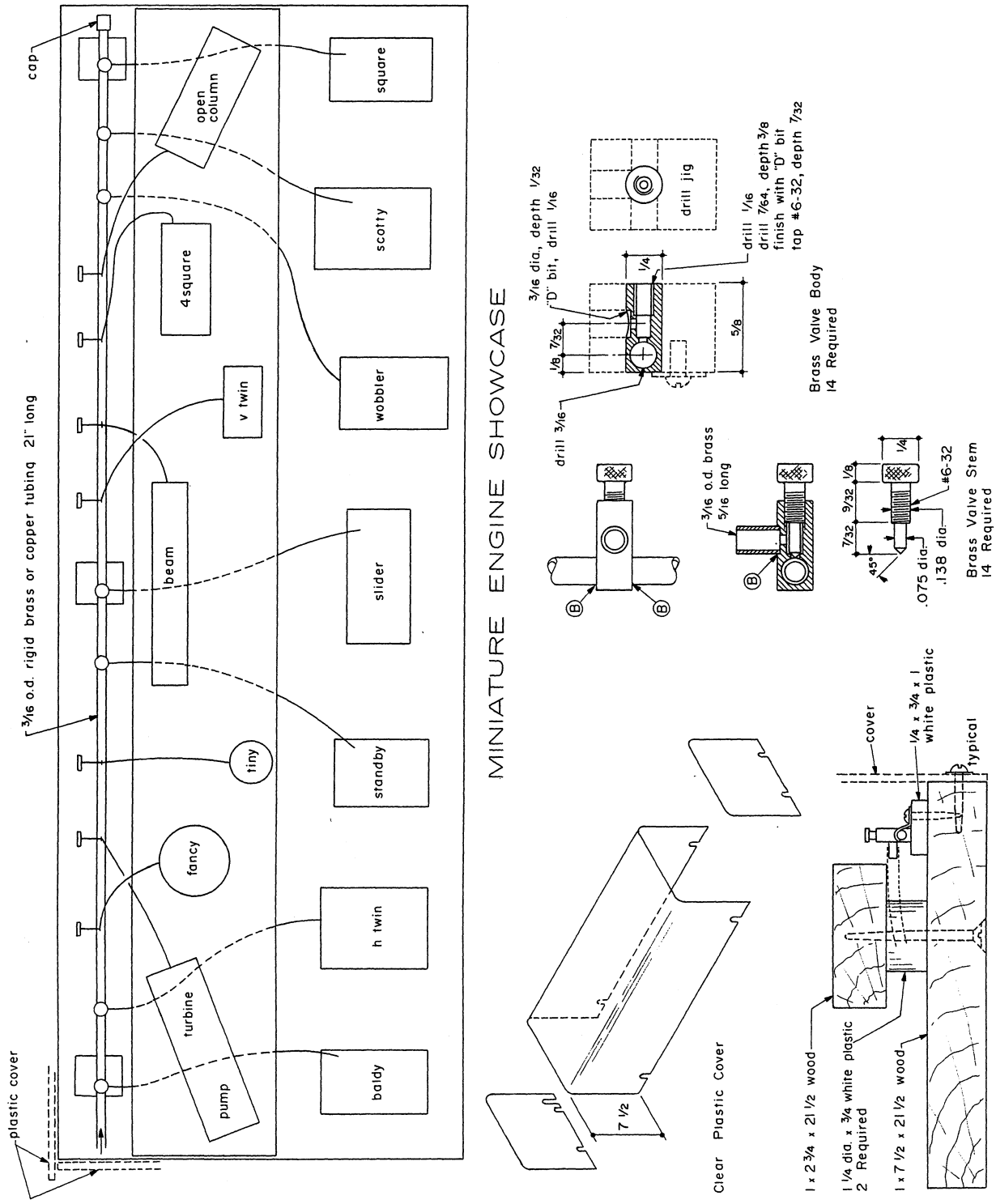

drill 3/32
#2-56
drill 1/16
3 1/32
33/64
CYLINDER
Hard Aluminum
#4-40
.130
SCREW
Steel
2 Required
drill 3/32
#10-32
SHAFT
Steel
drill 3/32
after
assembly
drill 3/32
BEARING
Brass
5/32 C
3/32 C
3/32 C
.125
ROCKER ARM
Hard Aluminum
2 Required
.130
3/32 C
1/16 C
CONNECTING ROD
Hard Aluminum
2 Required
ECCENTRIC ASSEMBLY
oil grooves
.010 x .005
approx.
1/16 C
1/16 x 31/64
pin
PISTON
Brass
2 Required
3/8 R
9/16 CS
CONNECTING ROD
Hard Aluminum
2 Required
SETTING ECCENTRICS
relationship of
eccentrics to
valve flats on
shaft
3/16 C
1/16
see text
.130
.125
ECCENTRIC
Steel
2 Required
5/64
one disc
only
see text
1/32
DISC
Steel
3 Required
soft wire
CONNECTING ROD ASSEMBLY

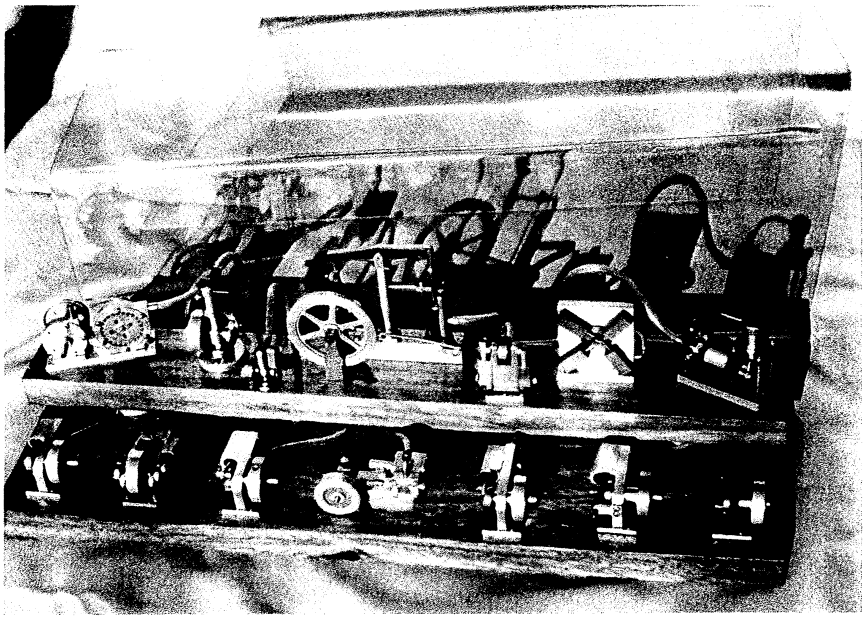
CHAPTER

31

Display and operate them all in

The Engine Showcase





Once you have built several of these engines you will want to display and operate them. An Engine Showcase is just what you need. You have a lot of leeway in mounting these units on a base. Use your own ideas and materials. The base shown is a simple piece of wood with a second narrower piece elevated on some round blocks. 3/16" tubing runs the full length at the rear and fourteen Valves are soldered to it. Each Valve has a 3/16" projection for 3/16" aquarium tubing going to each engine. If you can find them in the pet department, aquarium Valves will serve. Gangs of 5 Valves on one tube have been available in the past. Three of these will give you 15 outlets. These were brass and imported so the they may sometimes be scarce.

The **VALVES** shown call for a production setup and a turret tool post is handy. A tailstock turret adds still more convenience. However, these are not common on 3" lathes so it will take a bit of time. After soldering each Valve in the desired position, drill through into the long tube. All of the soldering on each Valve must be done in one pass and a heat sink may be needed to avoid softening the last Valve attached. The Valves are attached either vertically or horizontally, depending on the direction the plastic tubing has to go.

When making the Valve bodies, use the jig to drill the 3/16" through hole. Run about a 1" length of 3/16" rod through this hole and do the shallow 3/16" spot. It is very handy, if the short 3/16" tube has to be forced into this shallow cut so it will cling while soldering. Chuck into the 3-jaw and complete the seat and threading.

The Valve Stems for these Valves are also a simple production setup.

The matter of cases for displaying models is a subject in itself.

The **PLASTIC COVER** was made without wide knowledge or experience in this material. If you have worked with Plexiglas, you will be able to make a fine looking case. The material used was non-shattering storm door stock bought at the local hardware store.

One problem was to make the width of the case equal the base width. On the case shown, the base width was made to fit the plastic already bent, which may be getting the cart before the horse. The misfit can be as much as 1/8" or 1/4" and not ruin the appearance of the case. Just taper the end pieces to match.

The 1/8" (approximately) stock was cut to length, about 3/4" longer than the base (note it projects beyond the end pieces). The other dimension is about 1/2" to 5/8" more than the sum of the front, top and back. The fine tooth circle saw was used to cut this material using slow feed.

The protective paper was removed and scratches avoided from then on. The stock was squarely clamped to a piece of 3/4" plywood on a table with an amount equal to the case height plus 1/4" overhung. The medium to small flame of a propane torch was played on the plastic in very uniform passes right at the edge of the board which was visible through the plastic. The flame was run several inches past the edge of the plastic so as not to overheat when reversing at the end of the pass. Overheating causes roughness and bubbles. The torch was kept in motion at all times until it uniformly heated a narrow strip right on, or a bit away, from the edge of the board. It took a little time but, when enough heat entered the plastic, its own weight showed it would bend. Squareness was checked before it set.

The bend had a fair-size radius. Its size was noted so as to allow for this on the second bend. The best method is to make a trial run on a 2" wide trimming to see how it acts and how much to allow for the bend. Next it was mounted as before on the plywood. This time the bend that was completed was pointed down and the board mounted so this completed bend would clear under the table, or whatever, when making the second bend. It was heated the same way and the overhang supported and held squarely until set.

Uniformity in applying the heat was important. If one end got more heat than the other, it would have a different radius and affect the width of the case.

When set, the front and back were cut to a uniform height. Notches were made for bright wood screws and flat washers. With this piece mounted on the base, cardboard patterns were made for each end, the end pieces cut from plastic and notched for screws. A notch was added for the air line. These pieces were not cemented together. The photos show holes rather than notches, but I believe you would be most satisfied with notches.

A fine file and fine emery dressed the edges. When operating these engines, the case is easily removed. A small identifying mark was added so the cover could easily be returned to match the ends to which is was fitted.

CHAPTER

32 Tall Vertical Open Column

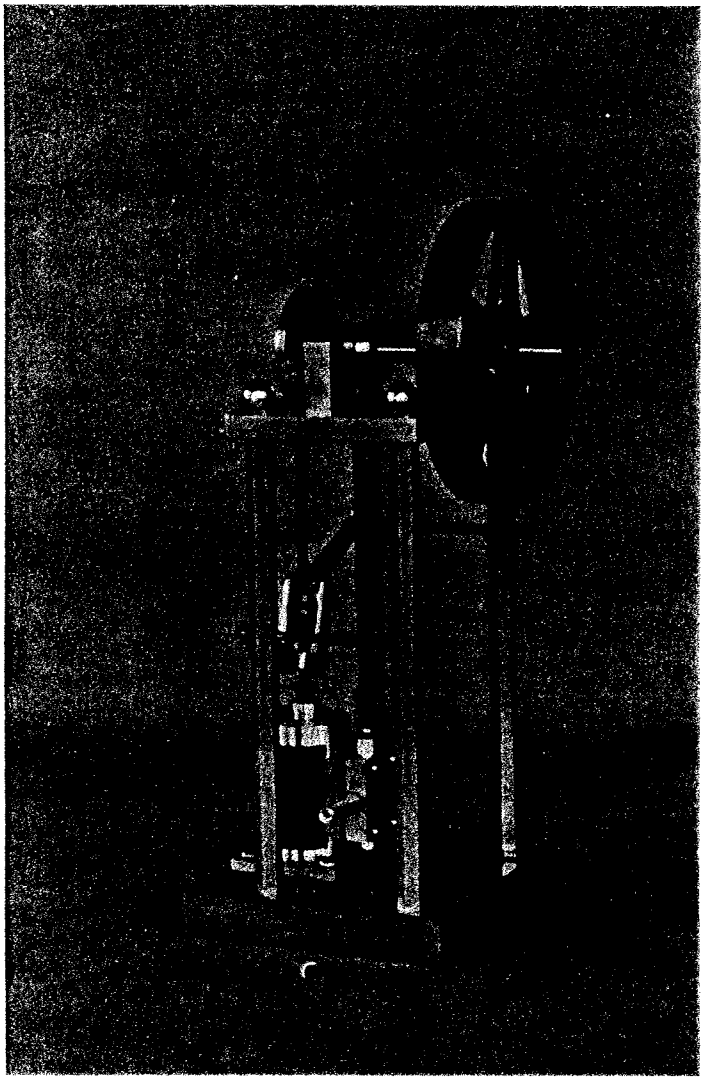
This engine is patterned after a popular engine which is sold in kit form; however, it has a 1/2" bore and 1" stroke instead of a 1" bore and 2" stroke. It is quite simple all around and should be no trouble for experienced builders. Only a few items will be mentioned.

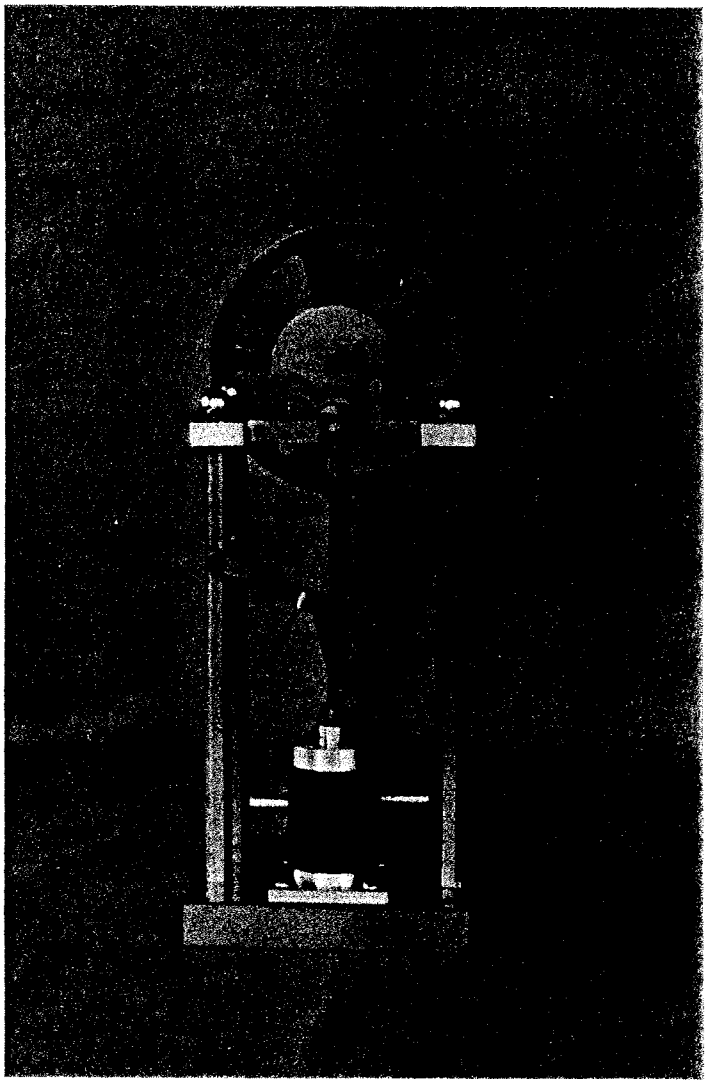
The **BASE** and **TABLE** use common machine shop practice. The steel Base has weight so the engine runs well without anchoring. Screws are used, up from the bottom, for the Columns as an aid in assembly, rather than threading them into the Base. The Rods that support the Arms square up easily so the cap nuts and base screws can be tightened. A little study will show how the Links and Arms produce straight-line motion. Hexagon stock was used on the engine shown. The flat faces of the hex make it easier to lay out and make the holes for the Rods.

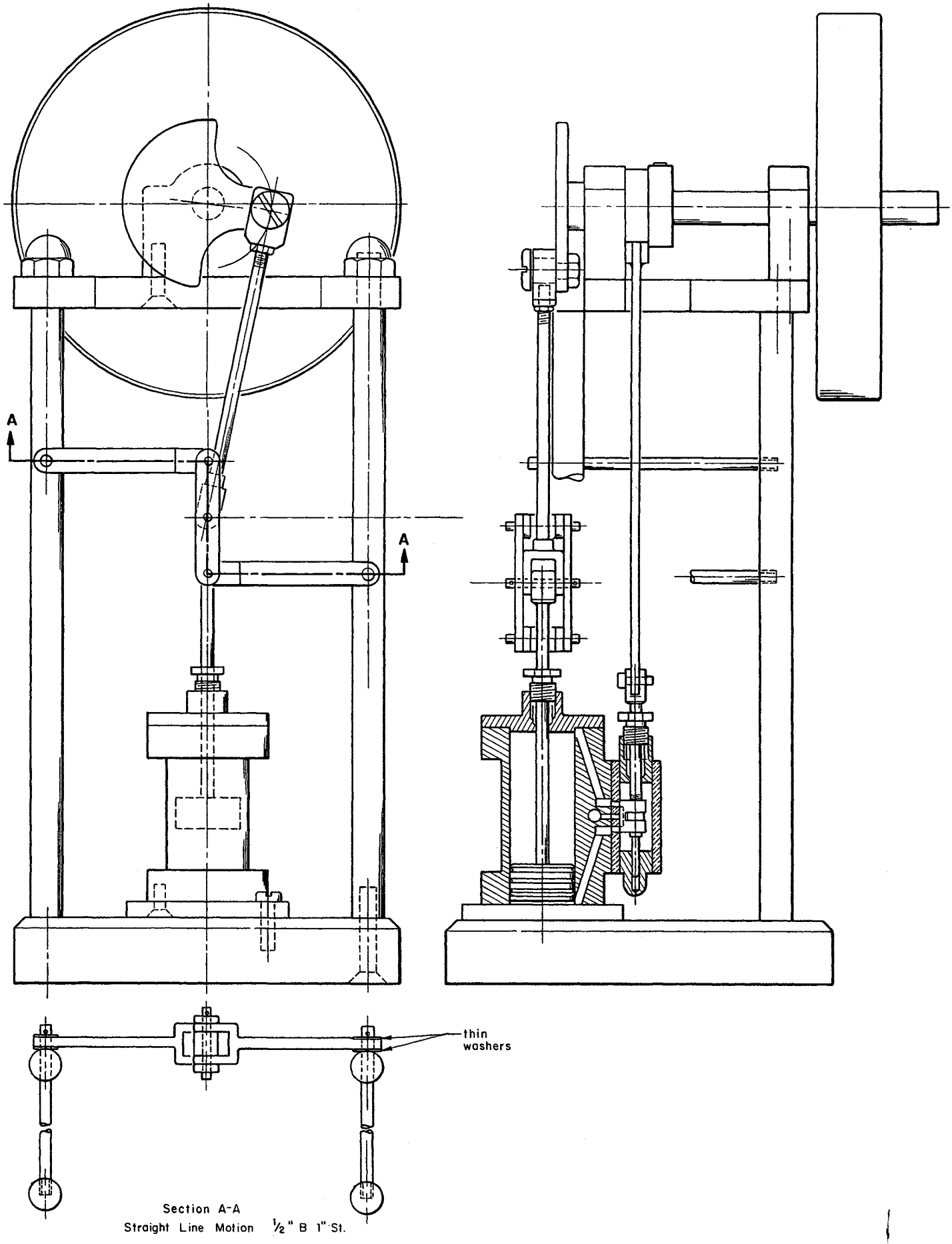
The **ARMS** are made out of the solid. The 3/32" and 1/16" holes are drilled while the stock is square and then the 3/32" Arm and 3/16" Fork are milled or shaped. Solder the 1/16" x 3/16" Pins as shown.

The **BEARING BLOCKS** are tapped #5-40 and the Shaft center is laid out and center punched on one piece. Both Bearings are squarely mounted on the table and then this assembly is squarely mounted in the cross-slide milling attachment. The Shaft center is picked up with a wiggler and drilled in easy stages, and then finally reamed to size. Bushings are optional here. These Bearings should be marked so they can be remounted in the position as they were reamed.

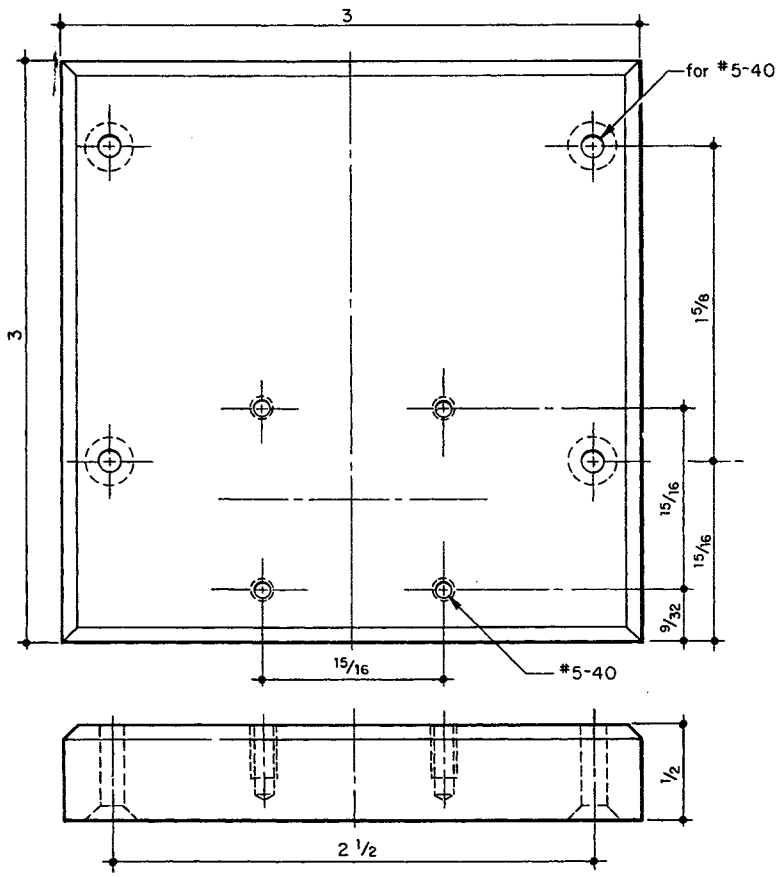
For the **CYLINDER**, make an accurate 1" x 1" x 1-3/8" (or 15/16" x 1" x 1-3/8") block. Lay out all the centers and lines on all faces and drill and tap all holes while the block is square. The Heads can be used as jigs after the center is bored for the Piston,



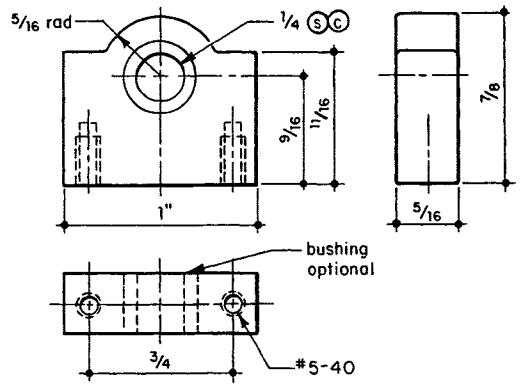




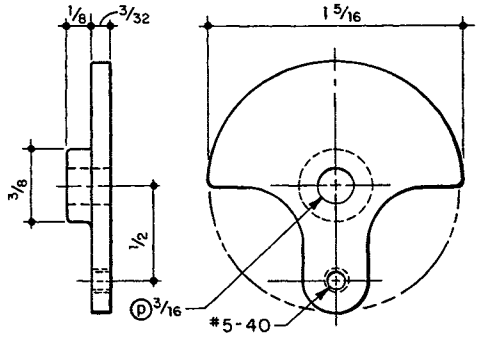
TALL VERTICAL OPEN COLUMN



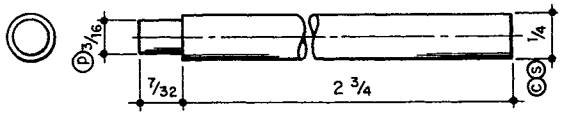
BASE
Steel



BEARING
Aluminum, 2 required



CRANK
Steel



SHAFT
Steel

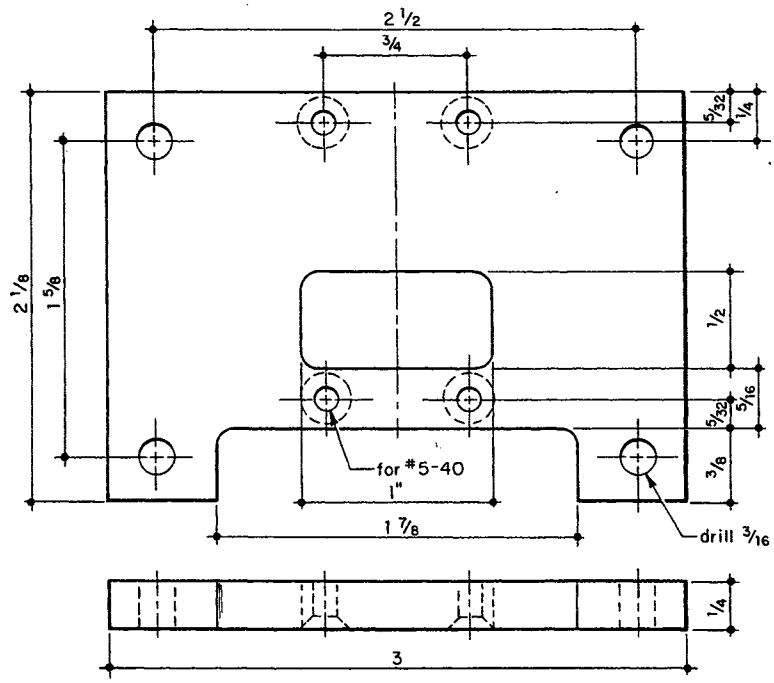
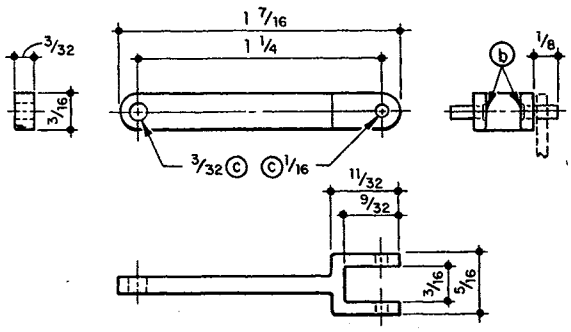
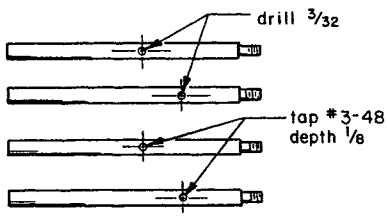


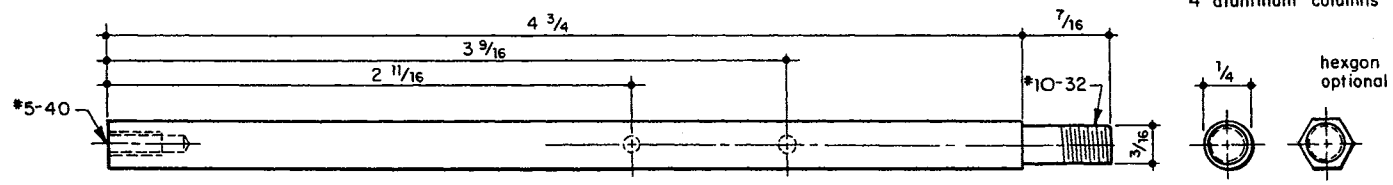
TABLE
Aluminum



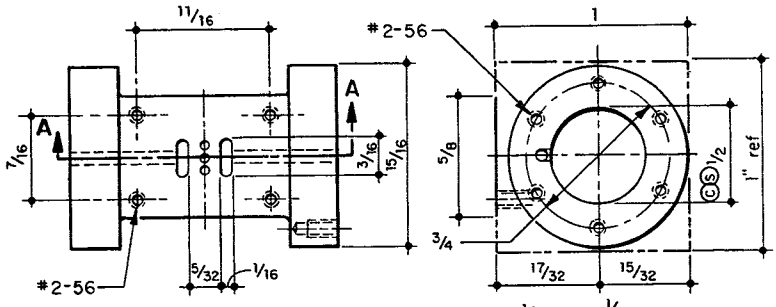
ARM, BRS.
2 required

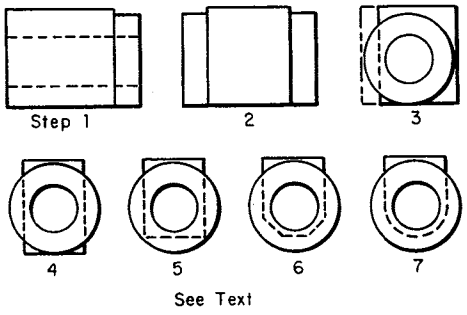


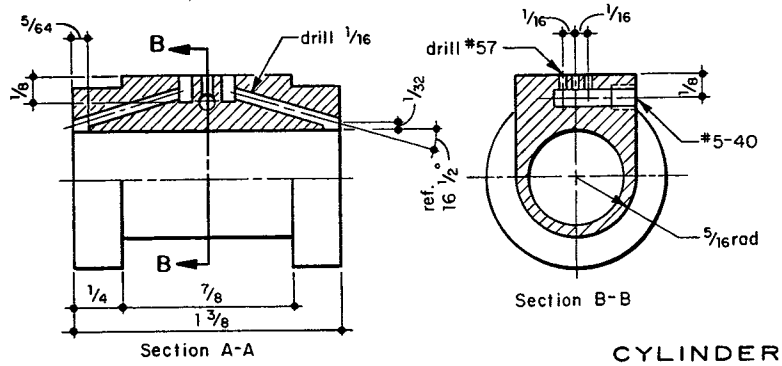
4 aluminum columns

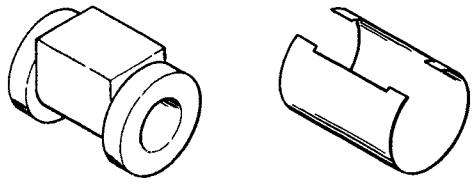


COLUMN
Aluminum, 4 required

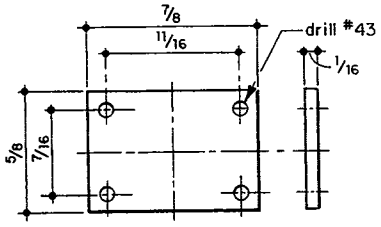




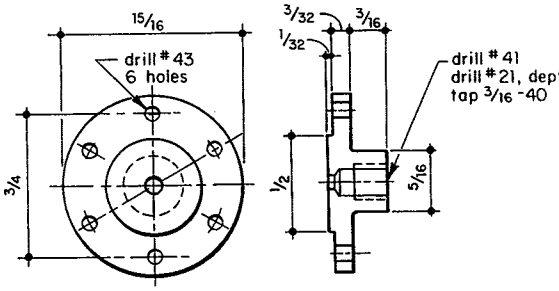




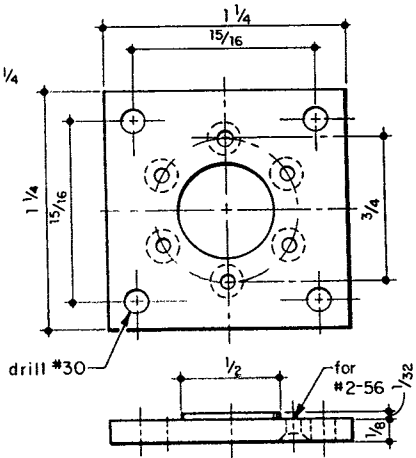
CYLINDER
Aluminum



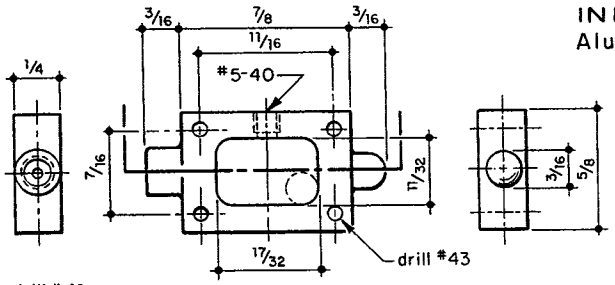
COVER
Brass

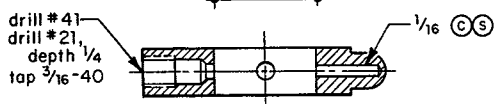


INBOARD HEAD
Aluminum

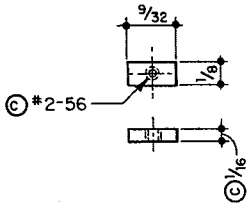


OUTBOARD HEAD
Aluminum

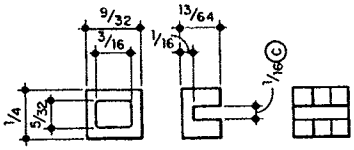


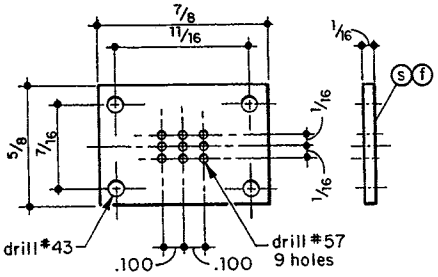


STEAM CHEST
Aluminum

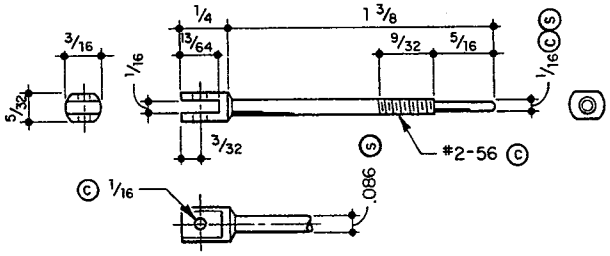


NUT
Brass

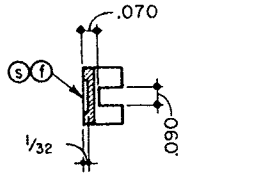




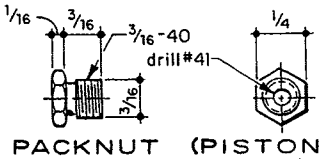
VALVE PLATE
Brass



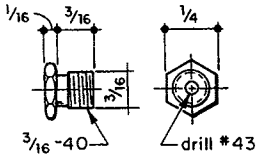
VALVE ROD
Brass



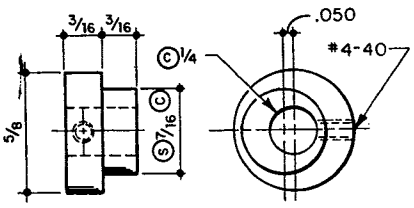
VALVE
Brass



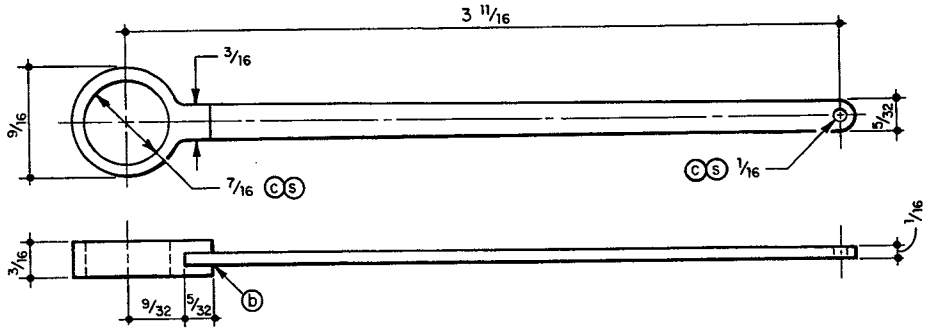
PACKNUT (PISTON)
Brass or Aluminum



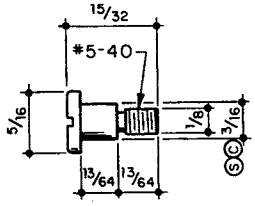
PACKNUT
(VALVE ROD)
Brass or Aluminum



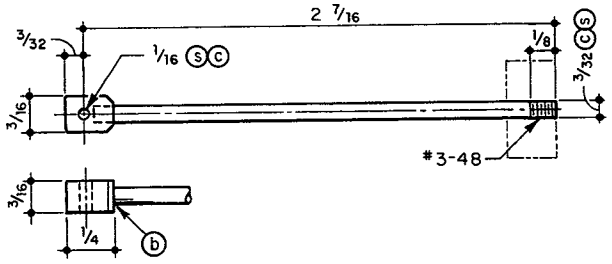
ECCENTRIC
Steel



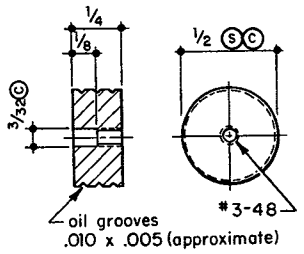
ECCENTRIC STRAP
Brass



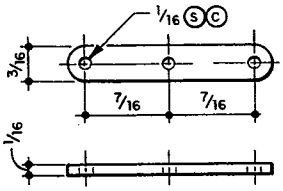
CRANK SCREW
Steel



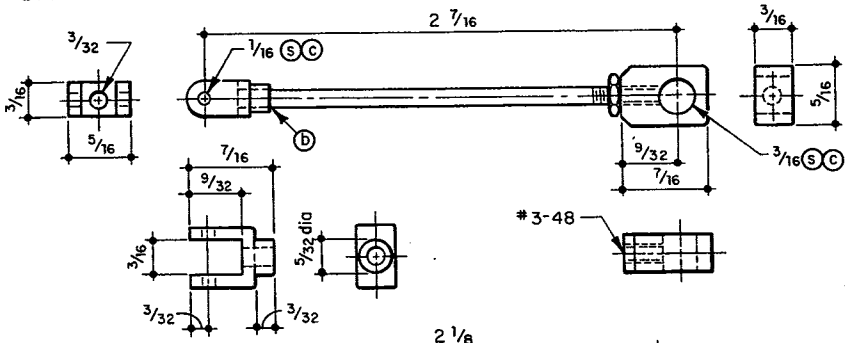
PISTON ROD
Brass

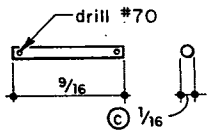


PISTON
Brass

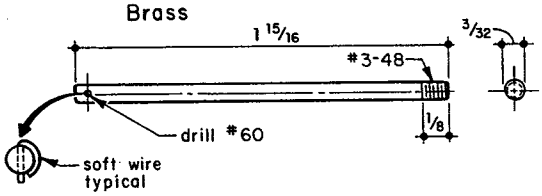


LINK

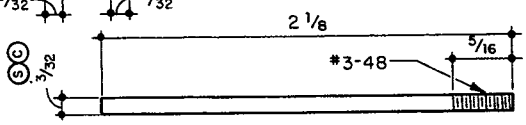




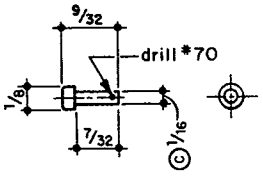
PIN
Brass



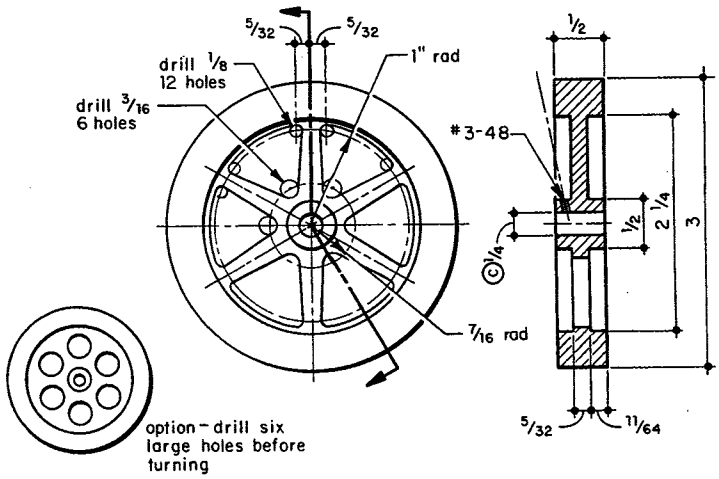
Brass, 2 required



CONNECTING ROD ASSEMBLY
Brass



Brass



FLYWHEEL
Aluminum

keeping the bolt pattern square with the Steam Chest face. Turn and bore as in **Step 1** and reverse in the lathe for **Step 2**. Make a milling setup for **Steps 3, 4, 5** and **6**. Rounding, as in **Step 7**, is optional.

The **LAGGING** is thin stock traced from a heavy paper pattern made by cut-and-try. Roll the metal to a diameter smaller than the flanges and carefully spring it in place.

The **STEAM CHEST** is laid out completely on an accurate 1/4" x 5/8" x 1-1/4" block. Center in the 4-jaw and turn each end and bore. Drilled holes form the radius for the inside opening.

In making the **VALVE**, try for freedom so it will float on the seat (steam pressure holds it down) and, at the same time, avoid sloppiness at the Valve Nut and Valve Rod.

Center 5/8" diameter stock in the 4-jaw for the **ECCENTRIC**. Brighten the O.D. and bore 1/4" for the Shaft. Offset .050" and turn 7/16" diameter. One method is to mount a square-ended bar in the tool post and bring it up against the stock. "Zero" the cross-slide collar and turn the chuck so two jaws are horizontal. Ease off the vertical jaws and back up the rear jaw about 1/16". Push the stock back, using the front jaw. Advance the cross-slide .050" and ease the stock back against the bar, using the rear jaw. Snug up all the jaws. Now, when the high spot just kisses the bar and then the chuck is rotated 180°, a .100" diameter rod should just pass between the bar and the stock. Spot the set screw on the centerline through the offset. It helps when you are tuning the Valve.

The **FLYWHEEL** shown was made from a salvage round-belt pulley. A Stuart-Turner 10H Flywheel is just right for this model or one can be made from 1/2" flat stock. Lay out and drill twelve 1/8" and six 3/16" holes as shown. Chuck in the four-jaw, gripping about 1/8" of the stock thickness. Center and turn the O.D., the 11/64" x 2-1/4" recess and the Shaft bore. Reverse and mount in the three-jaw, gripping on the rim I.D. and finish the O.D. and second recess. Apply layout dye to one entire web, scribe lines tangent to the holes and saw and file the spokes to shape.

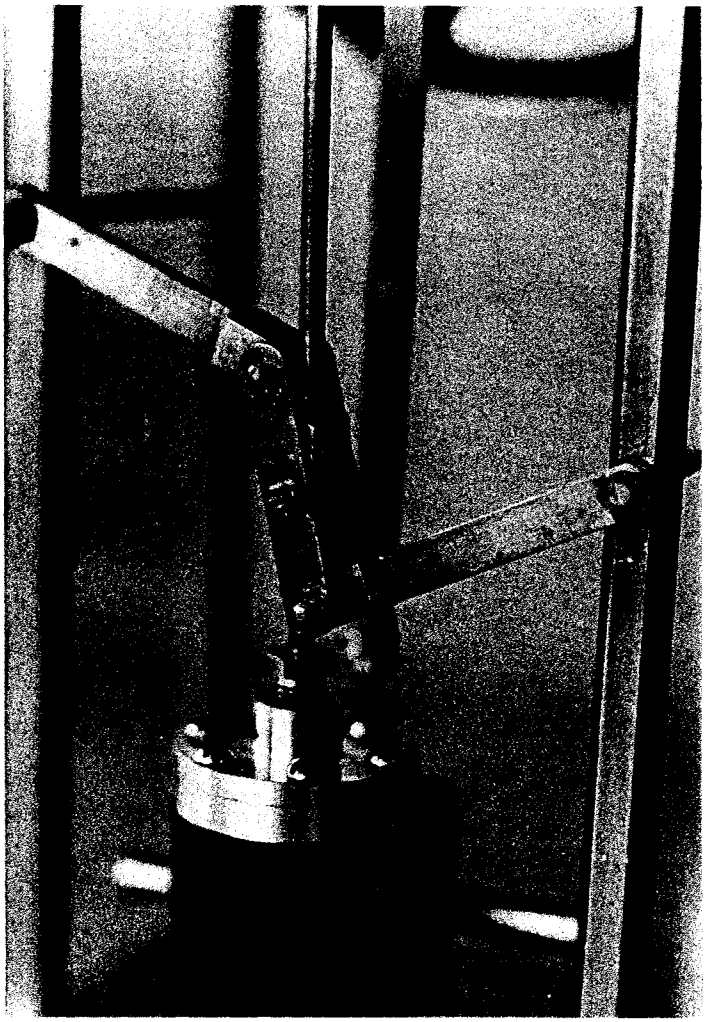
The **CONNECTING ROD** is provided with a bit of adjustment so the Piston travel can be centered in the Cylinder length.

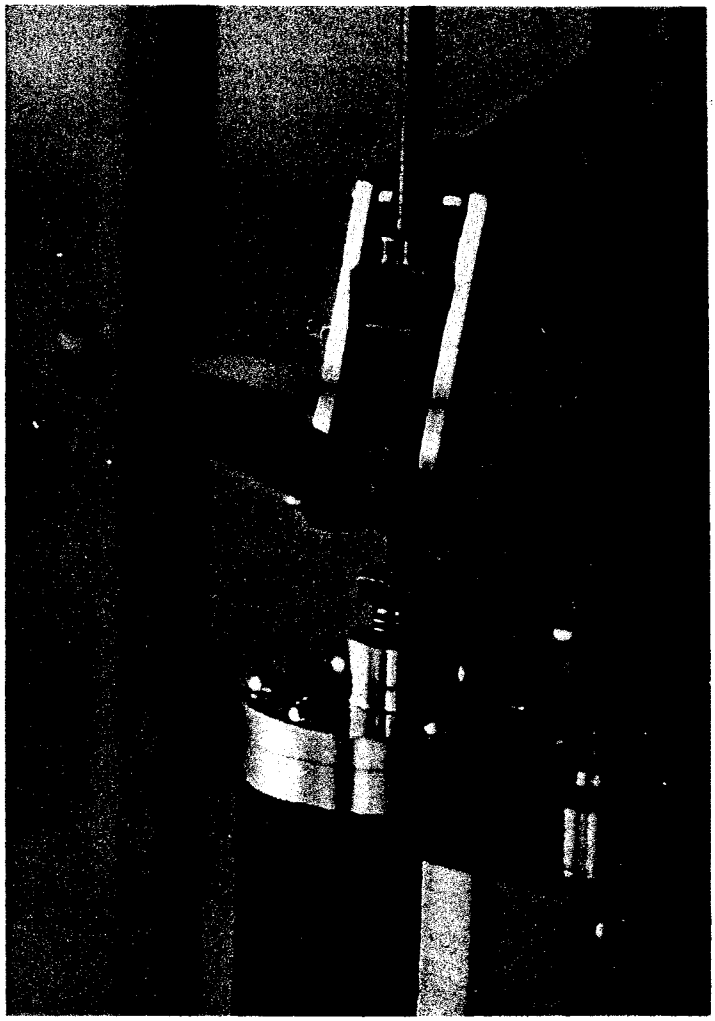
The **PACKING** is 1/16" strands unraveled from braided asbestos graphite Packing. Do not turn the Packing Nuts too tight. Turn them in lightly with the fingers. It is not strictly necessary to use this type of Packing.

Short pieces of soft wire in the #70 holes will keep the Links in place.

At **ASSEMBLY**, spot the Piston at one dead-center position and tighten the Eccentric with its axis at 90° from the centerline through the Crank. Temporarily fasten the Steam Chest and adjust the Valve so it equally exposes the Valve holes at each end of the stroke.

When the Piston is at one extreme of its travel no steam should enter the Cylinder.



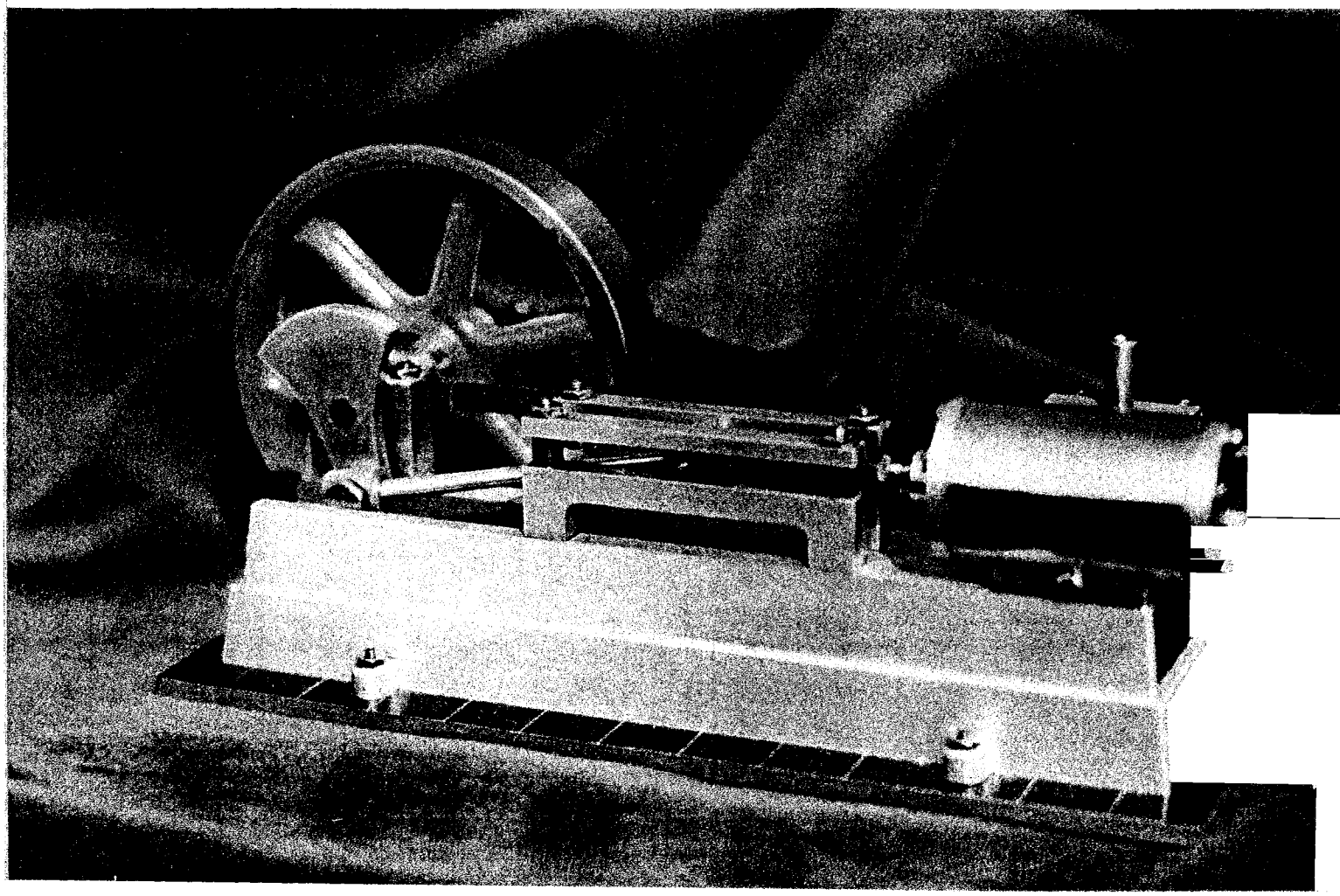


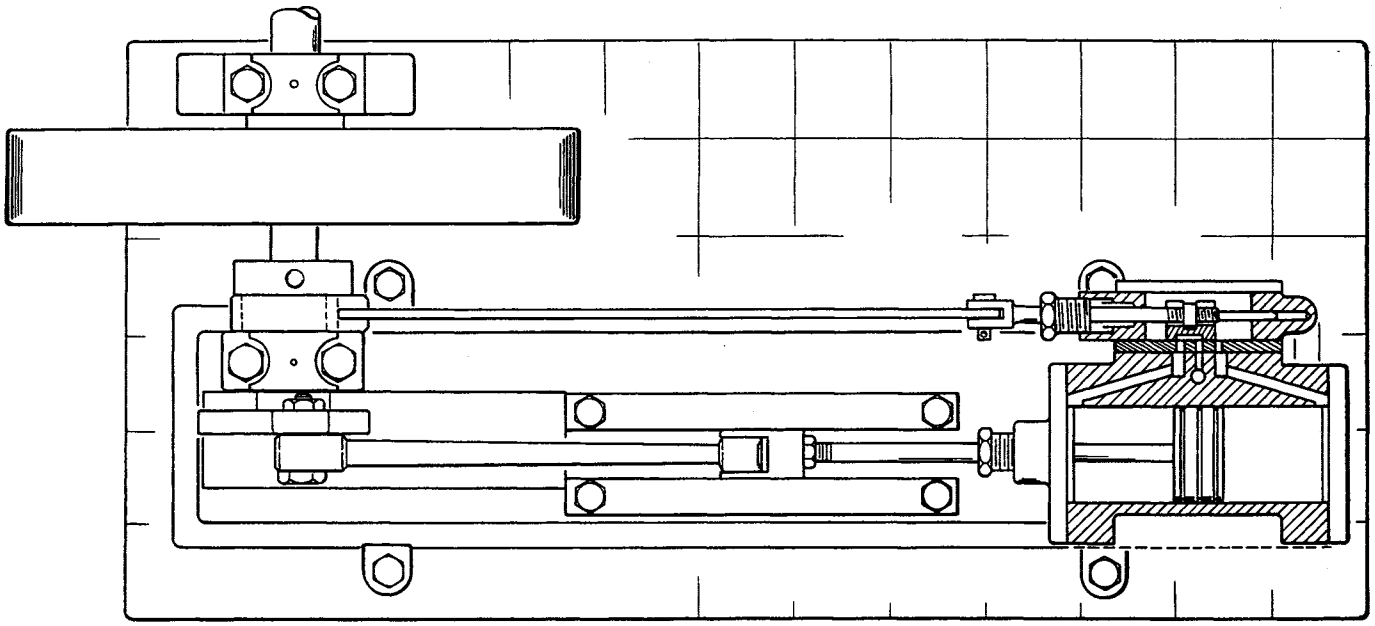
CHAPTER

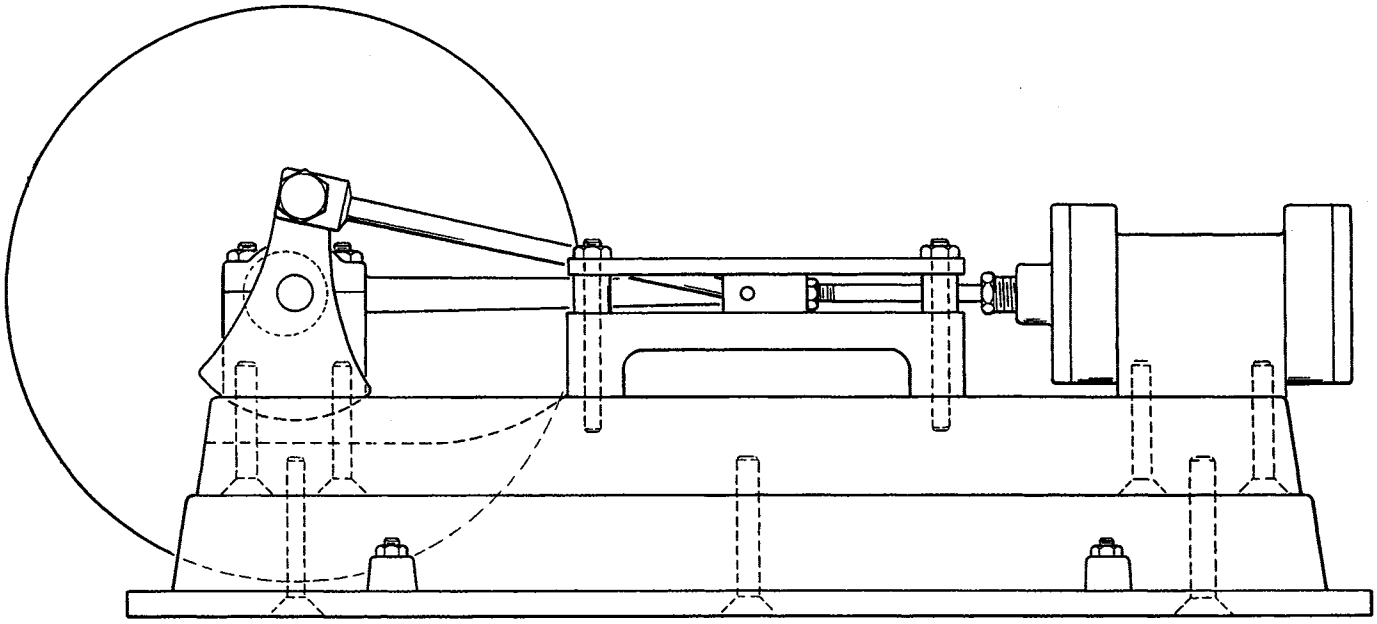
33 Mill Engine

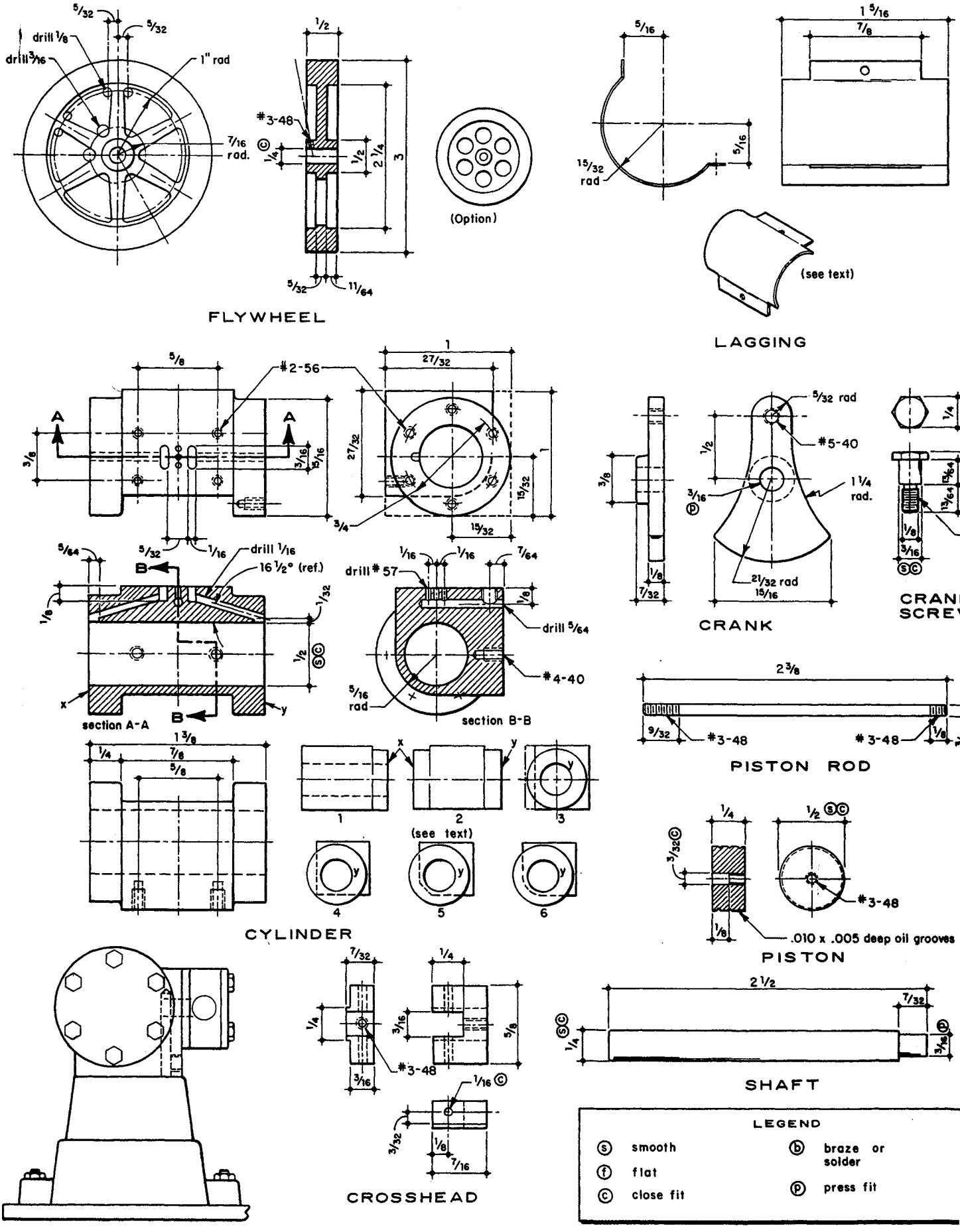
This is a small Mill Engine with 1/2" bore and 1" stroke. The proportions are fairly good and , using hexagon screws, it appears quite authentic. It runs good on as little as 5 psi air. No castings are required and most of the material can come from your scrap bin. On the model shown, most of the parts are made of a fairly hard jig-and-fixture grade of aluminum. The Piston is Teflon, although brass or bronze would be suitable. The Flywheel shown is a 3" Stuart Turner borrowed from a model 10H engine, but the drawings show a Flywheel made from 1/2" flat stock. Packnuts, Eccentric Strap, Valve Plate, Crosshead, Spacers, Steam Chest Cover, Valve, Valve Nut, Valve Rod, Piston Rod and the Valve Rod Pin are all brass. The Eccentric, Crank Screw and Crank Shaft are of steel. You can use any material you may have available and the use of steel and/or bronze instead of aluminum will make a more durable engine if it is to be run on live steam. Most of the parts need no special comments and follow customary machine shop procedures.

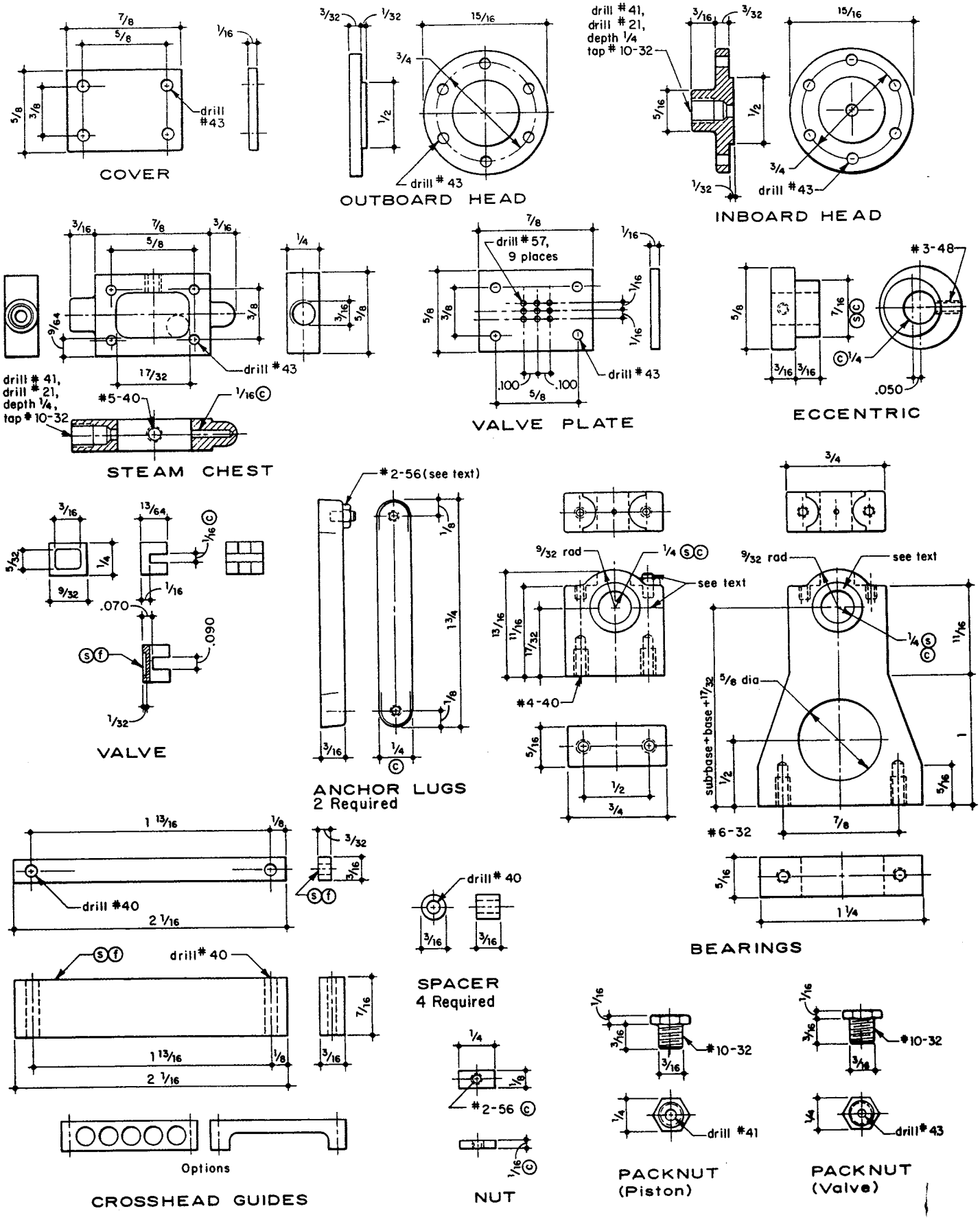
For the **BEARINGS**, start out with accurate 5/16" x 3/4" x 13/16" and 5/16" x 1-1/4" x 1-13/16" blocks. Scribe the outlines on the faces of each Bearing. Lay out and tap the Bearing mounting holes. Lay out the center for the shaft hole on the **TALL BEARING** and mill to outline. Assemble the Bearings to the Floor, Sub-Base and Base, all snug and well aligned. On the model shown, the assembly was mounted in the cross-slide milling attachment. The Shaft center was picked up with a wiggler and the Bearing holes line-drilled in easy stages to avoid strain on the setup. The last few thousandths were taken out with a reamer; in this case 3/8", since "Oilite" bushings were to be used. If you do not choose to use bushings, work up to a 1/4" reamer. A 1" long flathead bolt with a thick nut was used as a jack between the Tall Bearing and the Base to take some of the drill thrust. This operation might be done in a drill press, using an angle plate or a deep-jawed drill press vise. Mark each Bearing so it can be returned to its own position where it was machined. If you wish, you can actually make Split Bearings, but you must plan for this at the start. On this model, a deep scored line was

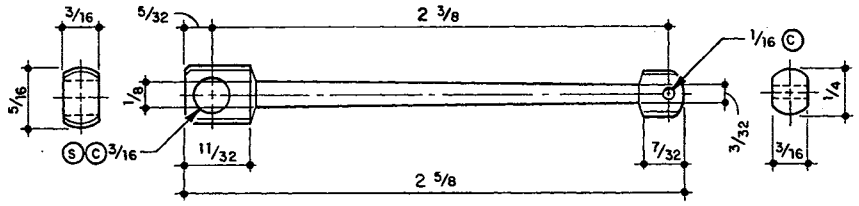




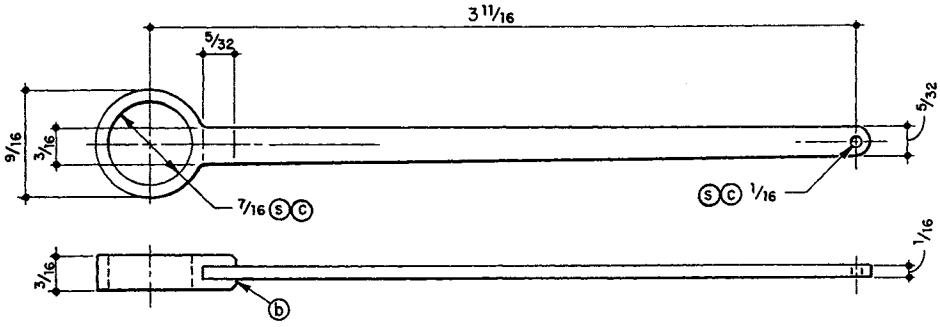



FLYWHEEL
(Option)
LAGGING
(see text)
CRANK
CRANK SCREW
PISTON ROD
CYLINDER
section A-A
section B-B
PISTON
.010 x .005 deep oil grooves
SHAFT
CROSSHEAD
LEGEND
s smooth
f flat
c close fit
b braze or solder
p press fit

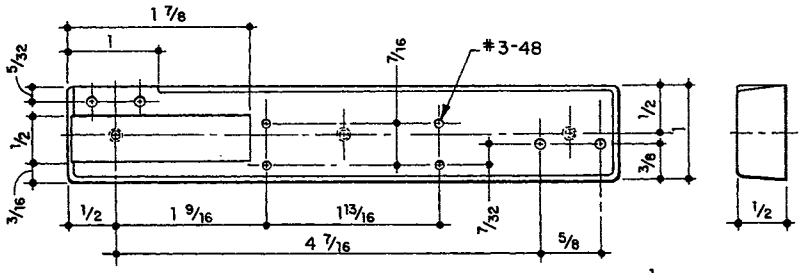

COVER
drill #43
OUTBOARD HEAD
drill # 43
INBOARD HEAD
drill # 41, drill # 21, depth 1/4 tap # 10-32
drill # 43
STEAM CHEST
drill # 41, drill # 21, depth 1/4, tap # 10-32
#5-40
drill # 43
VALVE PLATE
drill # 57, 9 places
drill # 43
ECCENTRIC
#3-48
.050
VALVE
.070
.090
ANCHOR LUGS
2 Required
#2-56 (see text)
BEARINGS
9/32 rad
see text
#4-40
5/8 dia
subbase + base + 17/32
#6-32
SPACER
4 Required
drill # 40
CROSSHEAD GUIDES
drill # 40
Options
NUT
#2-56
PACKNUT
(Piston)
#10-32
drill #41
PACKNUT
(Valve)
#10-32
drill # 43

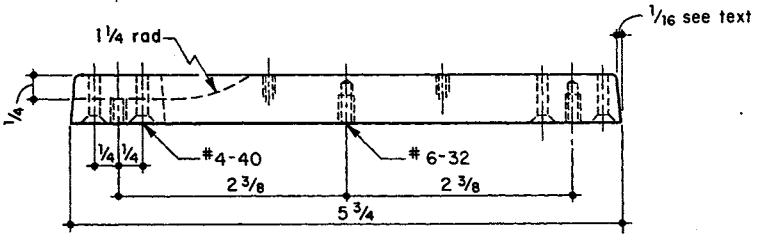


CONNECTING ROD

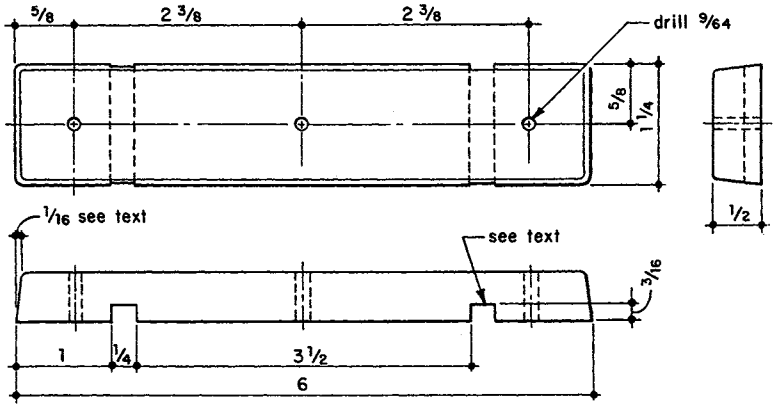


ECCENTRIC STRAP

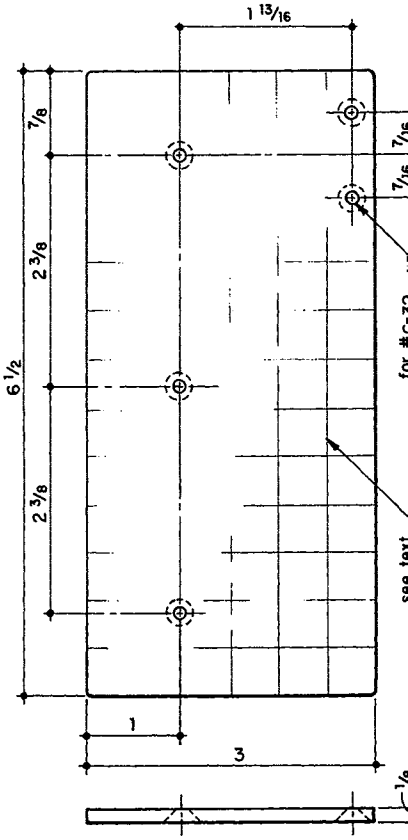




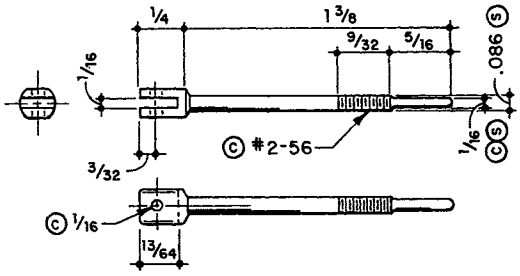
BASE



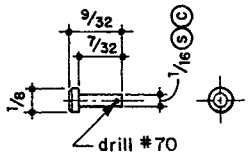
SUB BASE



FLOOR



VALVE ROD



VALVE ROD PIN

scribed to represent a Split Bearing and fake studs and nuts added in spot-faced holes. The 5/8" hole is optional.

The **CYLINDER** starts out as an accurate 1" x 1" x 1-25/64" block. Lay out all the centers and lines on all the faces. Complete all drilling and tapping. Note that the bore centerline is 15/32" from the faces at one corner. The Head bolt holes can be made by using a Head as a jig. Looking at the **Y** end in **Step 3**, note that the circle is at the lower left hand corner. The opposite end is **X**. Turn **X** end first so the 1/64" turned off the end makes it square with the bore for sake of the inboard Head. Make a milling setup and do **Step 3**, **4** and **5**. Rounding at **Step 6** is optional as Lagging will cover it.

The **CONNECTING ROD** is a piece of 5/16" x 3/16" stock, drilled, reamed and turned. Add extra length for a center hole for tailstock support when turning.

Try for good concentricity on the **PISTON** and **ROD** to avoid binding at the inboard Head.

The **STEAM CHEST** is laid out completely on an accurate 1/4" x 5/8" x 1-1/4" block. Center in the 4-jaw to turn each end and bore. Use drilled holes to form the radius in the center hole.

Make the **VALVE** of brass. Try for freedom on this part so it will float on the seat as steam pressure holds it down. At the same time, avoid sloppiness at the **VALVE NUT** and **VALVE ROD** thread.

The **VALVE ROD** is 3/16" stock, turned with tailstock support. Mount in the cross-slide mill attachment and mill the flats and the slot. It is well that the **NUT** fit the 2-56 thread closely to reduce pounding at the Valve.

The **ECCENTRIC STRAP** is a machined Bearing end, soldered to a flat bar.

The **FLOOR** on the model shown is salvaged blue-colored anodized aluminum and the 1/2" squares were easily scribed to represent tile. The scribing is optional but adds considerably to the appearance of the finished engine. However, the metal can be left bright or painted to suit your fancy... and don't overlook the possibility of scribing deep lines which can be filled with paint and the surface wiped clean to leave some color in the lines. There are some dyes on the market for coloring metal and they should make a background for the lines.

When making the **BASE** and **SUB-BASE**, make the beveling (which is optional) the last operation. You will have more accurate edges and corners for layout and holding. Mount the Guides, Brackets and Cylinder on the Base before beveling so you can see which areas can be beveled and which corners can be rounded. The fake **LUGS** are set in the Sub-Base with Loctite. Short trimmings from 2-56 screws plus hex nuts complete the fake anchor bolts.

The lower **CROSSHEAD GUIDE** can be simple solid pieces or drilled out or arched as shown. The Piston Rod hole in the **CROSSHEAD** should match the Piston centerline height in the Cylinder. Use a 1/16" x 5/8" Pin in the Crosshead.

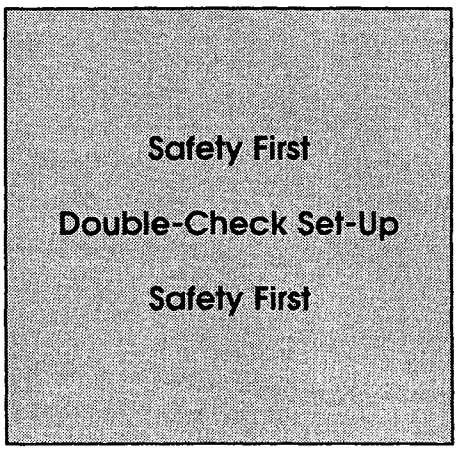
The **PACKING** is made from 1/16" strands unraveled from braided asbestos graphite packing. Do not snug up the Packing Nuts too tight, but turn them lightly with the fingers.

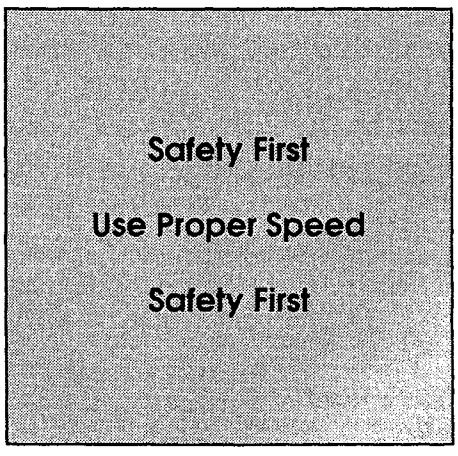
Next, chuck 5/8" diameter stock in the 4-jaw for the **ECCENTRIC**. Brighten the O.D. and bore 1/4". Offset .050" and turn the 7/16" diameter. Mount a square-ended bar in the tool post and bring it up against the stock. "Zero" the cross-slide collar. Turn the chuck so two jaws are horizontal. Ease off the vertical jaws slightly and back up the rear jaw about 1/16". Push the stock back to the rear jaw, using the front jaw. Advance the cross slide .050" and ease the stock back against it, using the rear jaw. Snug up all jaws. Now, when the high spot just kisses the bar and then the chuck is rotated 180 degrees, a .100" diameter rod should just pass between the bar and the stock in the chuck.

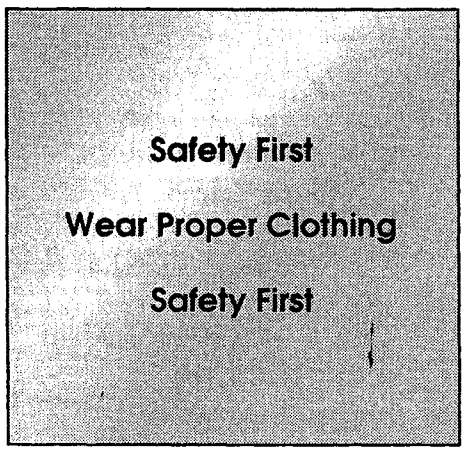
A **FLYWHEEL** can be made from 1/2" flat stock. Lay out and drill twelve 1/8" holes and six 3/16" holes as shown. Chuck in a 4-jaw, gripping about 1/8" of the stock thickness. Center and turn the O.D., the 11/64" x 2-1/4" recess and Shaft bore. Reverse and mount in a 3-jaw, gripping on the rim I.D., then finish the O.D. and the second 11/64" x 2-1/4" recess. Remove from the chuck and apply layout dye to one entire web face. Scribe lines tangent to the holes as shown, then saw and file spokes to shape.

The **LAGGING** is tin can stock. First, make a heavy paper pattern and transfer to the metal. The pattern is a cut-and-try job. Spot two tiny screws to hold the lagging in place.

At the **FINAL ASSEMBLY**, turn the Crank to one dead center position and tighten the Eccentric with it axis 90° from the centerline through the Crank. Temporarily hold the Steam Chest in place while adjusting the Valve to equally expose the Valve holes at each end of the stroke. Spot a few drops of oil on bearing and wearing surfaces and give it a trial run on air. This is the point at which all your efforts bear fruit and the enjoyment of watching the engine run will continue for years and years!







CHAPTER

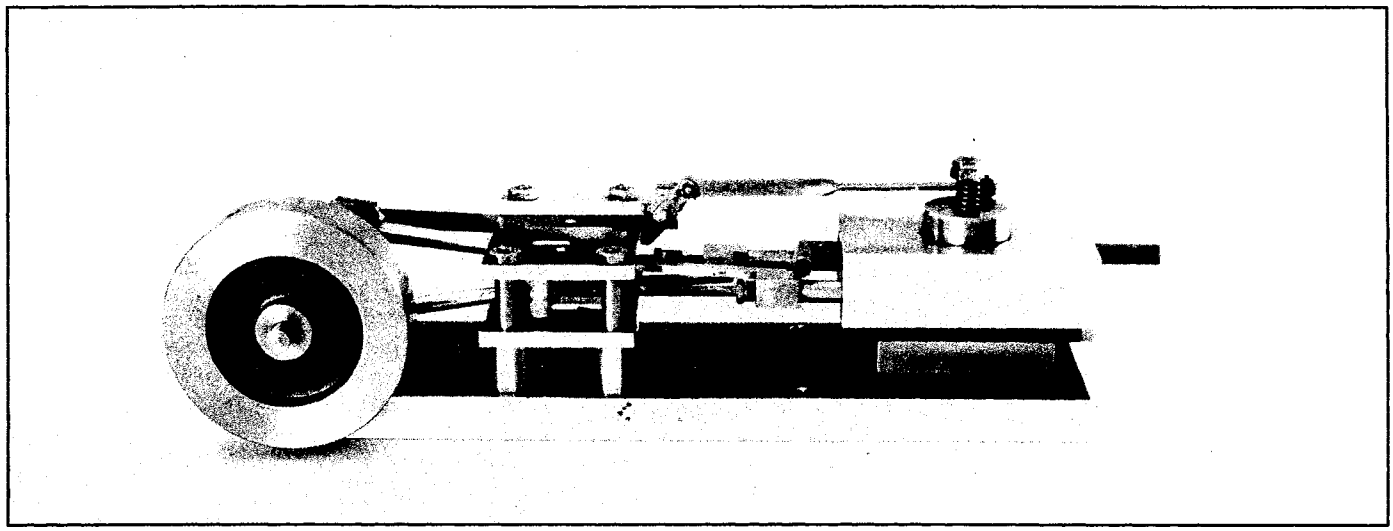
34 Cross Twin Engine

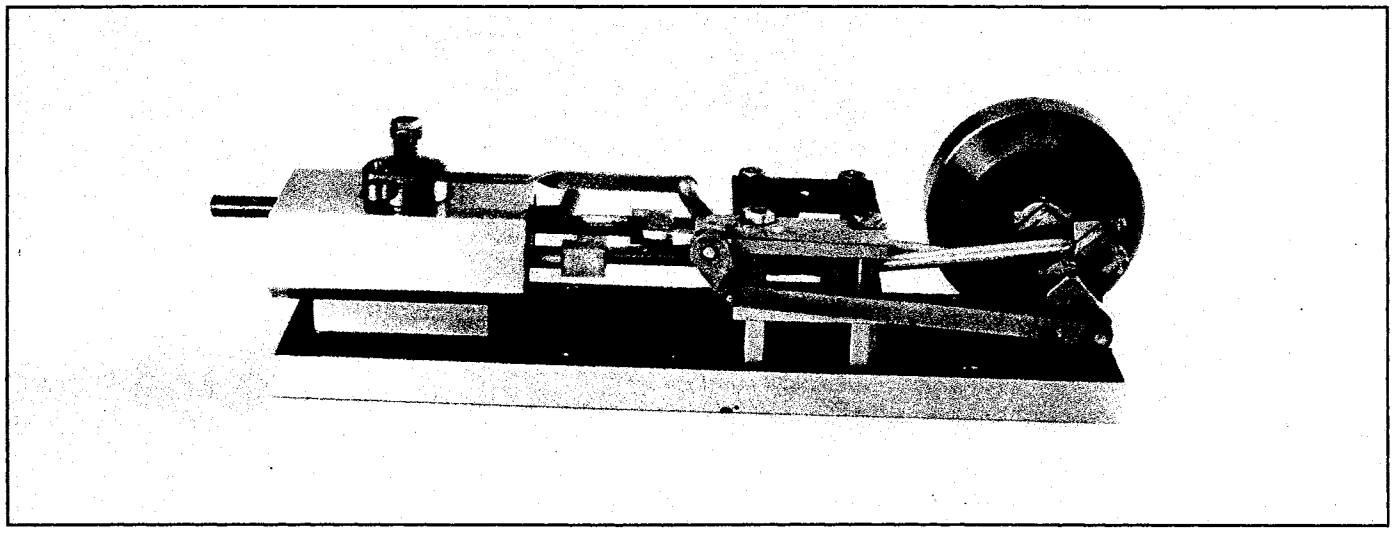
If you have made an assortment of the popular model engines, it may be interesting for a change to try this novel design. The idea came from a patent drawing for an engine made by D. H. Iseminger in 1901. There were no fine details or comments so everything had to be worked from scratch. About the only thing used was the general principle. The engine, as detailed here, is a fairly close likeness and not too difficult. It really is a conversation piece and a "show off" at club meetings, etc. Perhaps more durability should be built into it if it is to be run for long periods. For those who like to see a lot of action, it is a winner. The novelty is that it has two Cylinders, four Pistons and no Heads. The Valve and Linkage add to the action.

Study the assembly and note how the three components are related. The center-to-center distance across the Cylinders must be held across the Guides and at the throws of the Crankshaft. The height of the bore and Crosshead center are important for a free-running engine. This may call for a bit of filing and shimming at assembly. The Cross Links must be carefully assembled and soldered into the Stuffing Box. Some of the points that came up while building this engine are given here.

About the only thing to mention on the **BASE** is careful layout so the three sub-assemblies accurately straddle the centerline. It is a long and narrow engine. Mount the **BEARINGS** on the Base and line-ream for a close but free-running fit on the Crankshaft.

For the **CYLINDER BLOCK**, start with an accurate 3/4" x 1-5/8" x 2-1/8" piece and lay out all lines and hole centers. Note the pattern for the Valve holes and grooves are based on





six equally-spaced centers on a 1/2" circle. The same "six pattern" is used on the Valve so a 60° turn of the Valve matches the Cylinder pattern. Drill two shallow 3/32" holes on the 1/2" circle and mill the connecting groove with a 3/32" end mill. The 3/32" holes going down to the bores are centered in these grooves. Drill these holes before making the two 1/2" bored holes. The bores are made using the cross slide milling attachment. One hole is centered using a wiggler and bored and reamed. Feeding in .875" centers the other 1/2" bore. These bores could also be made in the 4-jaw, picking up the centers with a center test indicator. The remaining operations are straight machine work. Take care to have a clean flat surface to seal against the Valve. The **VALVE**, as mentioned above, has six evenly-spaced centers on a 1/2" circle. Drill shallow 3/32" holes and mill the grooves between them with a 3/32" end mill. Here, too, the face must be flat and smooth for a good seal on the Cylinder Block. The projection for the Link Pivot is a small block soldered into a milled groove parallel to the Valve grooves. Lay out the center for the Link Pivot 1/2" from the Valve center for a 1/16" pin. Set the pin with Loctite or solder.

The **VALVE LINKAGE** is mostly simple maching and soldering. The 1/16" pin entering the 1/16" thick link can be quite close fitting and still allow the movement through an arc at each end. In a large engine, these joints would require ball joints or self-aligning bearings of some sort.

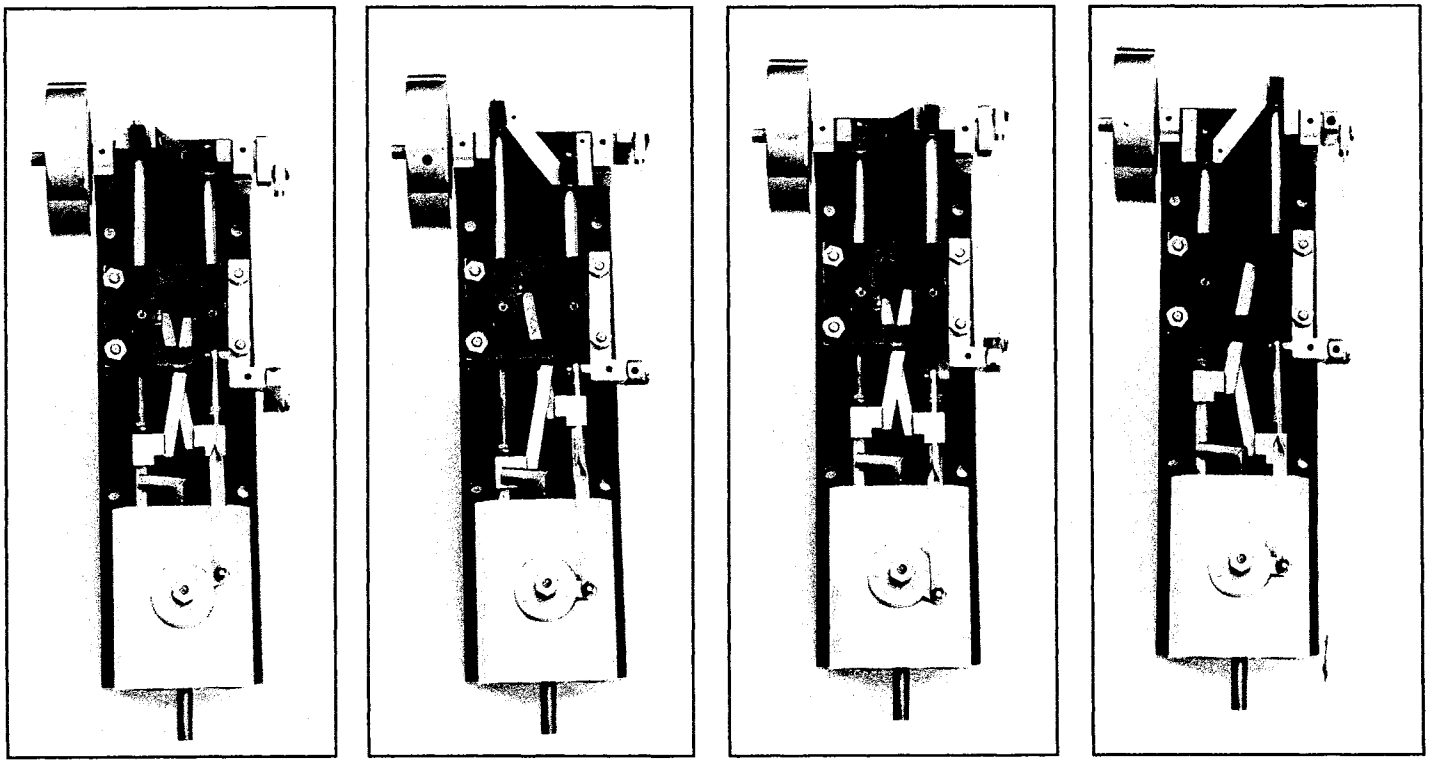
The **CROSS HEAD GUIDES** are made from a piece 1-3/4" x 2-9/16" x 1/8". Two parallel grooves that guide the Cross Heads, are made in this piece. While it is at this stage, lay out and make all the holes for the studs and cut out the 1/2" x 3/4" center hole. When all is to size and shape, cut the piece in two, forming the Upper and Lower Guides. It is important to have well-spaced and close-fitting, yet free-running, Guides. They have to take the forces from the Crank and angle thrust from the Cross Links. Perhaps some will prefer to cut the piece in two and lay out one piece and use it as a jig for the second piece. Take care that the upper and lower grooves are parallel at assembly. Be sure the holes match the tapped holes in the Base.

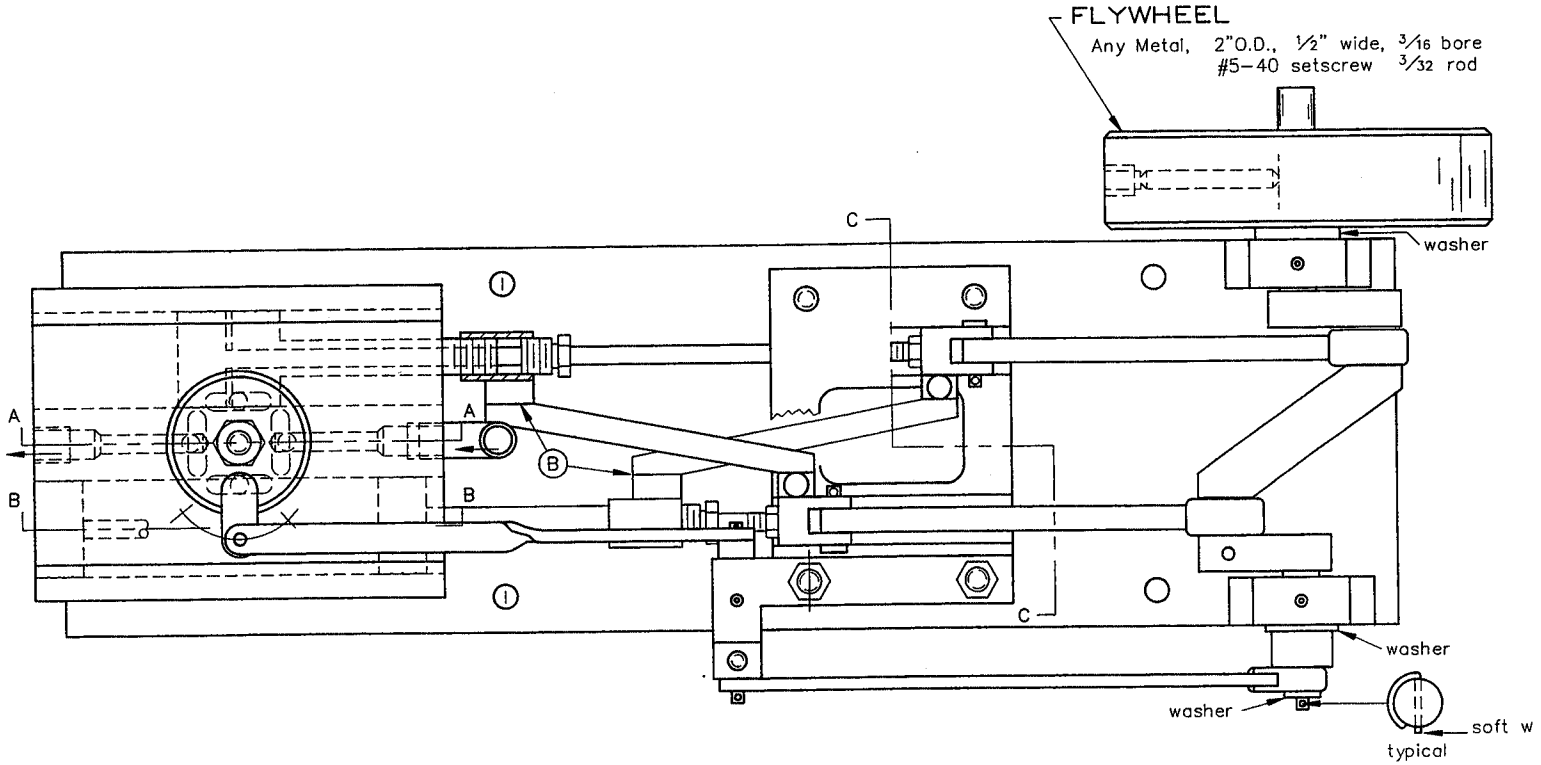
The **CROSS HEADS** are a bit more detailed and require the right fit in the Guide. A four-step plan is shown to help layout and machining. **Step 2** shows the 1/4" dimension that matches the groove width in the Guides. Make this dimension a few thousandths full so it can be carefully fitted to the Guide. Bolt the two Guides together using the studs and use as a gauge while fitting the Cross Heads. **Step 3** shows the cuts that make the Cross Link attachment. Here the cuts pick up the 1/4" dimension made in **Step 2**. Note: make both pieces alike. When they are assembled, one is turned over and provides for the two Cross Links to pass each other. **Step 4** shows the drilling and tapping. The 1/2" dimensions are important for a proper fit in the Guides. If you started out with a 1-1/32" piece and made a 1/32" milling cut, they should be close to size. Here, again, a few thousandths full will leave you a bit of "filin' and fittin'".

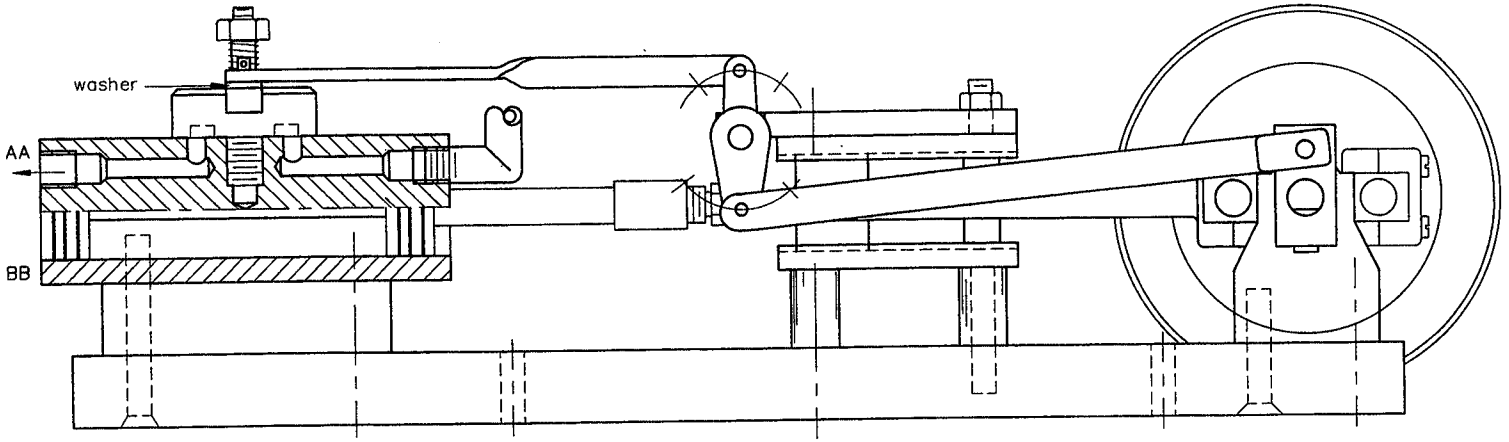
The **STUFFING BOXES** are less complicated than the Cross Heads. Again, make two alike.

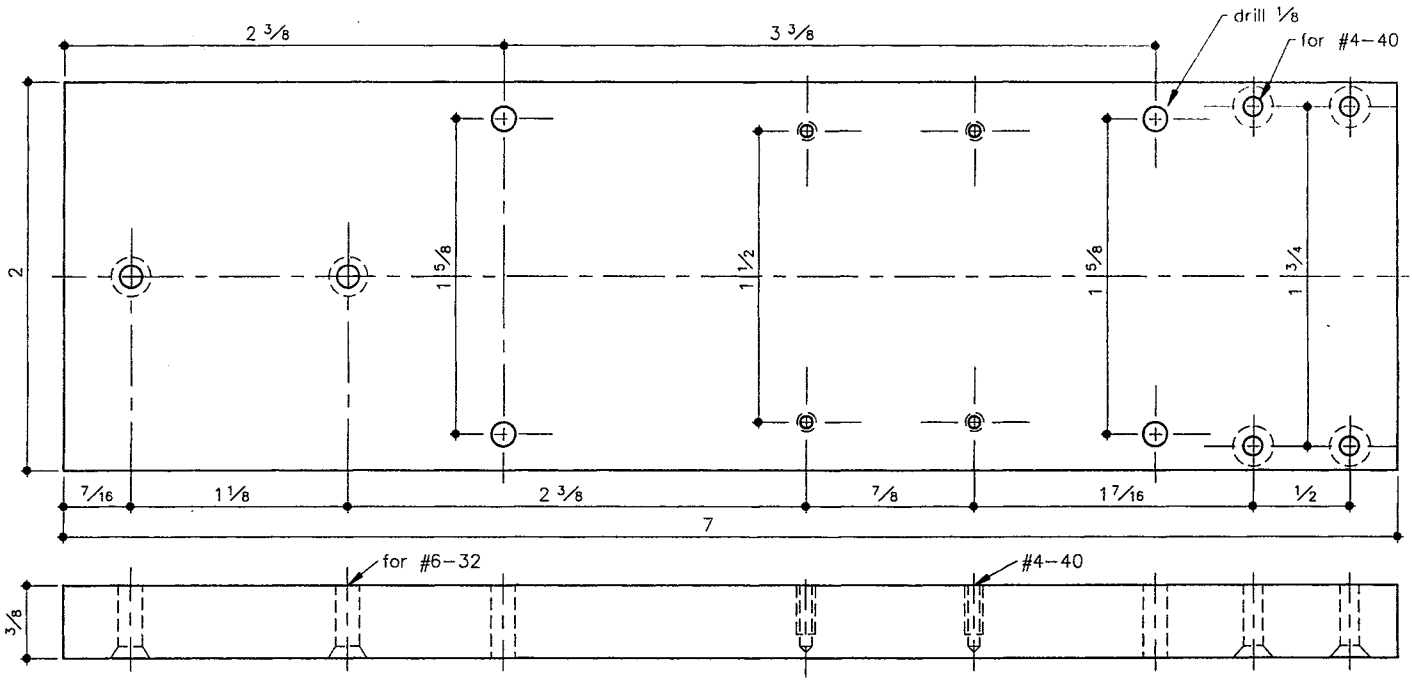
The **CROSS LINKS** are simple cutout jobs from 1/16" brass. At assembly, with Cylinders, Pistons, Base, Cross Heads, Glands and Cross Head guides in place, insert the Links in the slots and insert pins in the Cross Heads. Now, with the other end of the Cross Links in the Stuffing Box slots, add flux and a tiny pellet of solder. Carefully heat the Stuffing Box with a small propane flame until the solder melts and flows into the

The four photos below show the cross-action between the Piston Rods and the Cross Links. Note especially the relationship between the forward motion of the Cross-Links and the four dead-center positions of the Crankshaft.

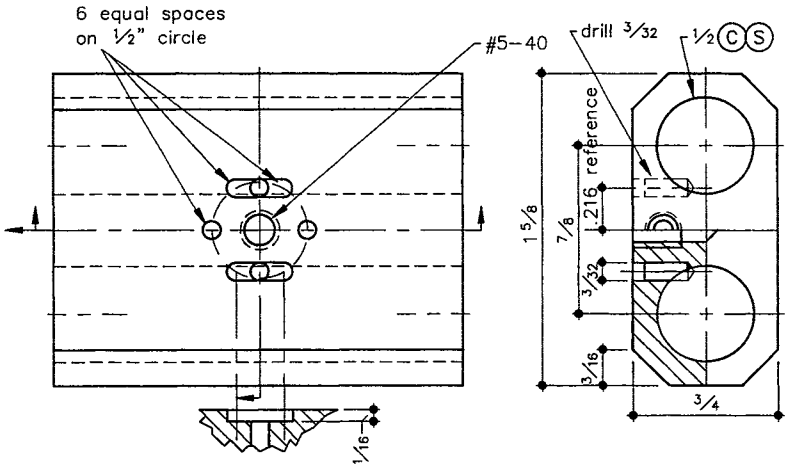


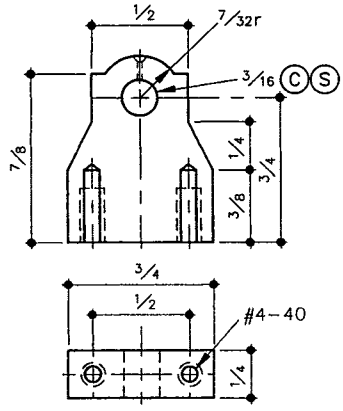

FLYWHEEL
Any Metal, 2"O.D., ½" wide, 3/16 bore
#5-40 setscrew 3/32 rod
washer
C
A
B
A
B
C
washer
washer
soft w
typical


washer
AA
BB

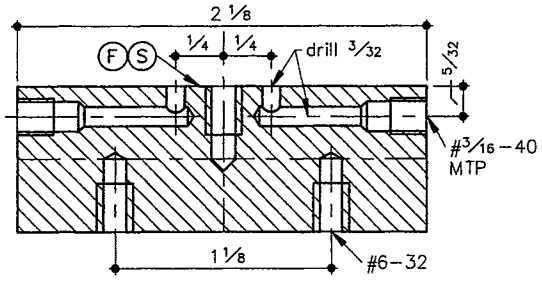


BASE
Any Metal

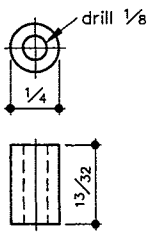




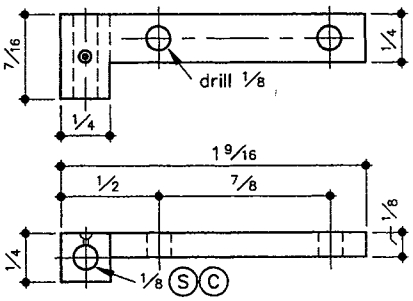
BEARING
Brass or Hard Aluminum
2 Required



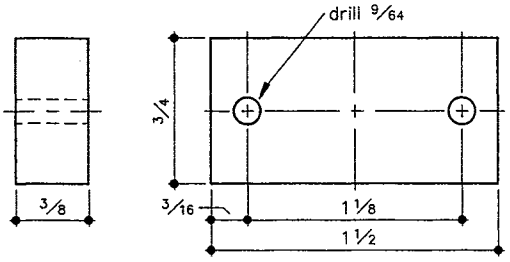
CYLINDER BLOCK
Fine Cast Iron, Brass or
Hard Aluminum



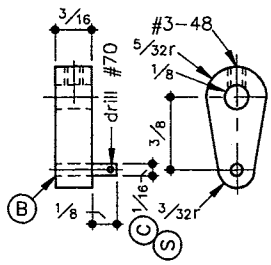
SPACER
Any metal
4 Required



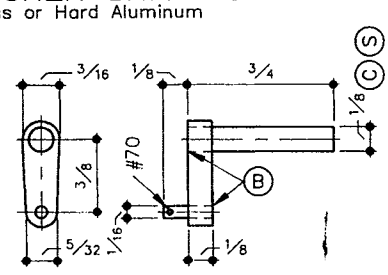
ROCKER SHAFT BEARING
Brass or Hard Aluminum



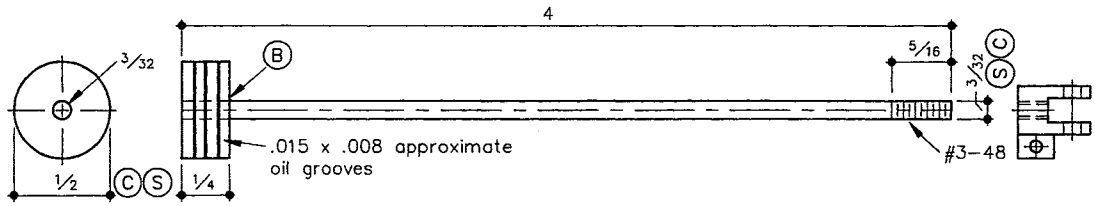
CYLINDER FOOT
Any metal



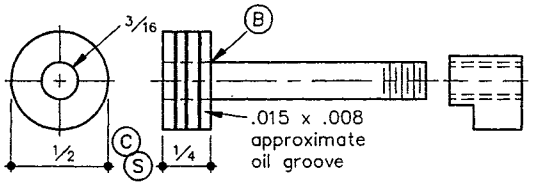
ROCKER CRANK ARM
Brass



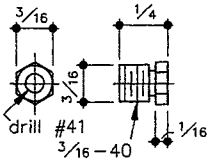
ROCKER SHAFT
Brass



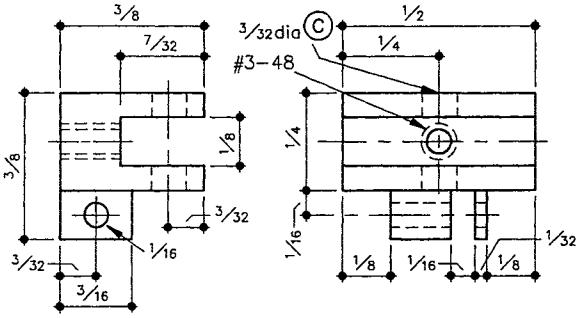
PISTON & ROD
Brass
2 Required



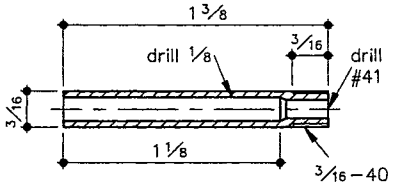
PISTON & TUBE
Brass
2 Required



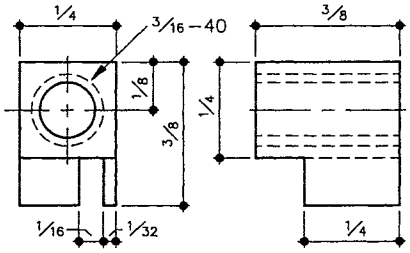
PACKNUT
Brass
2 Required



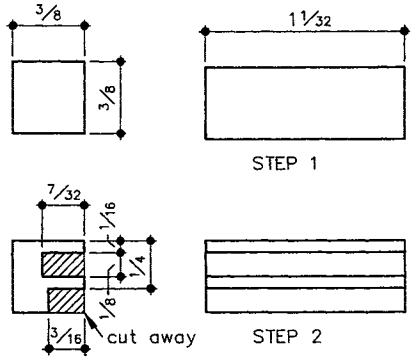
CROSSHEAD
Brass
2 Required

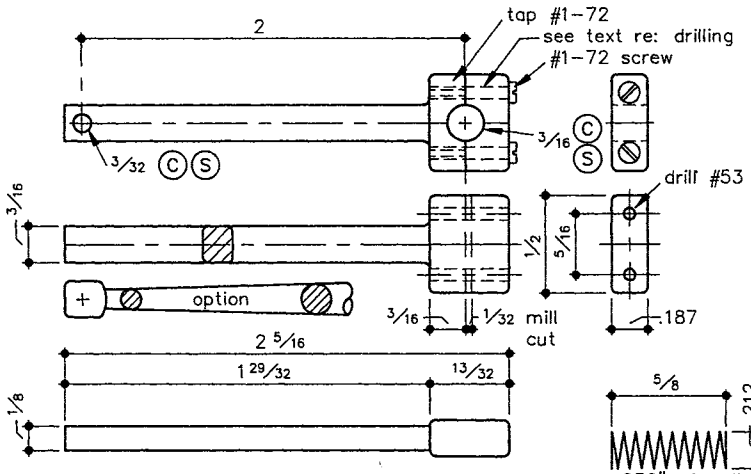


TUBE
Brass
2 Required

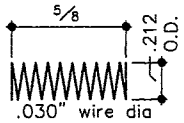


STUFFING BOX
Brass
2 Required

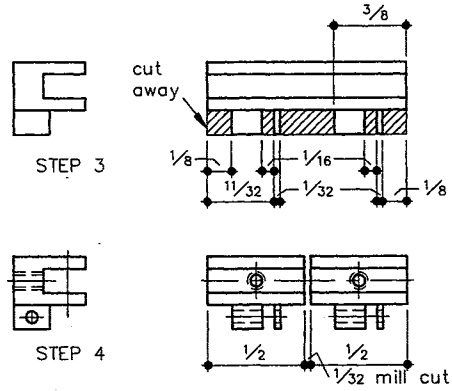


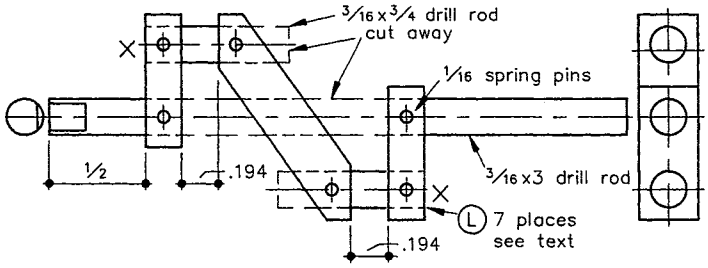


CONNECTING ROD
Brass or Hard Aluminum
2 Required

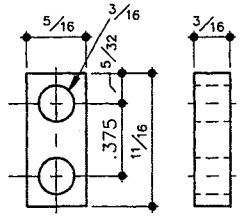


SPRING
Steel

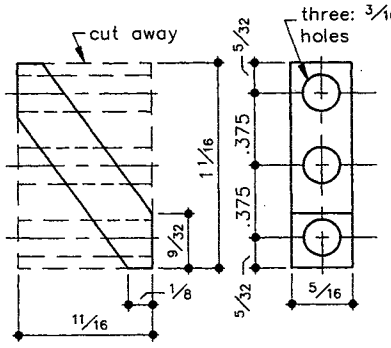




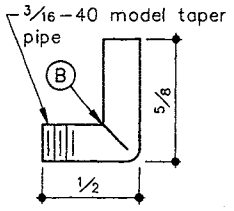
CRANKSHAFT
Steel



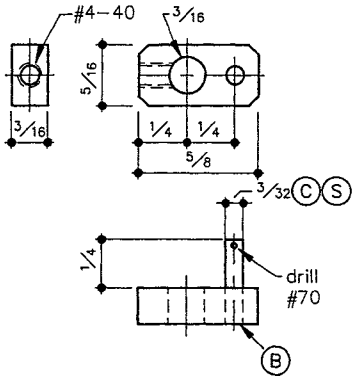
CRANK END BAR
Steel
2 Required



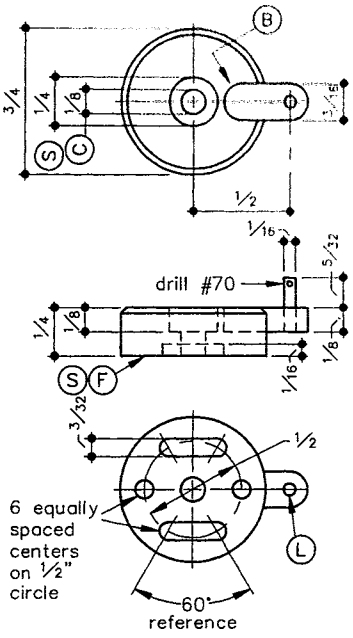
CRANK CENTER PIECE
Steel



STEAM CONNECTOR
Copper or Brass tubing (.035 wall)

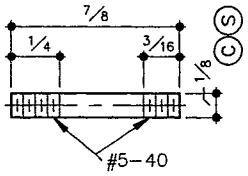


VALVE CRANK
Brass

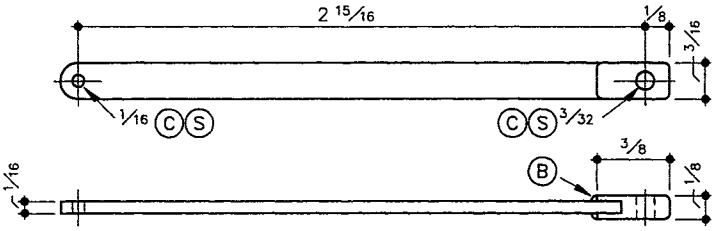


VALVE
Brass

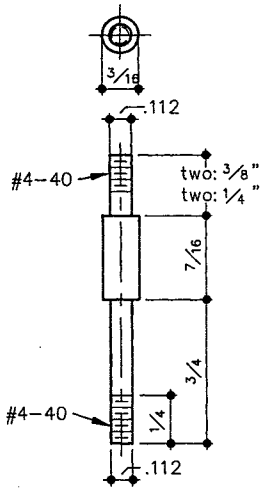
C close fit
S smooth
F flat
B braze or solder
L "loctite"



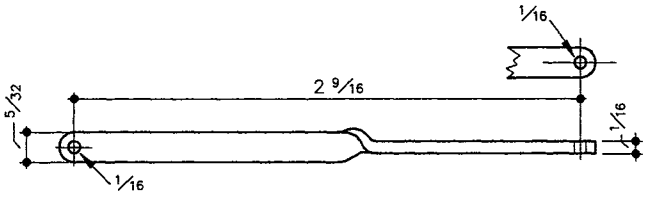
VALVE PIVOT
Steel



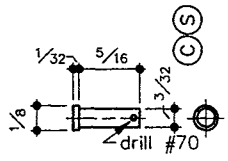
ECCENTRIC STRAP
Brass



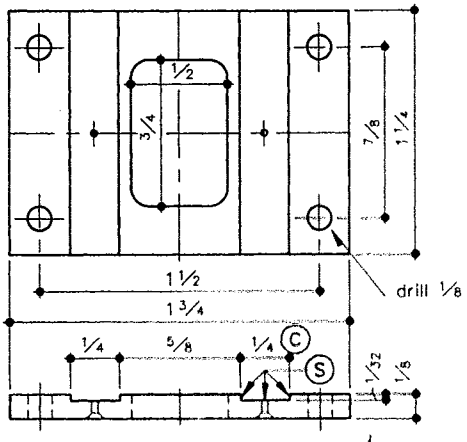
STUD
Steel
4 Required



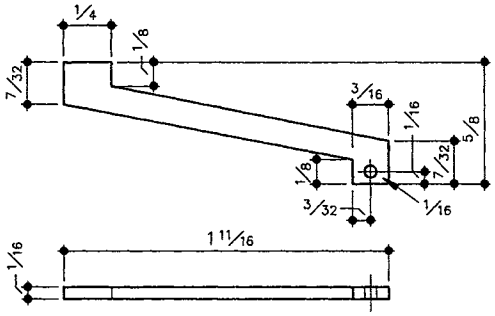
VALVE LINK
Brass



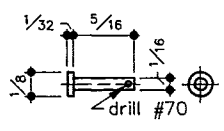
CROSSHEAD PIN
Brass
2 Required



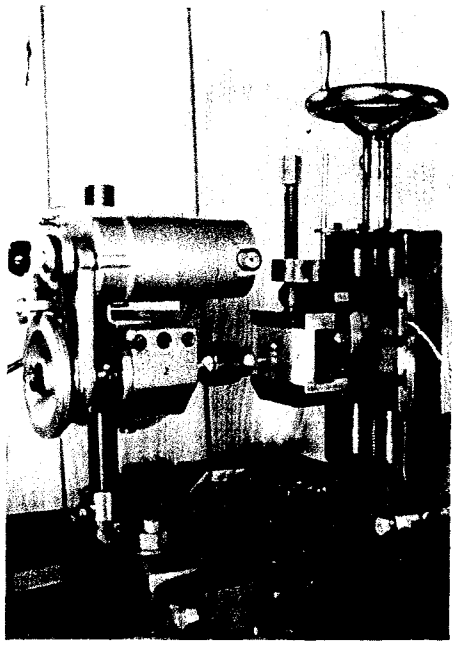
CROSSHEAD GUIDE
Hard Aluminum or Steel
2 Required

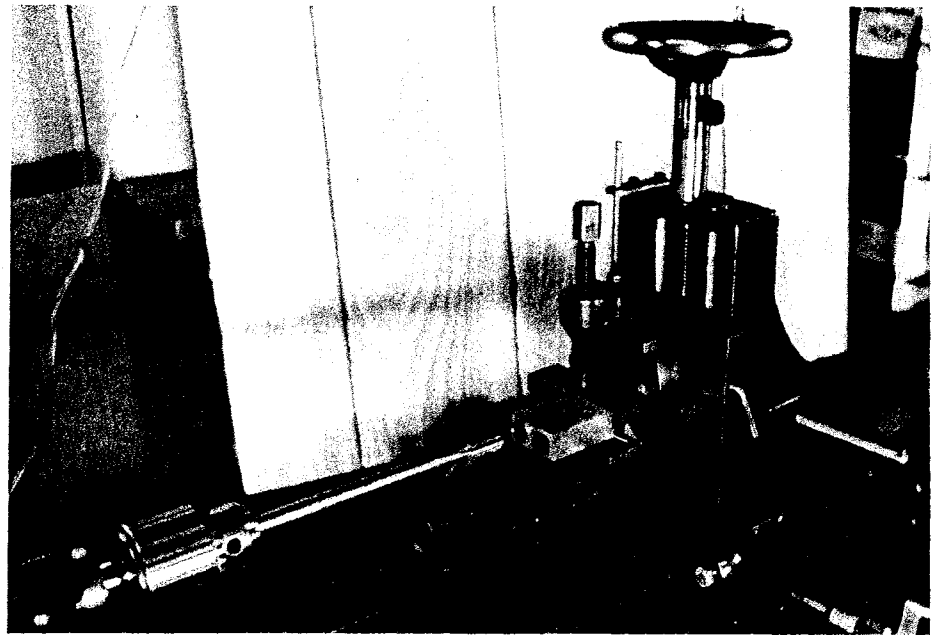


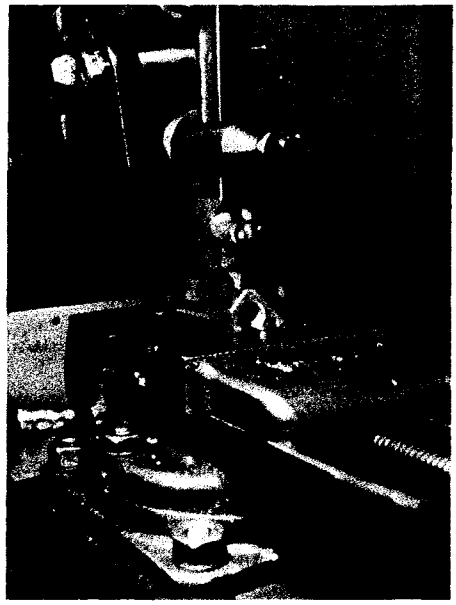
CROSS LINK
Brass
2 Required



CROSS LINK PIN
Brass
2 Required





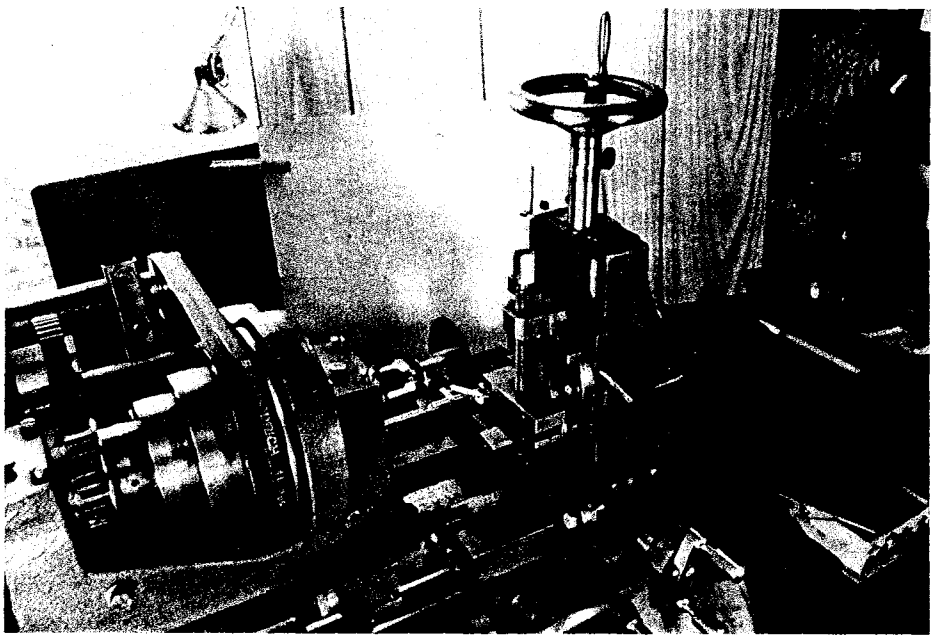


Upper left: Milling the ports in the Cylinder, using the Unimat spindle and cross slide milling attachment.

Upper right: Reaming the bores of the Cylinder Block.

Left: Shaping the bevels.

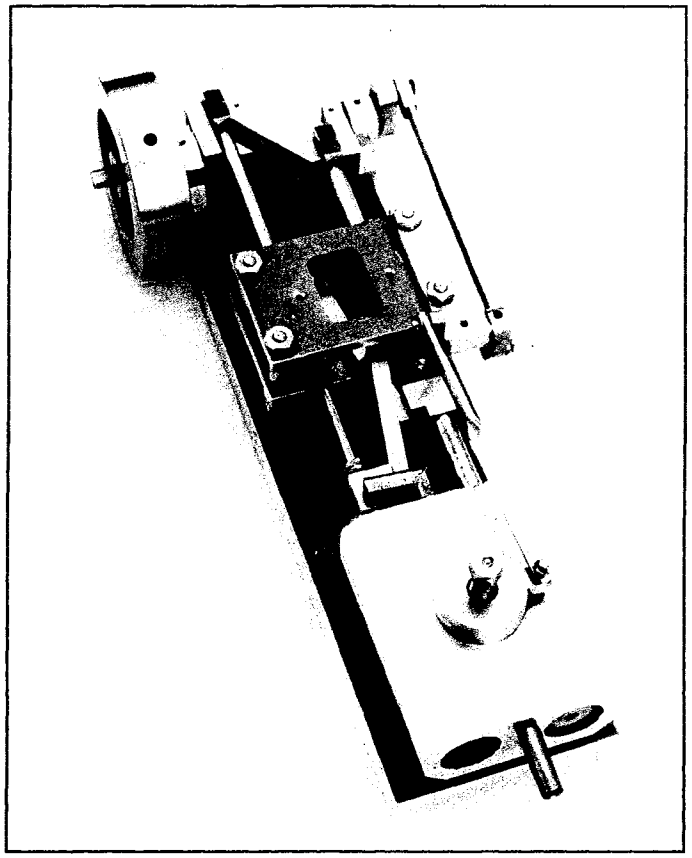
Below: Cutting away the Shaft material in the Crankshaft.

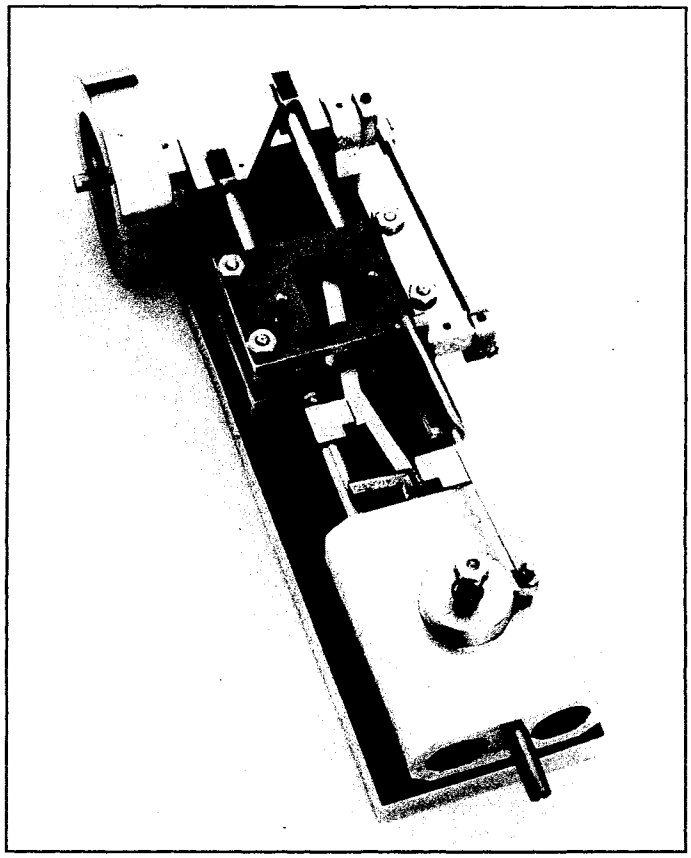


joint. This guarantees the Links will meet properly and match the center distance across the two Cylinder bores.

Use your favorite **PACKING** in the Stuffing Boxes. Thin strands of graphited asbestos were used in the model shown. Turn only finger-tight.

Make all the pieces for the **CRANKSHAFT**. Make two End Bars from 3/16" x 5/16" stock and the center piece from 5/16" x 11/16" stock. Lay out and prick punch the center hole in the center piece and one end hole in one EndBar. Lay out both holes in the otherEndBar. Drill #16 and ream 3/16" in the Center Piece and one end hole in each End Bar. Drill the second end hole in the one bar. With a close-fitting 3/16" guide pin, use this bar as a jig for drilling #16 for all the remaining holes. Ream 3/16" in all these drilled holes. Mill the Center Piece to shape. Assemble loosely on a flat surface. As you know, these joints must be clean for assembly with Loctite. Ease the pieces apart at **X** and apply Loctite at these two spots. Set the Crank Pins flush as shown and, with the rest of the joints still loosely assembled, set aside to cure with all the parts resting on a flat surface. Make two .194" **SPACERS**. Apply Loctite to the remaining joints and rest this assembly on the flat surface. Use the .194" Spacers, hold the 1/2" dimension and set aside to cure. Drill and insert 1/16" spring pins and cut away the Shaft as shown. The 1/16" pins are a bit large but very easy to use. The Crank shown used some 1" nails about .047"





Notice in the two views above that, as the left-hand Connecting Rod is at rear dead center, the left-hand piston is at the front end of the Cylinder Block. As the Crankshaft rotates, the opposite action takes place.

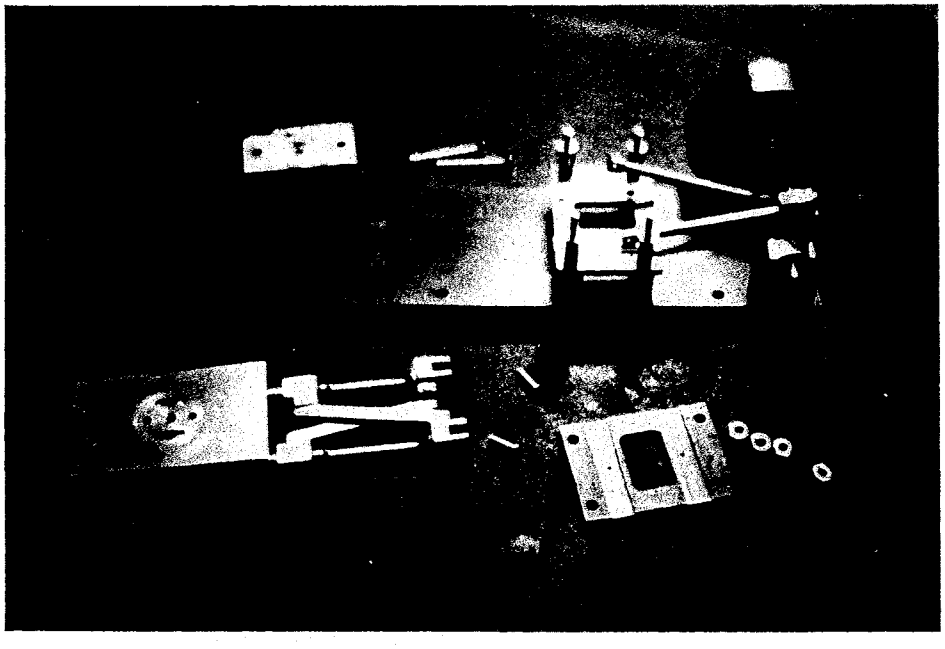
diameter set with Loctite.

The **CONNECTING RODS** start out as 3/16" x 1/2" stock. Lay out the outline of the Rod and tap-drill #53 for the 1-72 screws. Drill about 1/2" deep and make the 1/32" mill cut. Enlarge the holes in the small piece with a #48 drill. Tap the large piece #1-72. Assemble and lay out the 3/16" and 3/32" holes. Squarely drill and ream these holes to size. Cut 1/32" off each face to form the 1/8" thickness. Make similar cuts to form the 3/16" width. Dress up and polish to suit. An option is shown for a turned Shank. Using tail-stock support and the compound set at approximately 1-1/2° will produce a better looking Connecting Rod. While you still have square surfaces for holding and measuring, mill the 1/8" thickness about 1/4" wide at the Wristpin hole before turning this taper.

Make the 3/32" and 3/16" holes in the **PISTONS** a close, free fit on the Rods and Tube so solder will penetrate and make a good bond. 430° solder is the favorite in this shop, though common solder will do. The Piston **TUBE** is made from 3/16" solid rod. It threads into the Stuffing Box and has the same thread as the **PACK NUTS**, thus forming a cavity for packing.

The **VALVE SPRING** dimensions shown are for a spring found in the odds-and-ends department. Try one from your collection. At 8 to 12 pounds of air, this Spring doesn't have to be too strong. Less pressure on the Valve reduces the wear on a fairly light linkage system.

At final assembly, check the parts as they are brought together for a nice-running fit. Set the Valve Crank Arm 90° from the Crank Throw. Either port in the Cylinder can be used as intake. After about 1/2 hour running, this engine was running fine on about 10 pounds of air and really showing a lot of action.



CHAPTER

35 Steam Pump

This pump is a bit more novel, even, than most steam pumps and offers the Machine Shop fan another engine to add to his collection. The design was suggested by Ralph Jarvis of Fenton, Michigan and the Ball-End Crank sliding in the Flywheel actuates the Steam Valve through an Eccentric and Rock Shaft.

The model shown is mostly aluminum. The Shaft, Eccentric and Flywheel are steel. All the tiny hardware is brass. You can adapt your own stock material as needed.

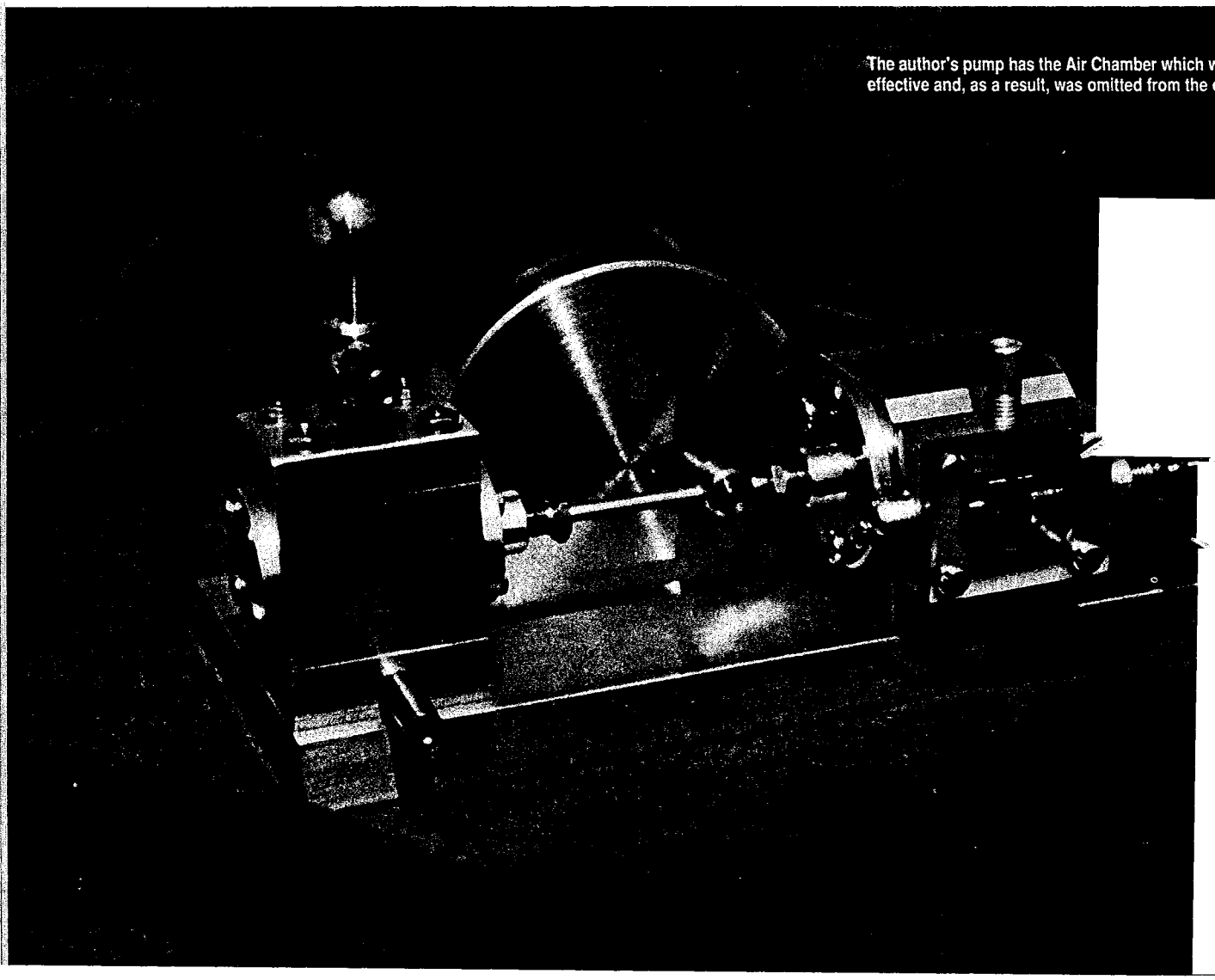
On the **STEAM CYLINDER**, the 3/4" height to the 5/8" bore must match the stack-up of the three pump parts.

The **CRANK ARM** shown was made by using a small ball-turning tool mounted on the lathe compound. The simplest method would be to purchase a ball from a supplier. Cole's Power Models lists bronze balls that can be attached to a rod as shown. Bore the Flywheel to a close fit on the ball.

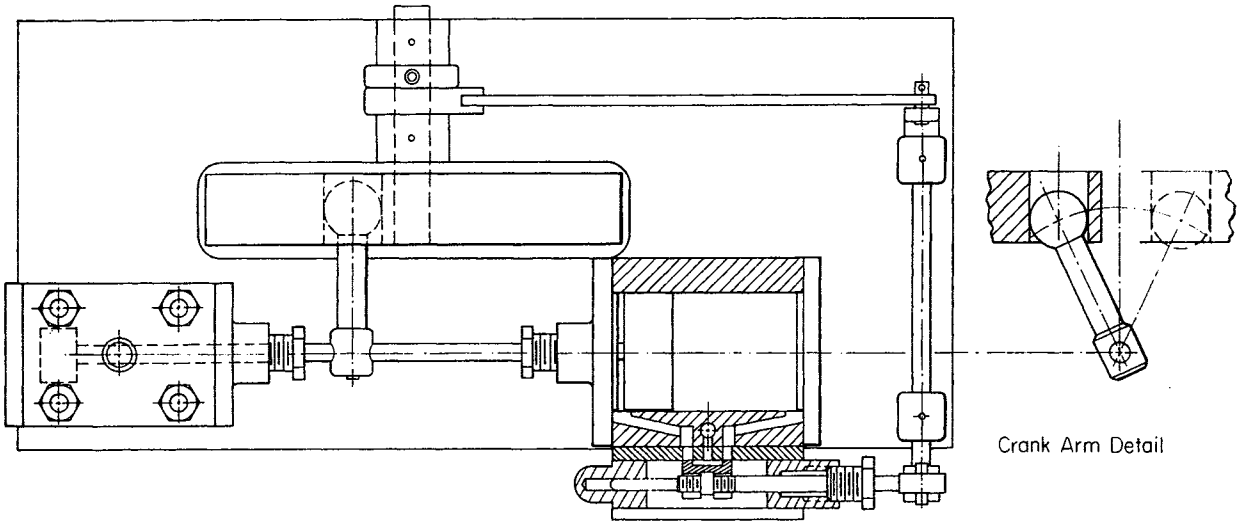
The **PISTONS** and **ROD** are simple. Quite a bit of thought was put into the Pump Piston. The model was to be run on compressed air, using 3/16" aquarium tubing, and it was to pump water. Then the problem of material and sealing suggested tiny cup rings and a two-piece Piston. All was put aside and a straight cylindrical Piston without rings or any fussing was used. The pumpage would be common medicinal mineral oil which is clean, a lubricant, non-corrosive, and odorless. It works fine! The oil used was labeled "heavy" but it would be better to use a lighter grade.

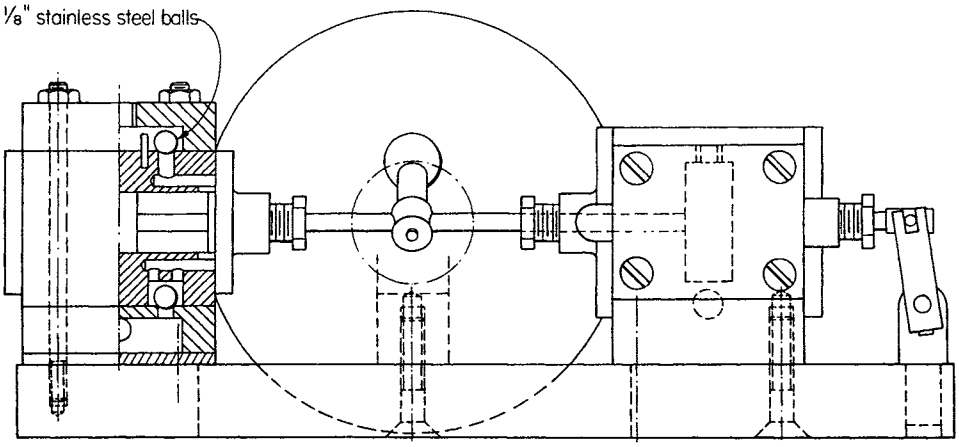
The **BEARING** is brass and the Eccentric is a close fit, acting as a collar to control the end-play in the Flywheel Shaft.

For the **ECCENTRIC**, turn to 1/2" diameter and bore the shaft. Mount a square-ended bar in the tool post and squarely bring it up against the 1/2" diameter. "Zero" the cross-slide collar and rotate the chuck so two jaws are horizontal. Loosen the ver-



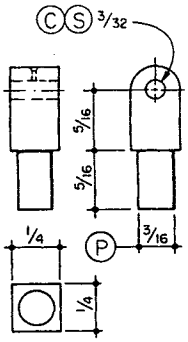
The author's pump has the Air Chamber which wasn't too effective and, as a result, was omitted from the drawings.



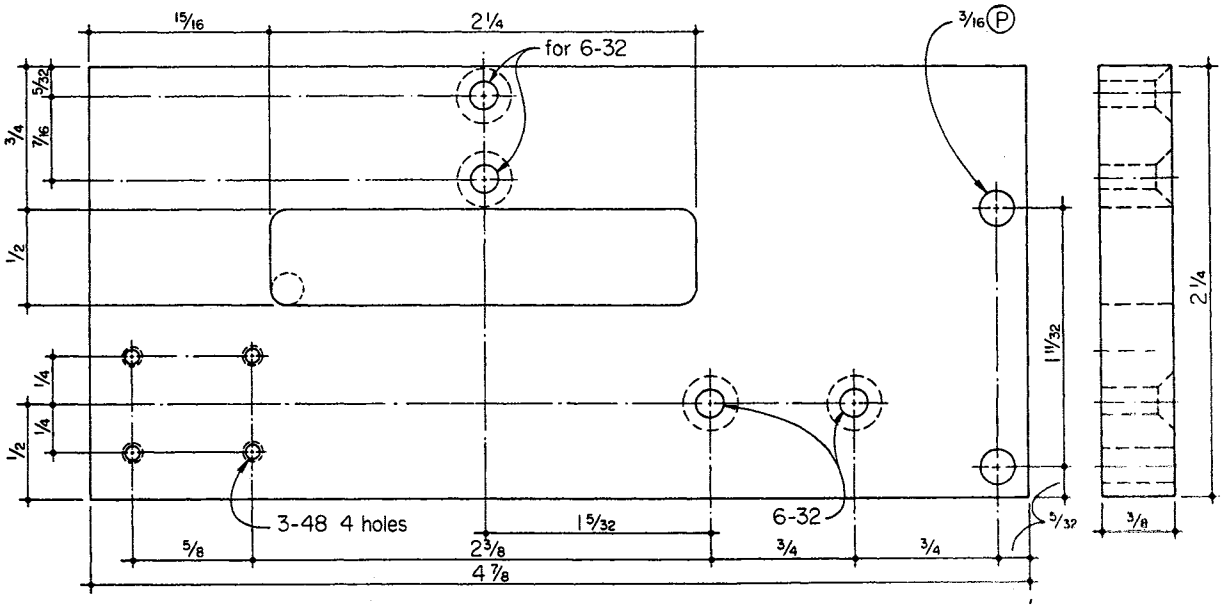


EV/jjw

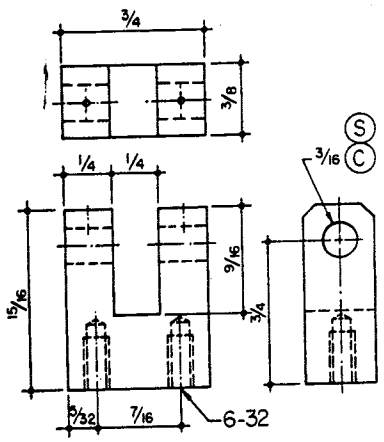
STEAM PUMP



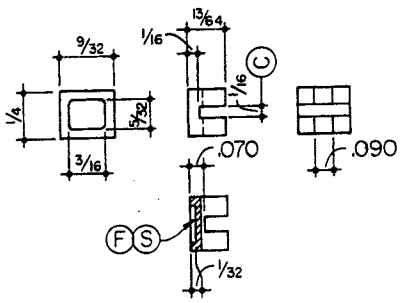
ROCKSHAFT BEARING
2 Required



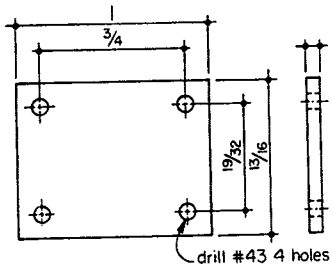
BASE



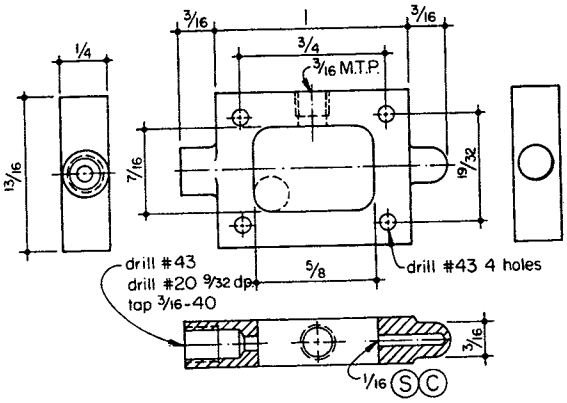
BEARING



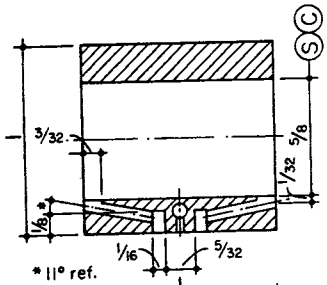
VALVE

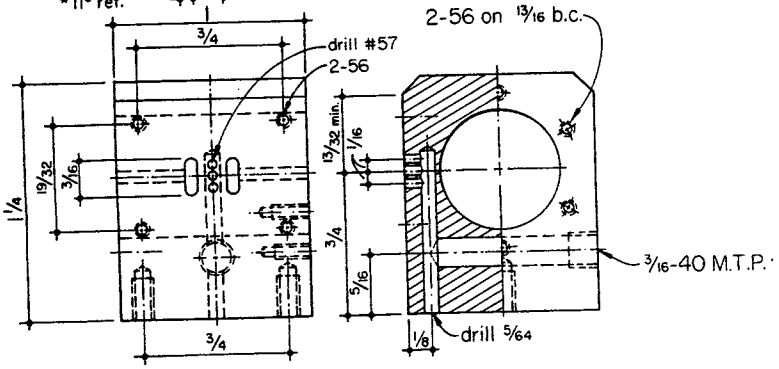


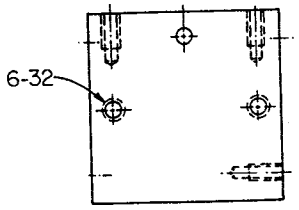
COVER



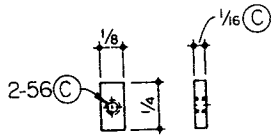
STEAM CHEST



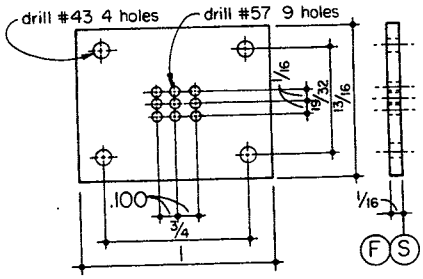




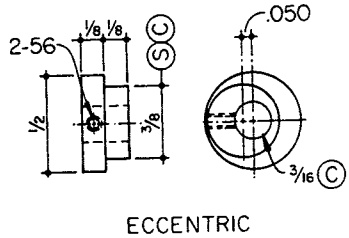
STEAM CYLINDER



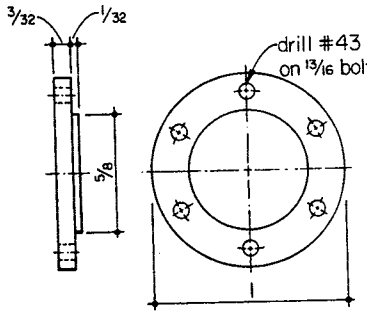
VALVE NUT



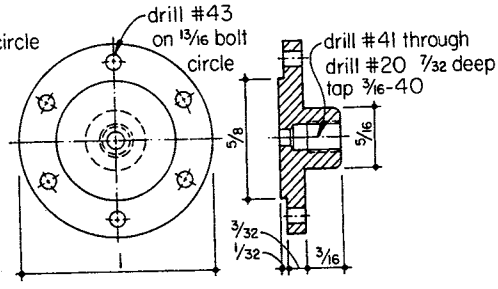
VALVE PLATE



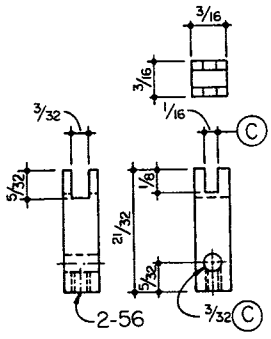
ECCENTRIC



OUTBOARD HEAD - STEAM

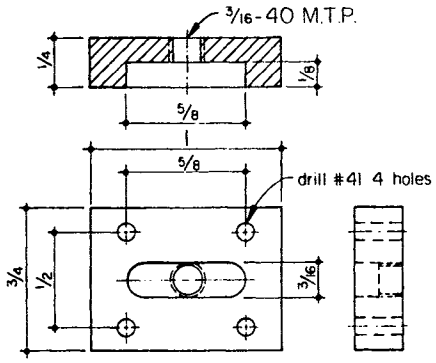


INBOARD HEAD - STEAM

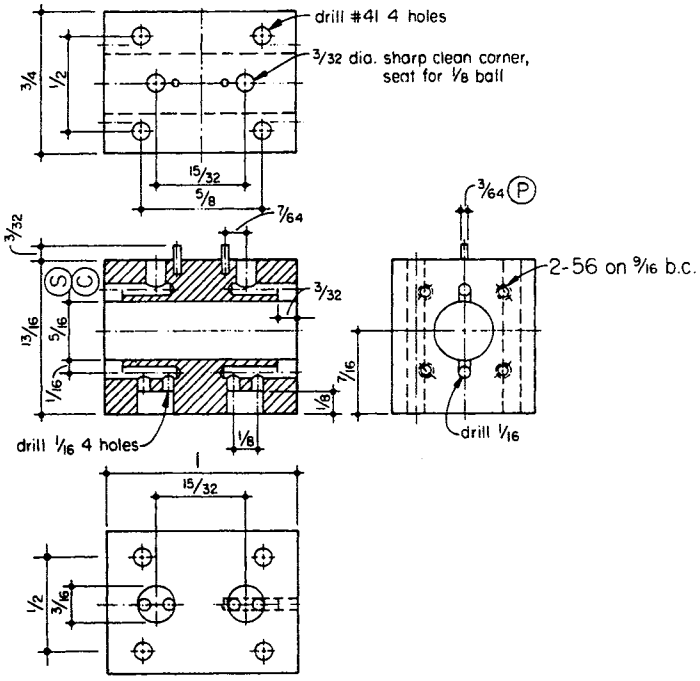


FORK

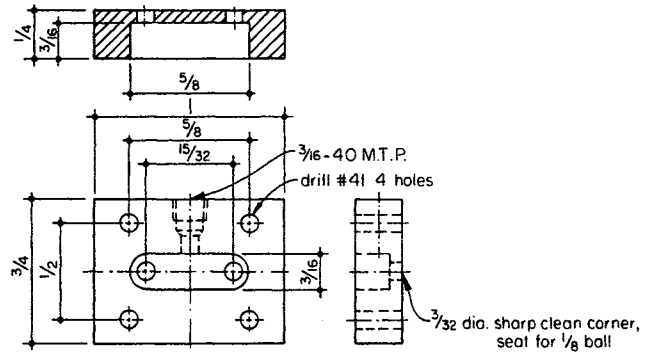
EW/jw



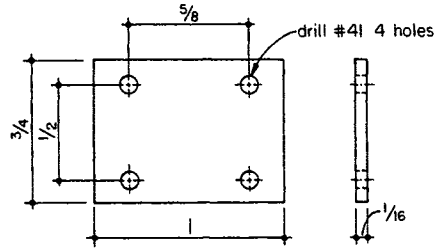
UPPER VALVE CHAMBER



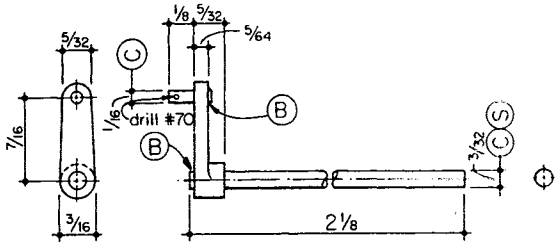
PUMP CYLINDER



LOWER VALVE BLOCK



EV/jw PUMP FOOT PLATE



ROCKER SHAFT

tical jaws slightly. Back up the rear jaw about 5/64" and feed the front jaw in, forcing the piece back about 1/16". Turn the cross-slide in .050" and ease the piece back against the bar, using the rear jaw. Now, when the high spot just kisses the bar and the chuck is rotated 180°, a .100" diameter rod should just pass between the bar and the stock in the chuck. Snug up all the jaws and turn the 3/8" diameter to a close fit in the Strap.

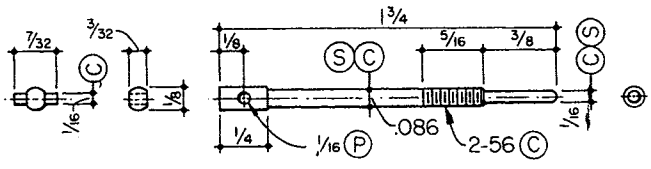
When making the **VALVE, VALVE ROD** and **NUT**, try for close but free fits. That is, the Valve should float on the seat, held there by steam pressure and not bind against the Rod. Try for a minimum of shake in the 2-56 threads.

On the **STEAM CHEST,** turn the gland end and, very carefully, drill the 1/16" hole — preferably with a new drill at a high spindle speed. Withdraw the drill very often and add a bit of "Liquid Wrench" each time. Counter-drill and tap 3/16-40. Carefully-drilled holes will have to serve unless you have reamers in these sizes.

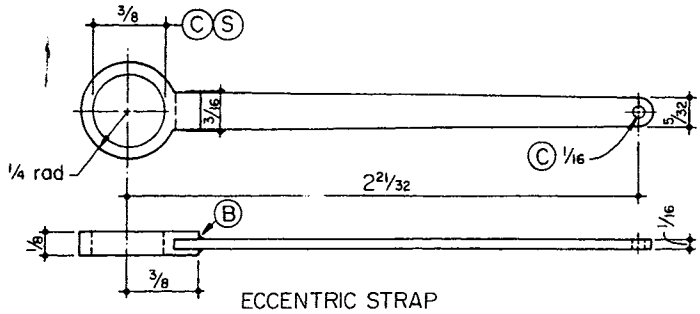
The **ECCENTRIC STRAP** is a brass end, bored and filed to shape and soldered to the flat bar. After soldering, dress the edges to a neat outline and locate the 1/16" hole 2-21/32" from the center of the 3/8" bore.

The **VALVE ROD** is made from 1/8" rod, chucked in the 3-jaw and supported by the tailstock center. Plan enough stock length for chucking and to cut away the tailstock center hole later. Mill the flats, drill and fit the 1/16" x 7/32" Pin.

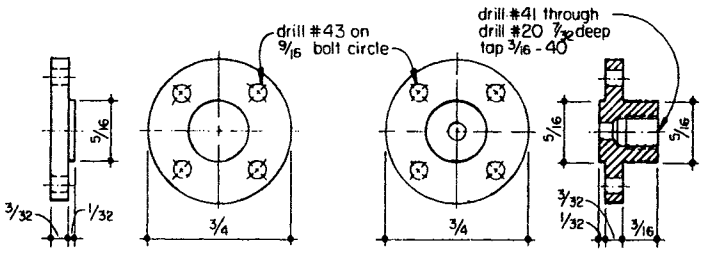
On the **PUMP CYLINDER**, the 3/16" diameter x 1/8" deep holes require a square-ended drill, **D** bit or an end mill. Try to hold the 1/8" depth, as it controls the amount the Ball Valves can rise. All the remaining holes are simple operations



VALVE ROD

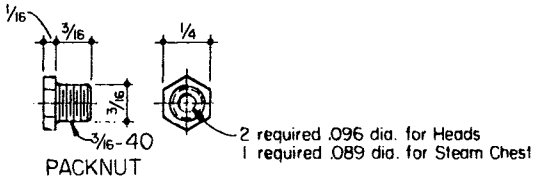


ECCENTRIC STRAP



OUTBOARD HEAD - PUMP

INBOARD HEAD - PUMP



PACKNUT

except the holes for the head screw. Take them very easy as they break into the tiebolt holes. You may have to file about 1/64" off the head screws. Stainless steel balls are used as Valves. The seats were made by using a hard steel ball, a bit of brass rod and tapped a light hammer blow. The 3/64" pins are required to keep the balls in the Valve area so they will always fall back onto the seat.

The **UPPER VALVE CHAMBER** is straight work with no problems. A 3/16" end mill is required. Again, hold the 1/8" depth.

The **LOWER VALVE BLOCK** requires seating as on the Cylinders.

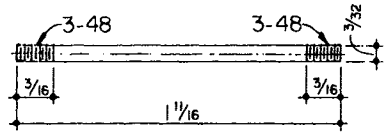
The **AIR CHAMBER** was an after-thought since Piston Pumps have a pulsating flow ... but it wasn't much of an improvement.

When setting the Eccentric, spot the Flywheel ball socket on the vertical centerline. Tighten the Eccentric with the centerline through the throw, 90° from the Flywheel socket centerline. That is, with the Piston at midstroke, the Valve should be at one end, completely exposing one set of Valve holes. For fine adjustment, turn the Valve Rod 1/2 turn and rotate the Flywheel each time until the Valve holes are equally exposed at each end of the stroke. A final tiny bit can be adjusted by rotating the fork on the Rock Shaft.

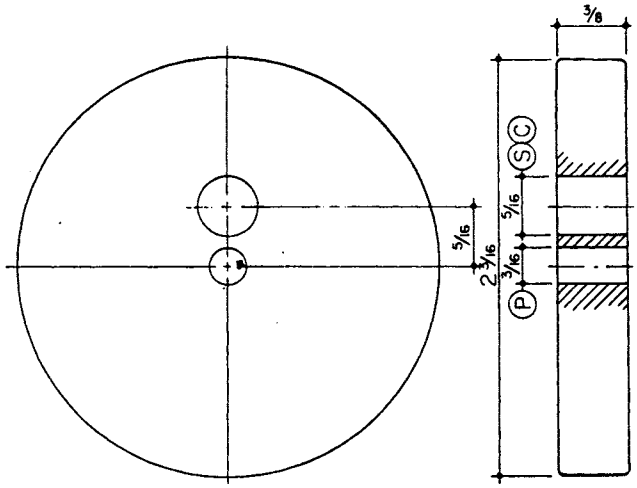
The 5/8" Steam Piston has four times the area of the 5/16" Pump Piston, resulting in 1 psi of steam exerting between 3 and 4 psi on the Pump.

On trial, about 5 psi of air ran the Pump with a fair flow of oil.

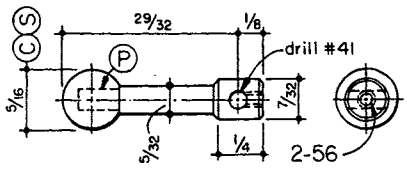
Here's another project to keep you busy for a few evenings ... and it will fascinate you and your friends for hour after hour in the years to come.



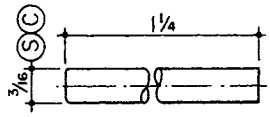
TIEBOLT - 4 required



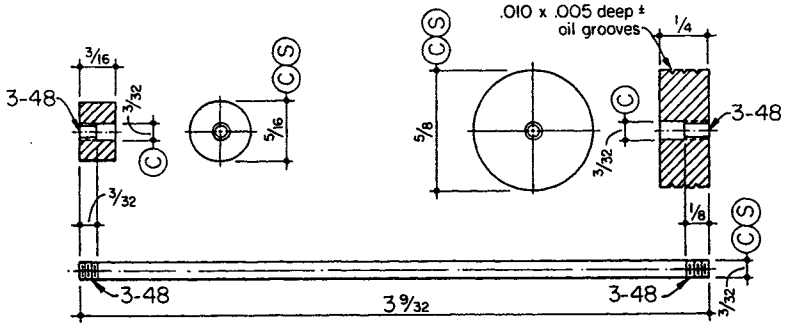
FLYWHEEL



CRANK ARM



SHAFT



PISTONS AND ROD

EV/JJW

CHAPTER

36 Vertical Reversing Wobbler

This engine is about the right size for a 2- to 3-foot boat. It isn't too easy to make an engine reversible but the type of reversing valve here is a common type. The Column is complicated by a bit of drilling and plugging, though not difficult if you make accurate layout lines. It has a 5/8" bore and 3/4" stroke with simple drilled holes for ports. It is double acting.

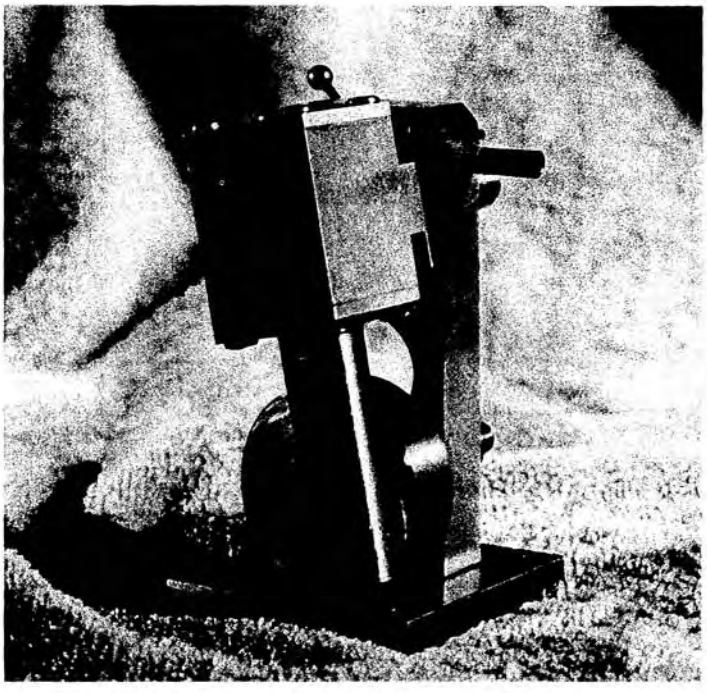
All the simpler parts that are straight machine shop practice will not get any mention here.

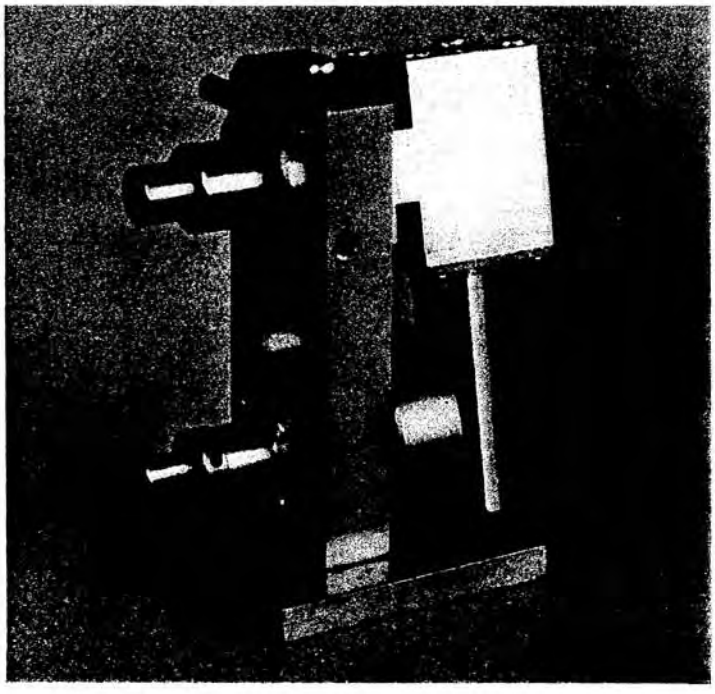
The **CYLINDER** starts as an accurate 1" x 1-1/4" x 1-3/8" block. Lay out all the centerlines and surface lines on all five faces. You may choose to use the heads as jigs for spotting for the eight bolt holes. The port holes are located with the drill jig. Chuck the block in the 4-jaw, centering on and machining the Pivot Shaft Hole. If necessary, make a very light skin cut on the face to square it up with the pivot hole. Turn the flange to 1/16 thick down to the 1-3/32" diameter. Use a protective pad on this face and chuck, centering on the 5/8" bore. The faces will not quite clean up so go back and rotate the chuck by hand and feed the bit in with a "shaper" motion the way Kozo Hiraoka makes a halfround in the lathe. Cut away the four small corner points and bore a smooth 5/8".

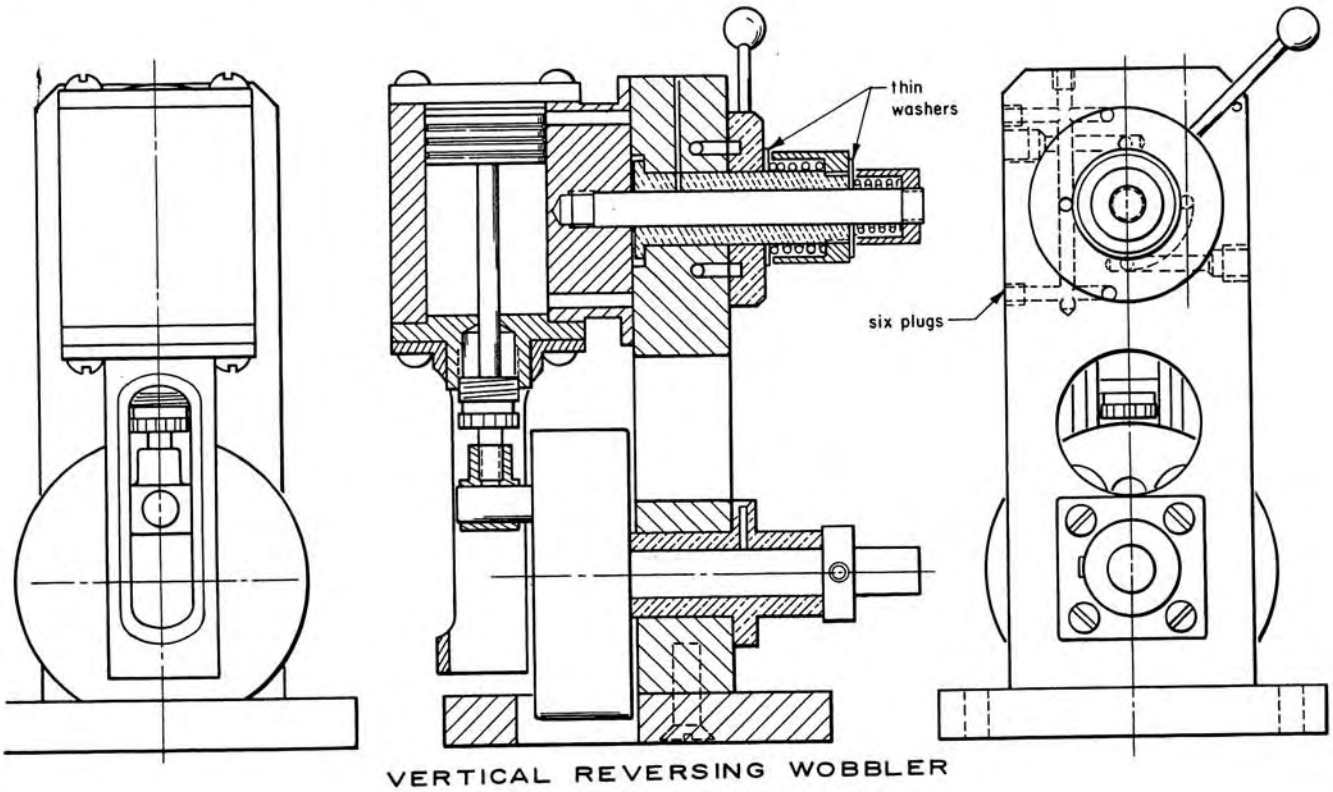
When the Inboard Head, Piston and Rod, Crosshead and Guide, Drill Jig and Pivot Shaft are complete, assemble, and drop the Jig over the Pivot Shaft. Run a 3/16" pin through the Jig and Crosshead. Drill the two 5/64" port holes. The Pin and Shaft must be close fitting in the Jig for accuracy of port location.

The **COLUMN** shown is a hard fixture-grade aluminum, anodized. Steel would be good for this part. The flatness and finish were OK on both surfaces. Here again, make a complete layout of all centers. Center in the Lathe with face running true for the Pivot Bearing Hole and for the Crank Bearing Hole. The 3/4" hole is optional and can also be done neatly in the lathe.

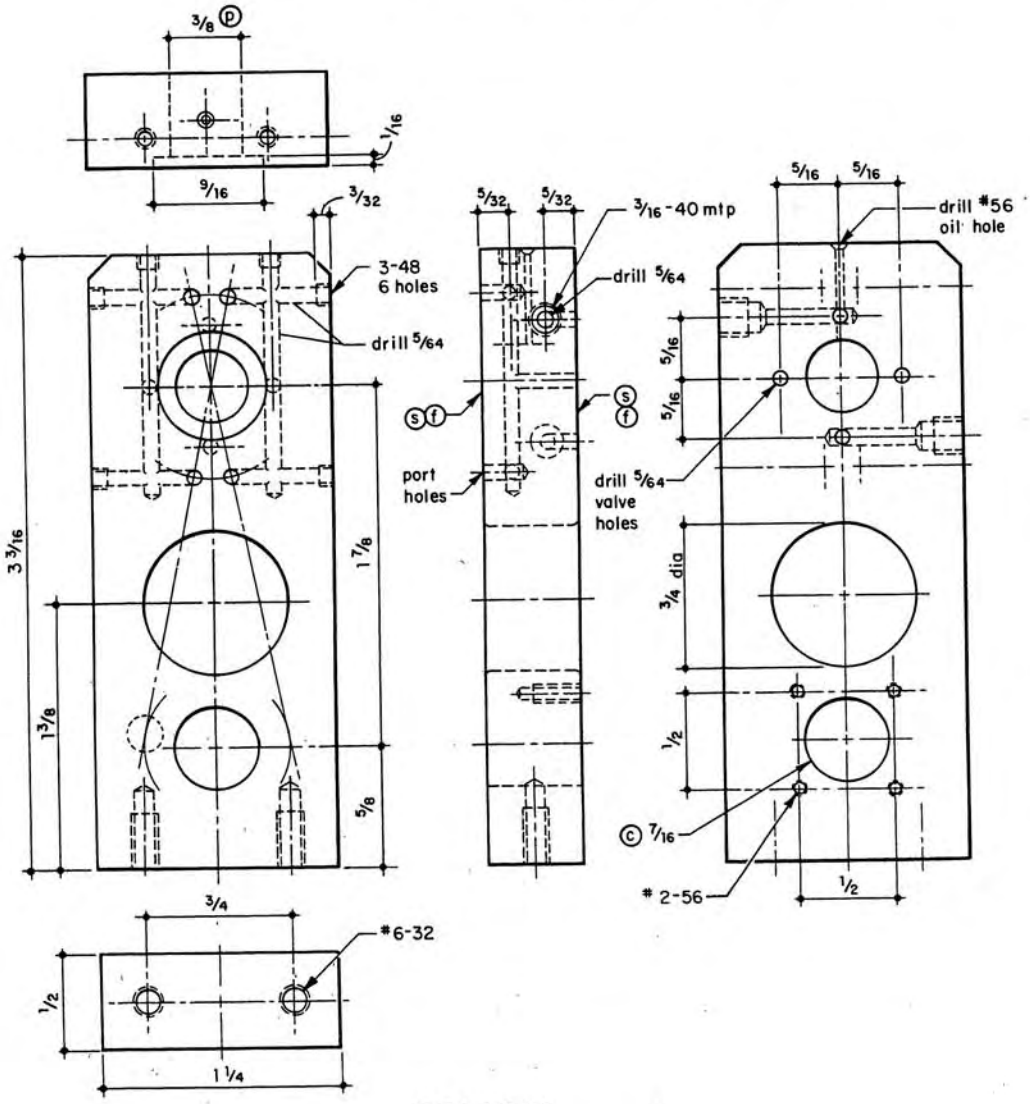
Make the Pivot and Crank Bearings. If you intend to use live steam, it might be best to try for a good press-fit for the Pivot Bearing since the heat may affect the Loctite. Insert close-fitting 3/16" and 1/4" pins in the bearings and place the Jig over the 3/16" pin and against the 1/4" pin. Hold the Jig tight against the 1/4" pin while drilling two of the port holes. Turn the Jig over and do the same for the other two port holes. Drill these about 1/4" deep. Drill the deep vertical 5/64" holes. Pick up the centers of these port holes and transfer around onto the edge of the Column; then, drill and tap 3-48 the horizontal holes to the port holes. Drill the 5/64" horizontal steam connection holes 11/16" deep and tap 3/16-40. Drill the four 5/64" valve holes. When all the machining is done and there is little danger of chips getting into the passages, plug the six places with short pieces of 3-48 threaded rod using a bit of gasket cement. Cut off and dress smooth and flush. If you thread a .099" diameter rod with 3/32" of thread and jam the metal home, the plugs will barely show after dressing. Complete the remaining holes and clean up the Column and polish. Check for flatness and smoothness where the Cylinder and Valve rub. This is a metal-to-metal seal and may require lapping. Enamel the surface inside the 3/4" ornamental hole with



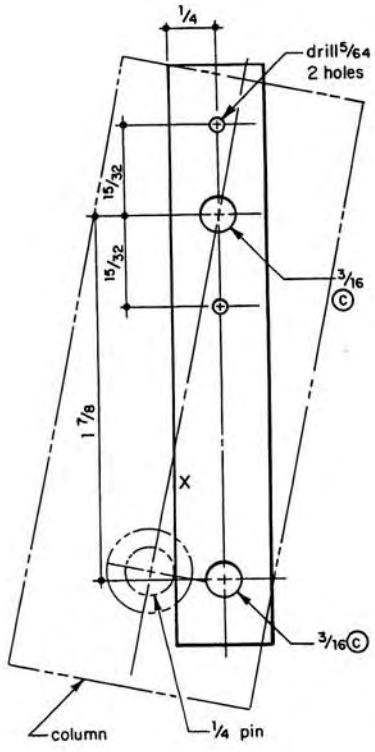




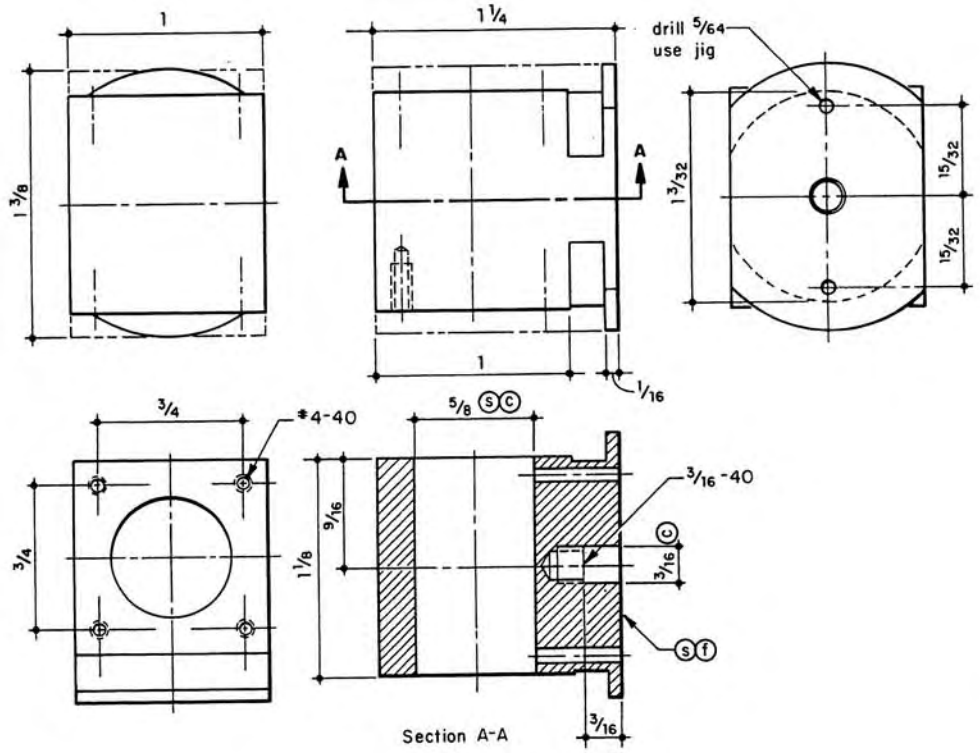
VERTICAL REVERSING WOBBLER



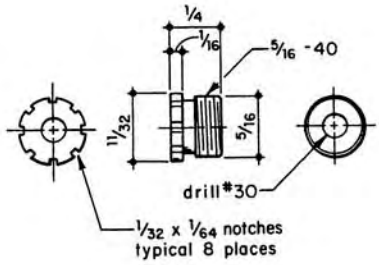
COLUMN



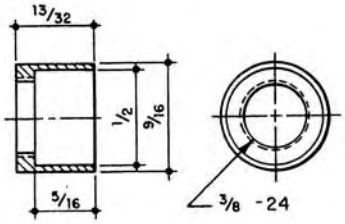
DRILL JIG



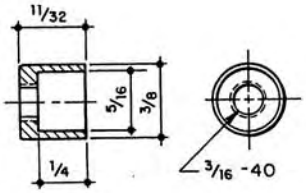
CYLINDER



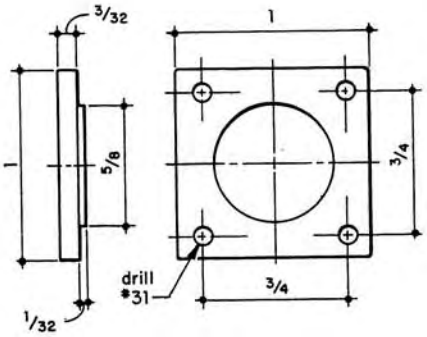
PACKNUT



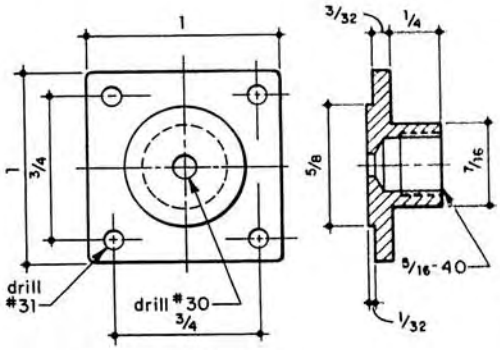
VALVE NUT



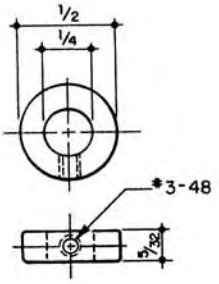
PIVOT NUT



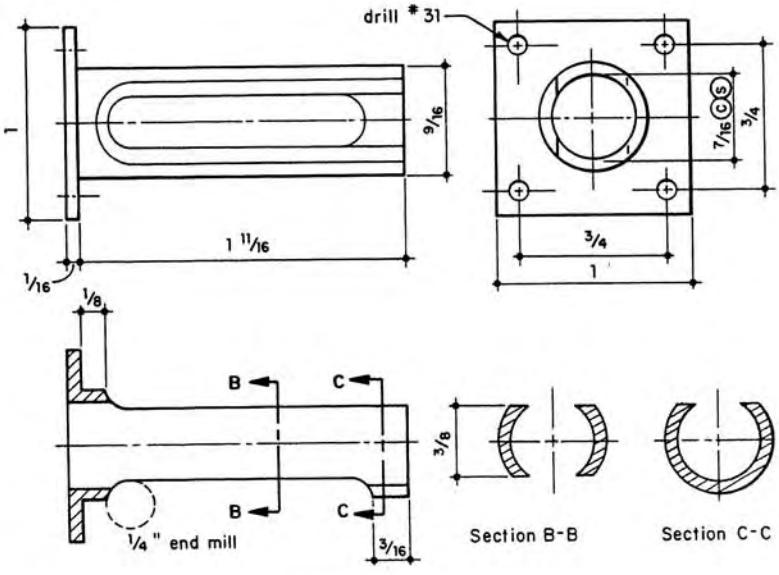
OUTBOARD HEAD



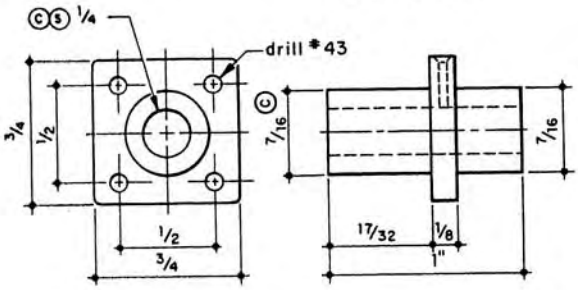
INBOARD HEAD



COLLAR

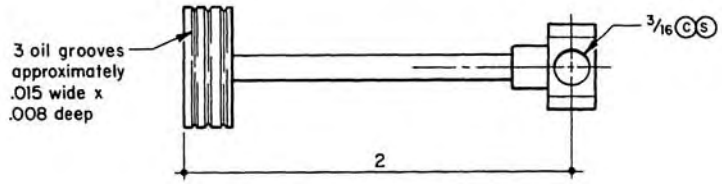


CROSSHEAD GUIDE

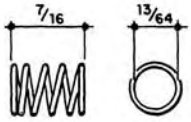


CRANK BEARING

(s) smooth	(f) flat
(c) close fit	(p) press fit or "loctite"

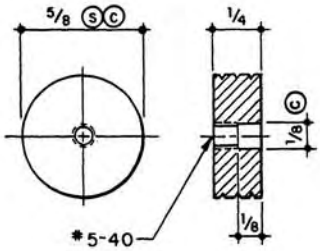


PISTON ROD ASSEMBLY

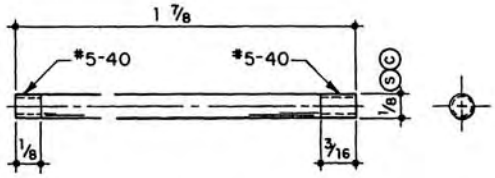


approximately 7 coils
.040 wire

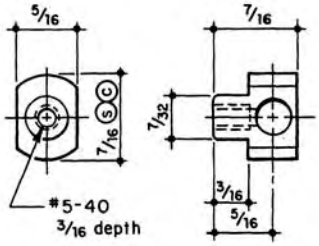
PIVOT SPRING



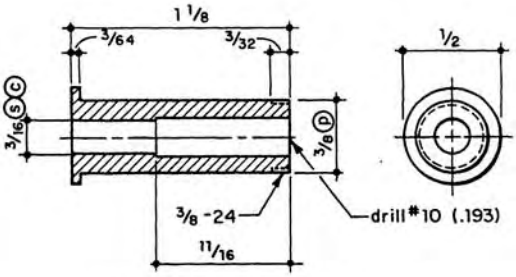
PISTON



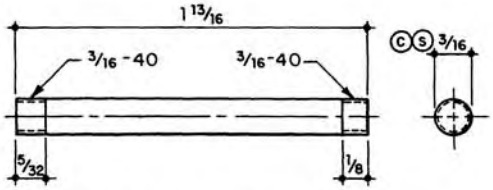
PISTON ROD



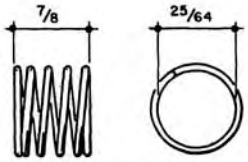
CROSSHEAD



PIVOT BEARING

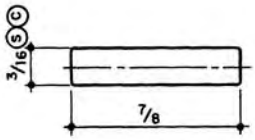


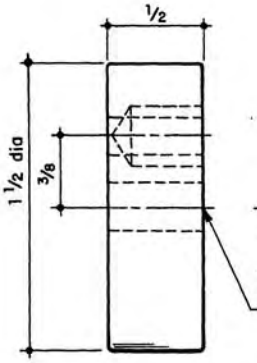
PIVOT SHAFT

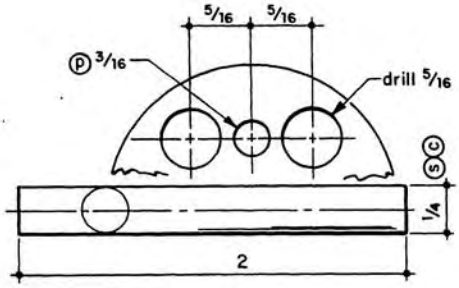


approximately 5 coils
.045 wire

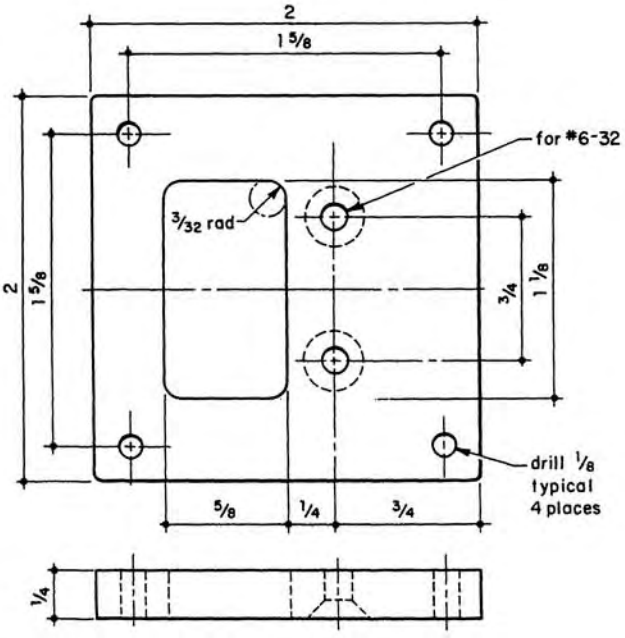
VALVE SPRING



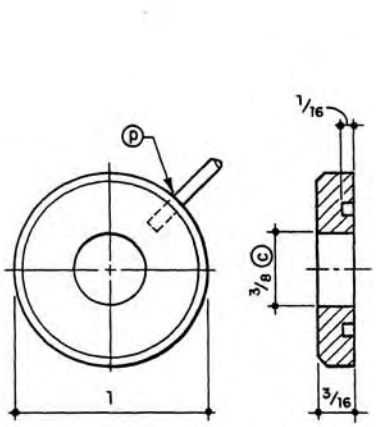


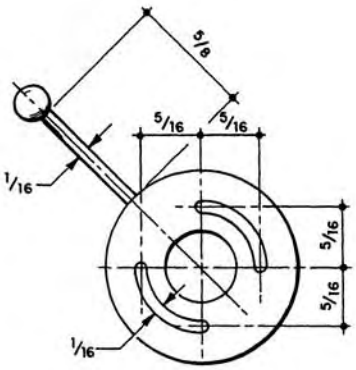


FLYWHEEL—CRANKSHAFT



BASE





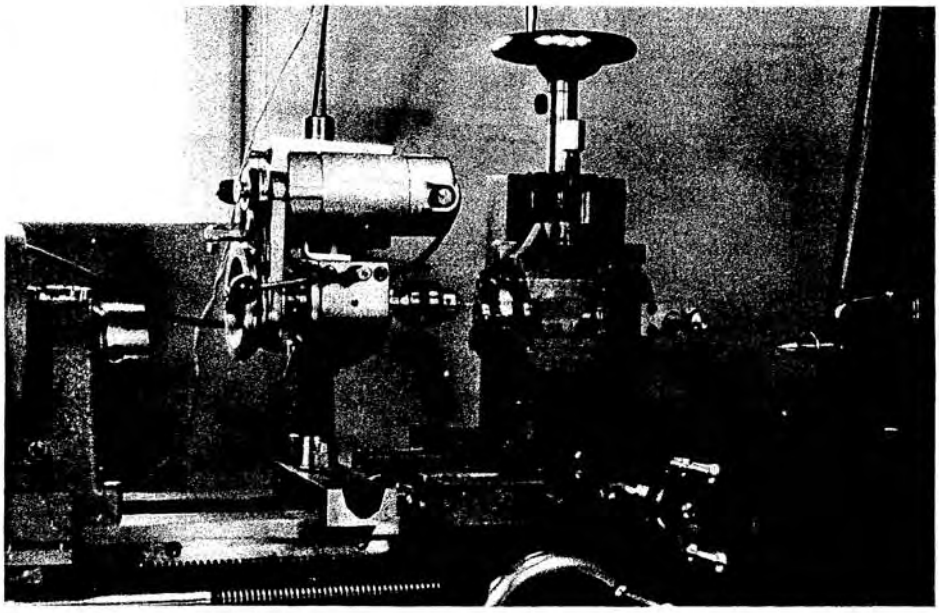
REVERSE VALVE

some bright color of your choice.

The **CROSS HEAD GUIDE** can be two pieces hard soldered together or cut from the solid, though it makes a lot of valuable metal into chips. The axis of the Cylinder Bore should be exactly on the axis of the Cross Head Guide, so squareness and concentricity are important on the Piston, Rod, Crosshead, Inboard Head and this Guide.

The **SPRINGS** are from the scrap box and the dimensions shown are the proportions finally used. You can do a bit of cut-and-try from your collection.

The curved tracks in the **REVERSING VALVE** were first drilled 1/16" deep at each end at the 5/16 dimensions shown and then milled with a 1/16" end mill. The photo shows a set-up that may be interesting to you. A heavy 1" x 2" x 7-1/4" steel bar was slotted and fitted with a stud and clamp to anchor to the bed ways. A socket was added at one end to take the milling column of the Unimat SL lathe. The lathe head was mounted with the 1/16" end mill in the drill chuck. An indexing block, using the Unimat chuck and lathe change gear, was mounted in the cross slide milling attachment. The gear was used as a handwheel to rotate the work. About four passes were made to get a 1/16" + depth. It was not difficult to turn by hand.



Milling the steam passages in the Reverse Valve

This same indexing feature was used to make the eight notches in the **PACKNUT.**

A short tiny shoulder pin was used in the 5/64" Valve hole in the Column and a 1/16" diameter end made to enter the grooved passage in the Valve. (Don't make it too short and lose it in a blind hole in the column.) Turning the Valve to the two extremes will help you spot the location of the two stop pins. Spot them well up in the corner so as not to break into a steam passage.

The **PACKING** is 1/16" strands of unraveled braided graphited asbestos packing. Do not set up too tight. Add a drop of oil.

This turned out to be a fairly powerful and compact engine. It will idle along on as little as 5 psi air. Like all single cylinder engines, it has to be nudged to start if it has stopped on dead center.

SAFETY FIRST

KEEP EVERYTHING IN ORDER

CHAPTER

37 Grasshopper Engine

This engine is a beam type with linkage suggesting the looks and motion of a grasshopper. The layout here is a simplified version and quite easy to build. One important thing about this is that the Links must equal one-half the distance between the end holes in the Beam. The centerline of the pivot holes for the Links at the Column Fork must be on the Cylinder center. A few items will be mentioned to help get you going.

When making the **BASE,** take care at the notch made to take the **LEG**, and in drilling the two pin holes in the Leg. If you have made close fits all around but the milling and drilling are not quite square, the Beam may not center in the Fork. Opening the holes a few thousandths may be all you need. If the "off-center" is greater, a solution, (which good machinists hate to admit) is to mount the Leg in the vise and, using a wrench with padding, give the leg a few thousandths twist. The few are amplified about 4-1/2 times so it won't take very much.

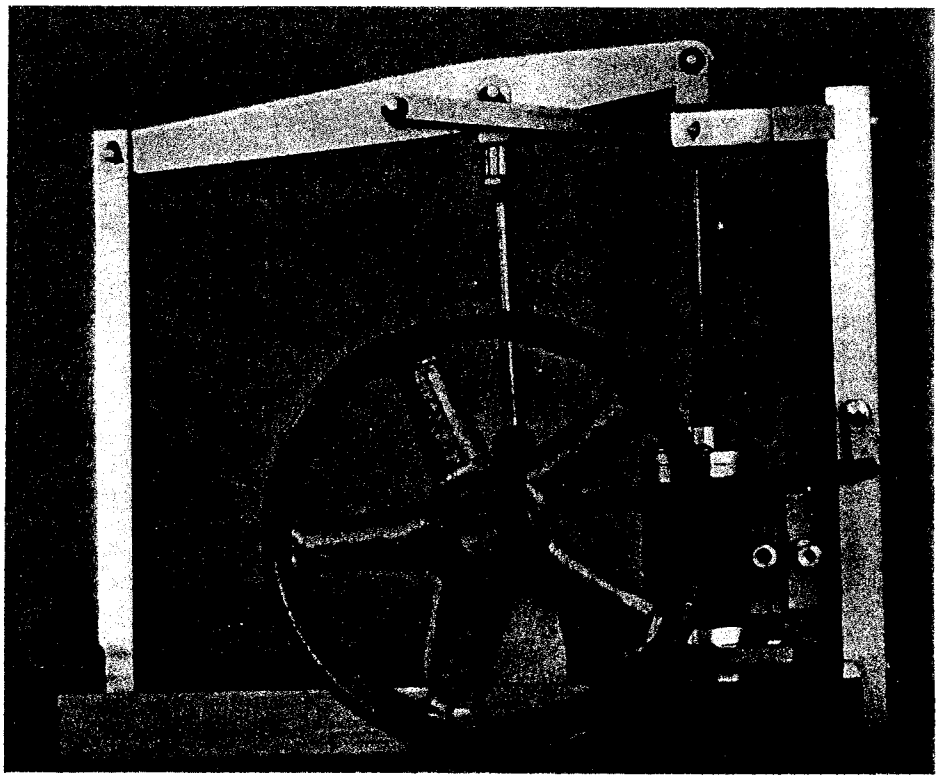
The **BEARING** Blocks are tapped 5-40, and the Shaft center laid out and center punched on one piece. Both Bearings are squarely mounted on the Base and this assembly sqaurely mounted in the milling vise. The Shaft center is picked up with a wiggler, drilled in easy stages and finally line-reamed to size. Bushings are optional here. Mark so each Bearing can be returned to the position it had when reamed.

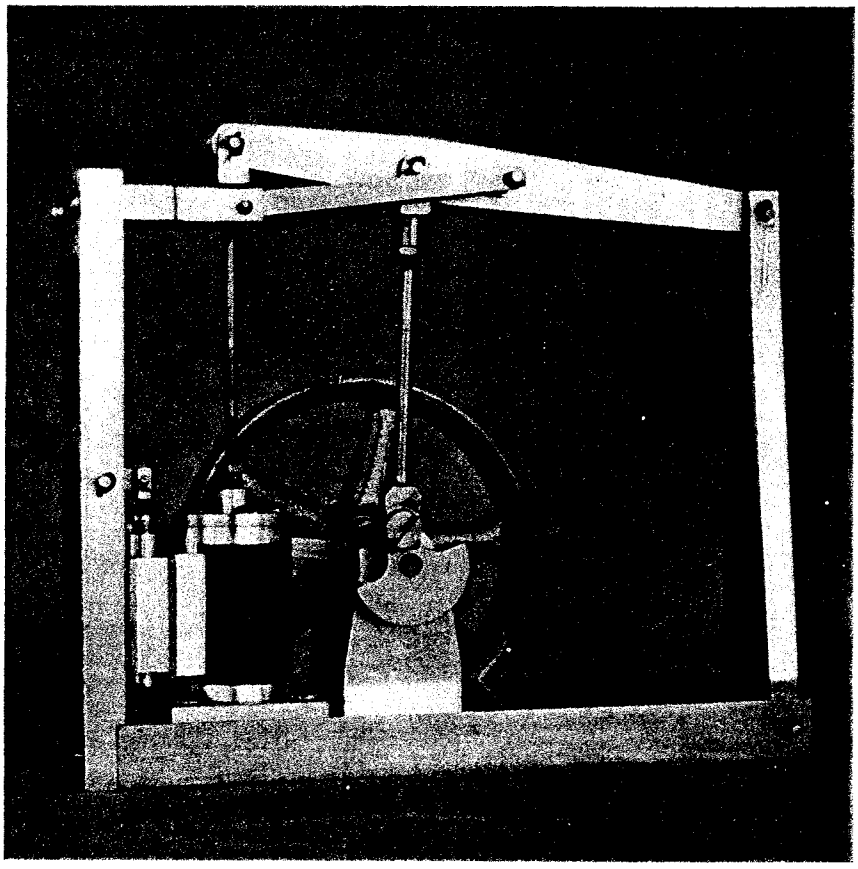
Construction of the **CYLINDER (Type F)**, the **STEAM CHEST, VALVE, ECCENTRIC**, and **FLYWHEEL** are described in the Appendix.

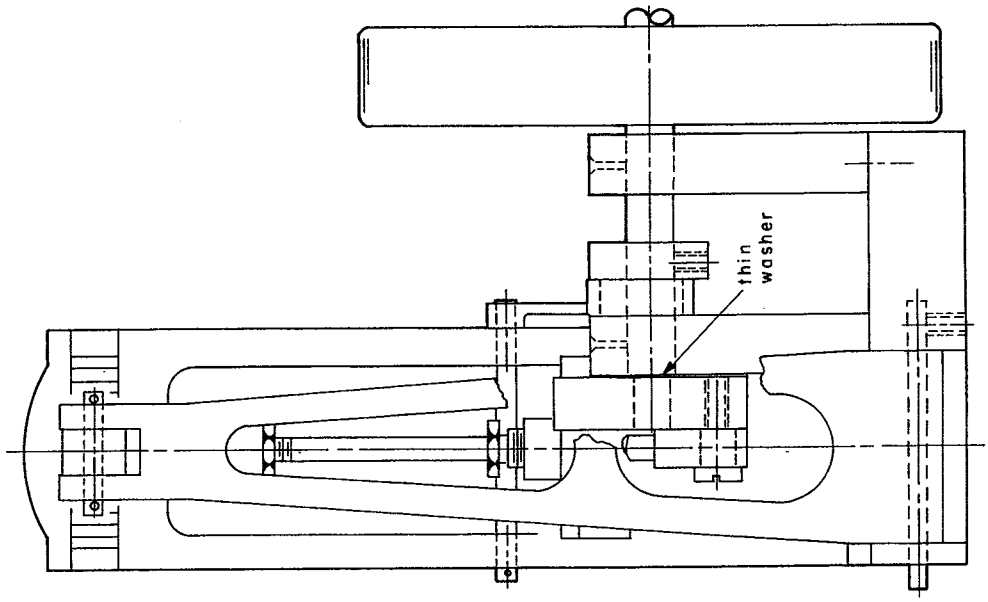
The **LAGGING** is thin stock traced from a heavy paper pattern made by cut and try. Roll the metal to a diameter smaller than the flanges and carefully spring into place.

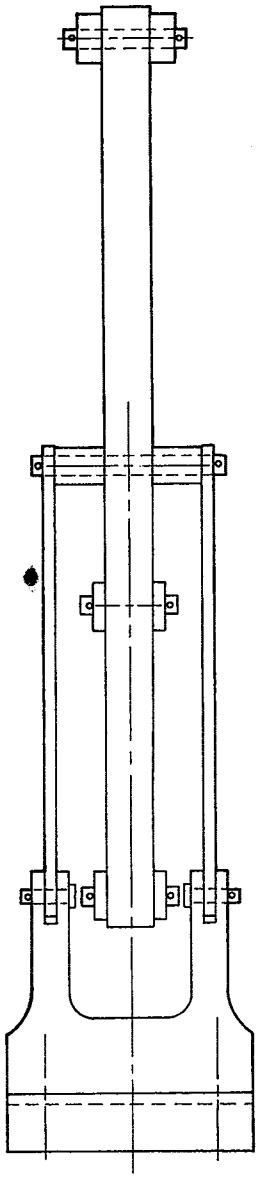
Both **CONNECTING ROD** and **PISTON ROD** are provided with adjustment to make the Piston travel midway in the Cylinder length.

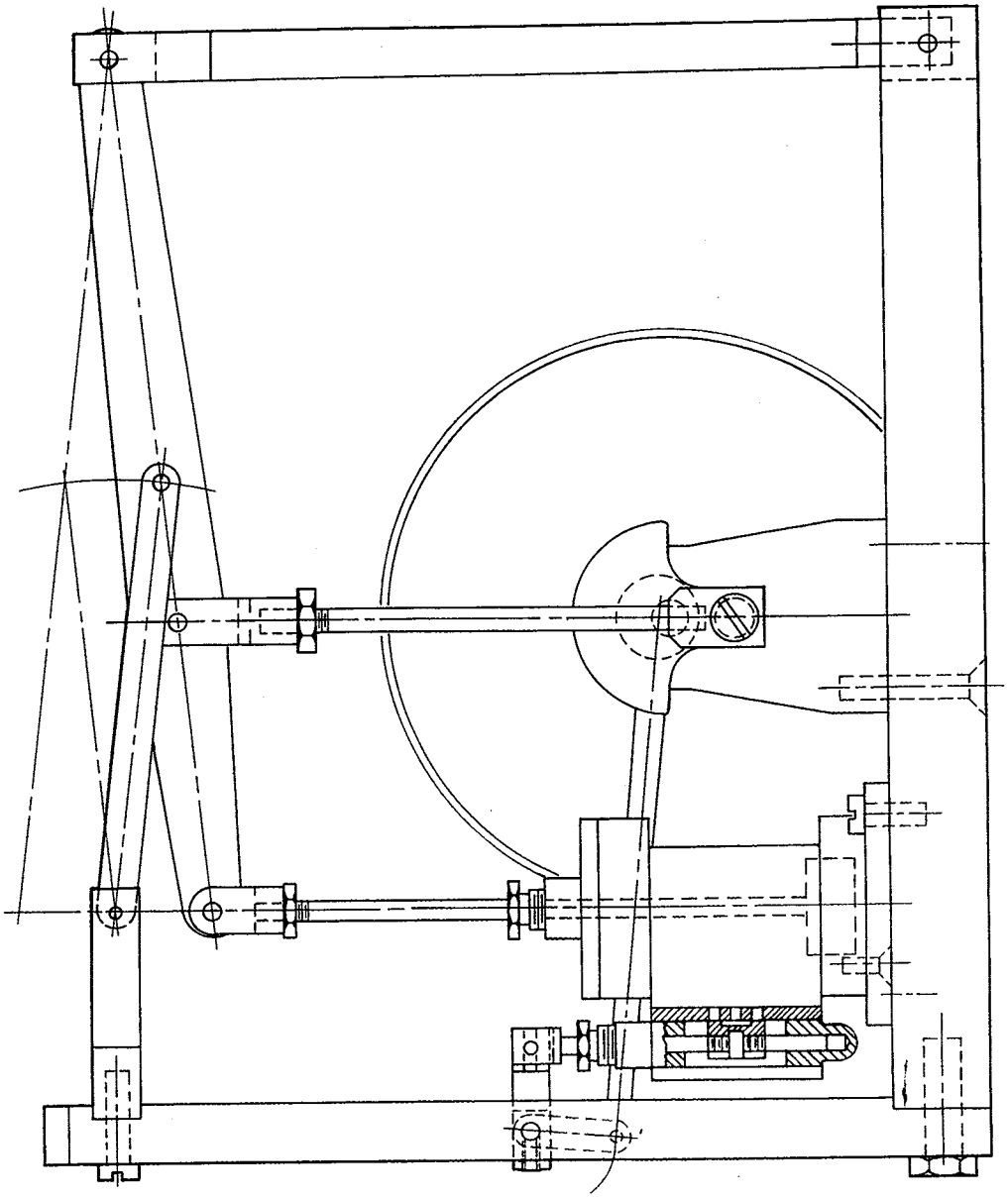
The **PACKING** is 1/16" strands unraveled from braided asbestos

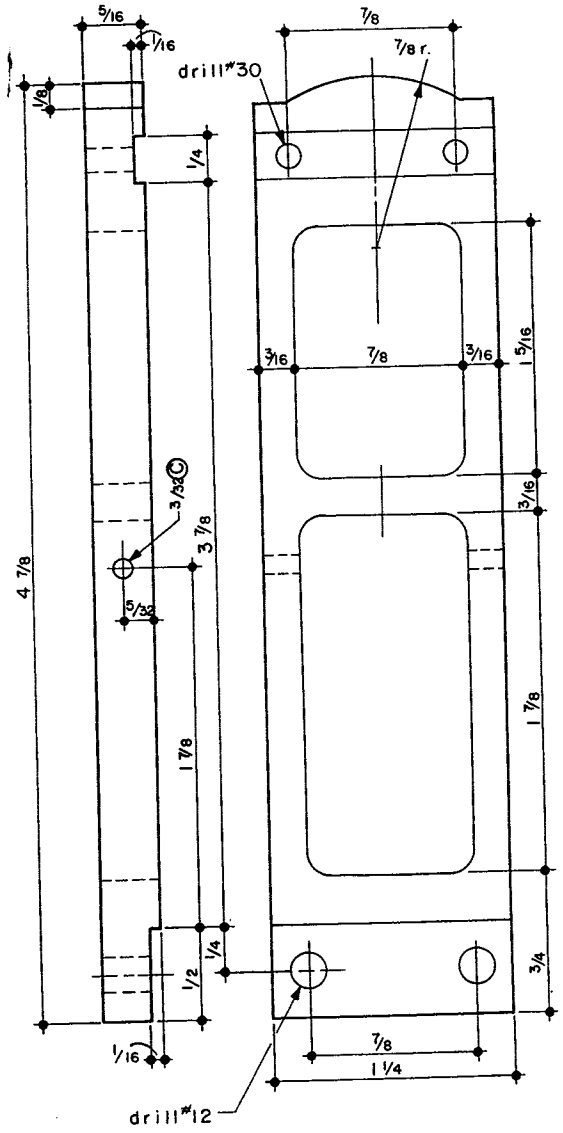




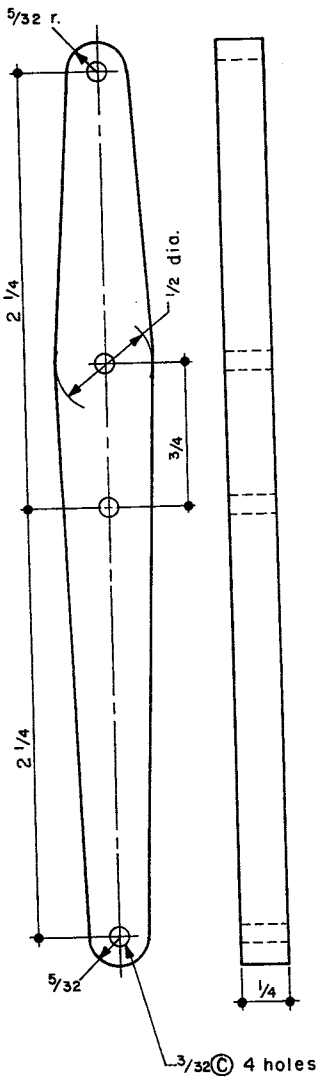

thin
washer



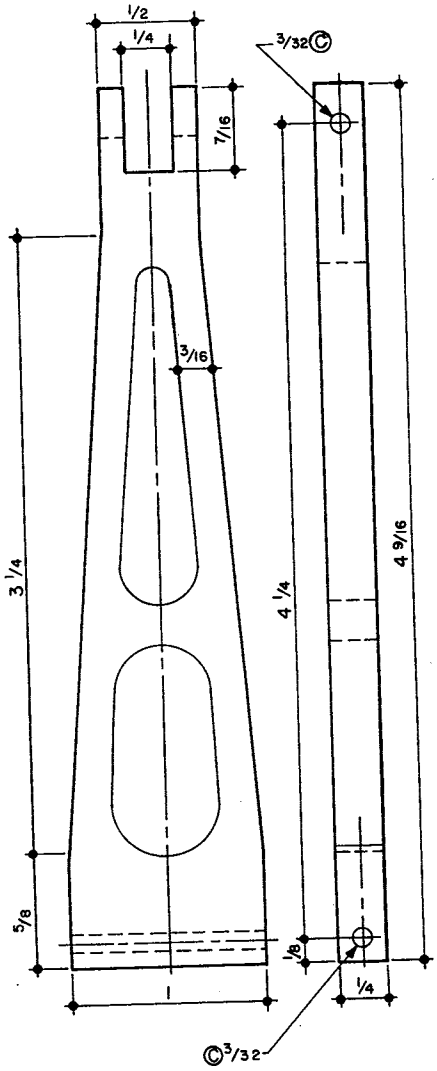




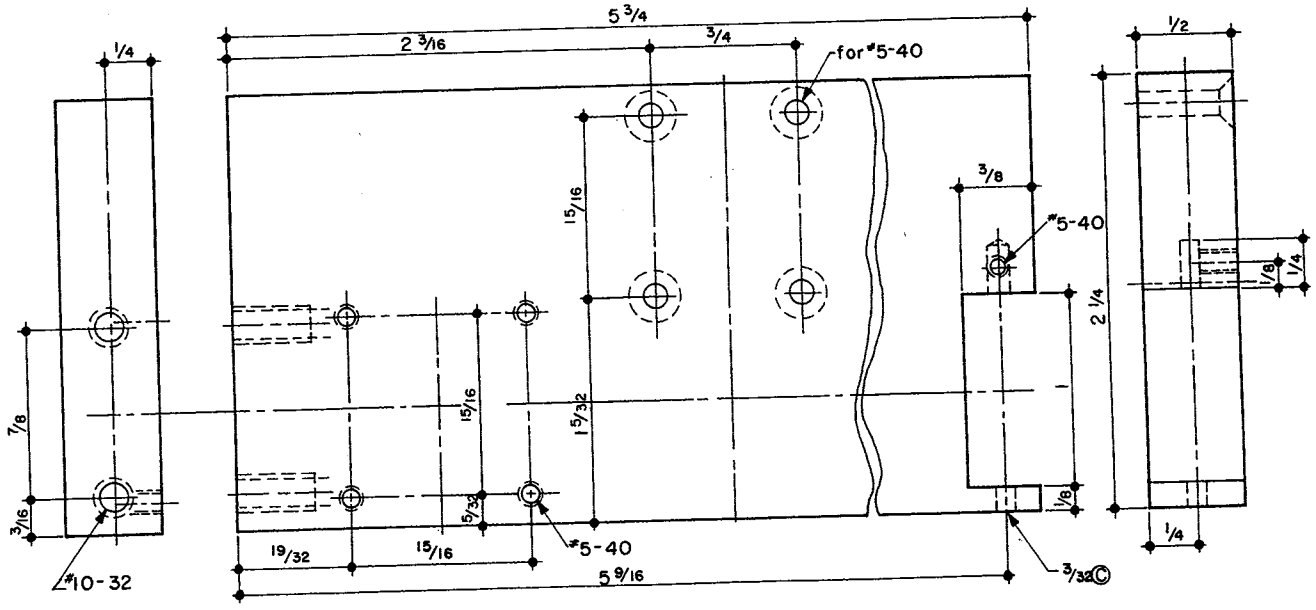
COLUMN
Aluminum



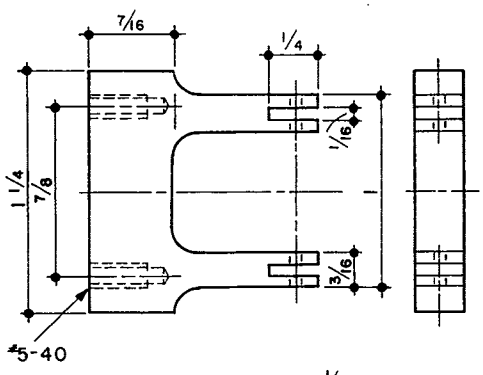
BEAM
Aluminum

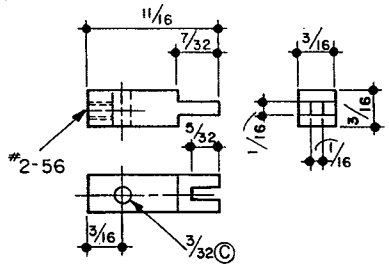


LEG
Aluminum

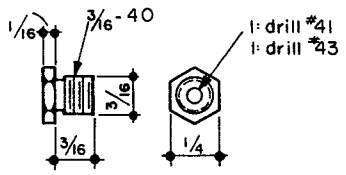


BASE
Steel

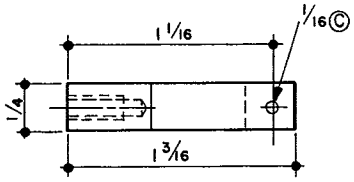




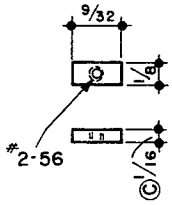
FORK
Brass



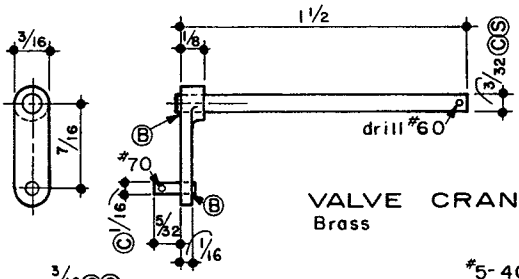
PACKNUT
Aluminum
2 Required



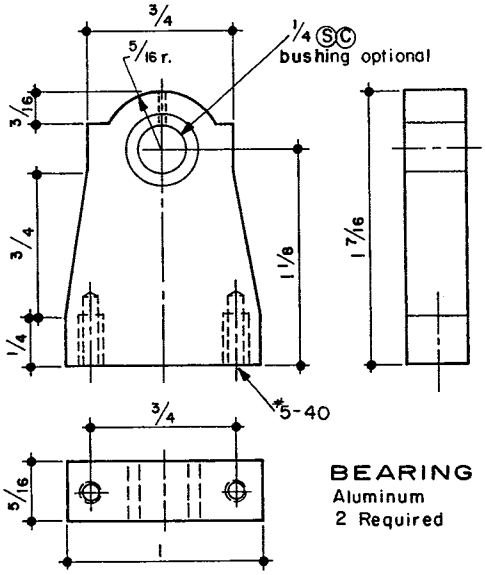
COLUMN FORK
Aluminum



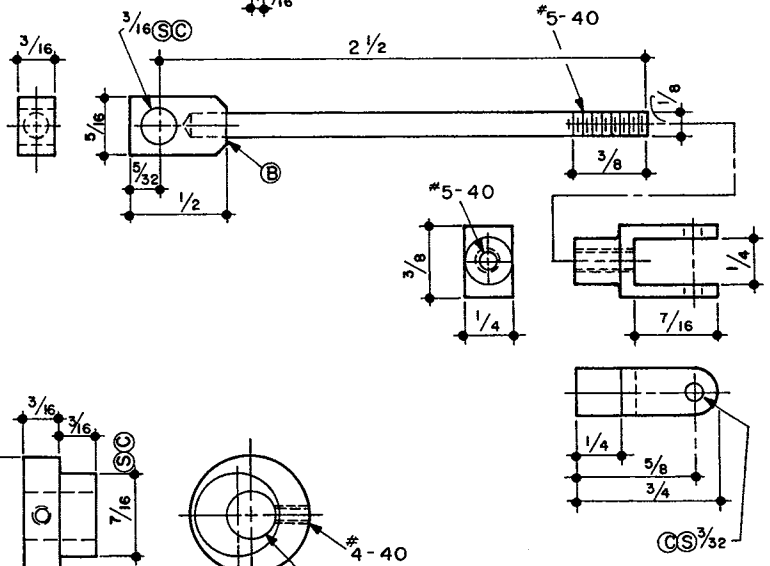
NUT
Brass



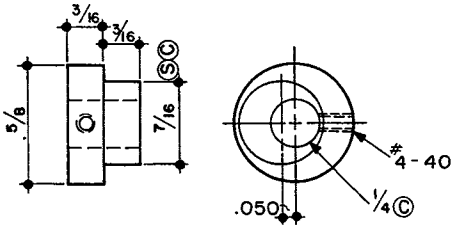
VALVE CRANK
Brass



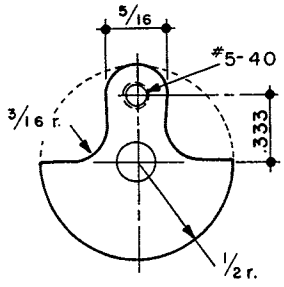
BEARING
Aluminum
2 Required

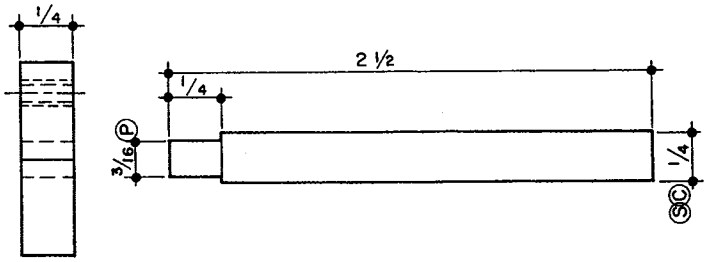


CONNECTING ROD
Brass

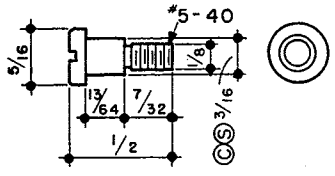


ECCENTRIC
Steel

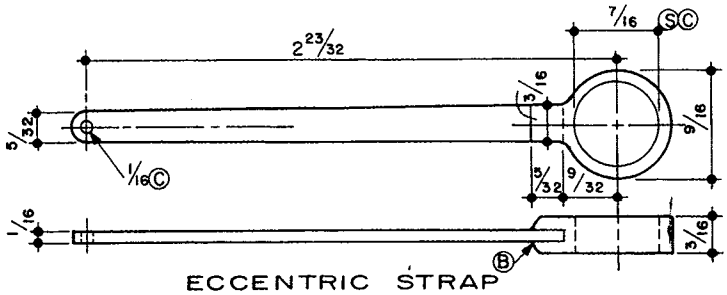




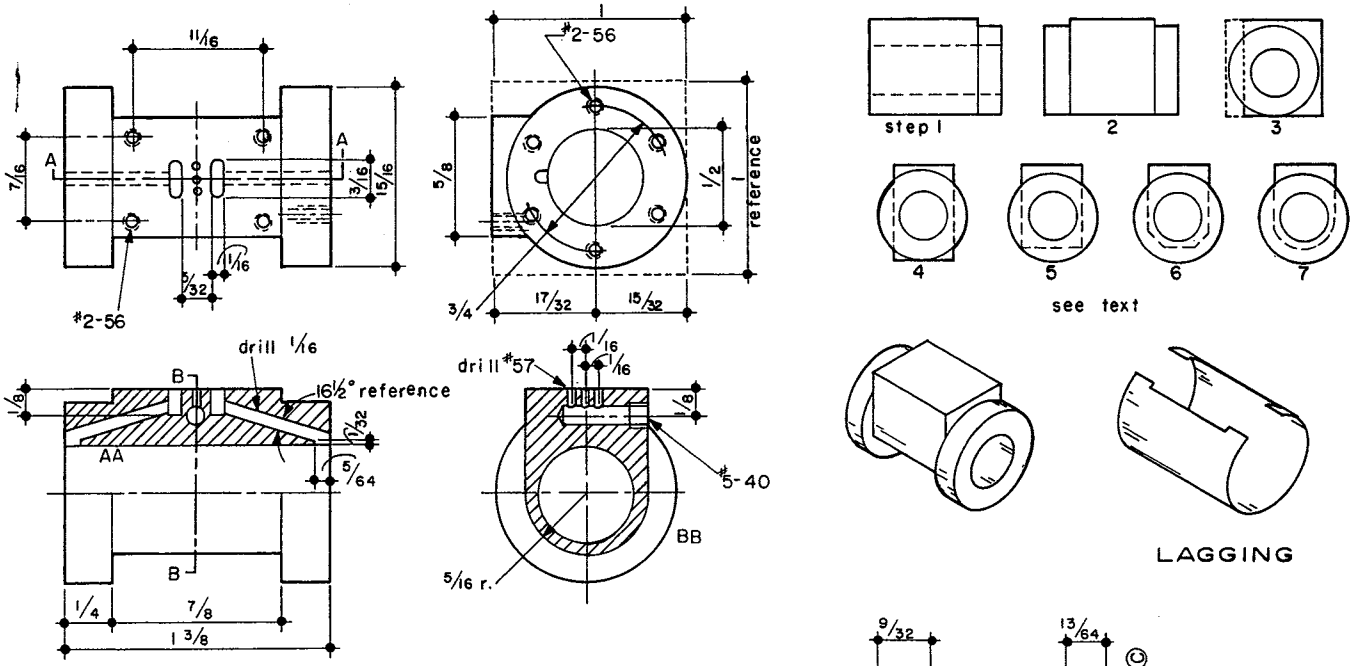
CRANKSHAFT
Steel

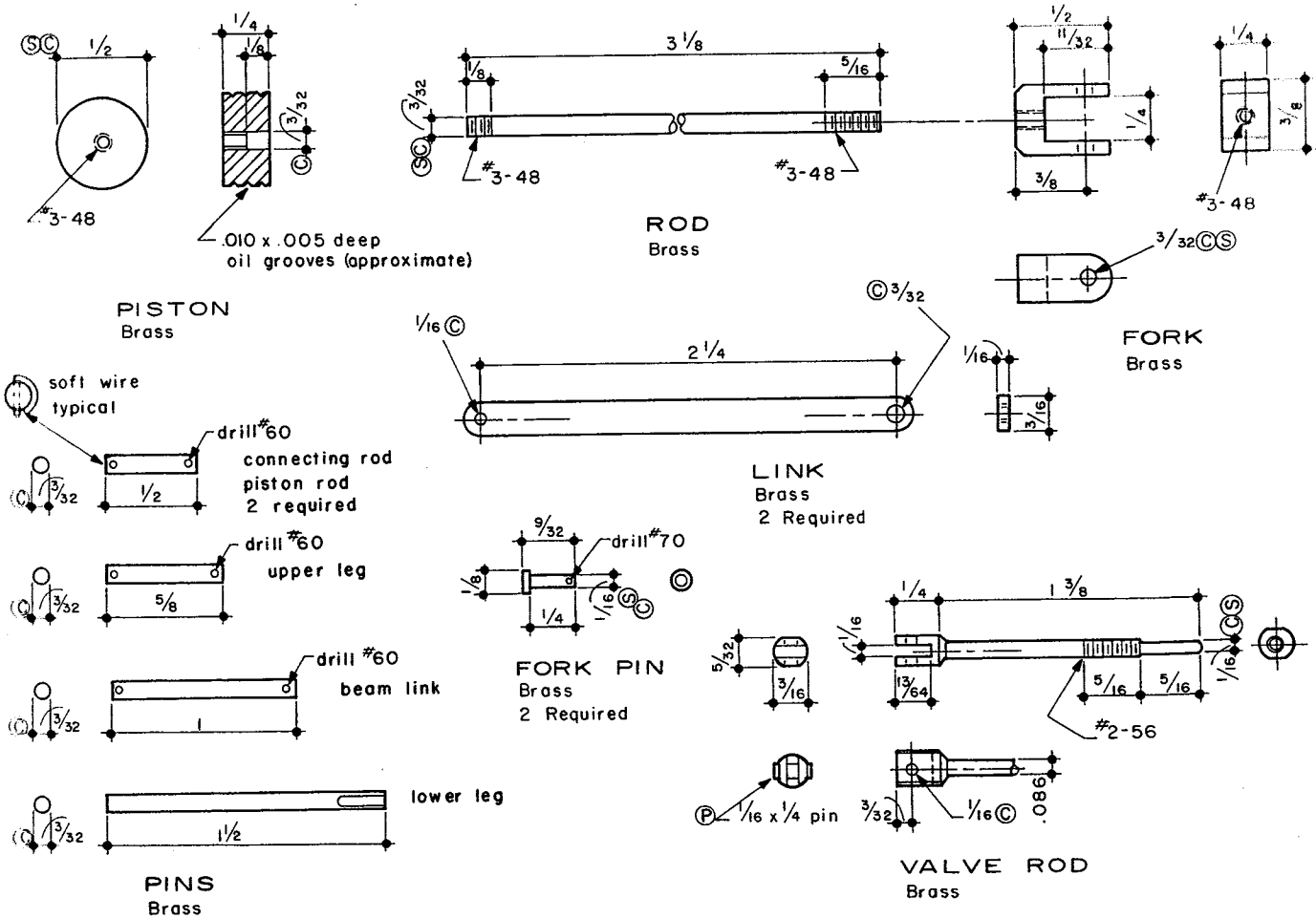


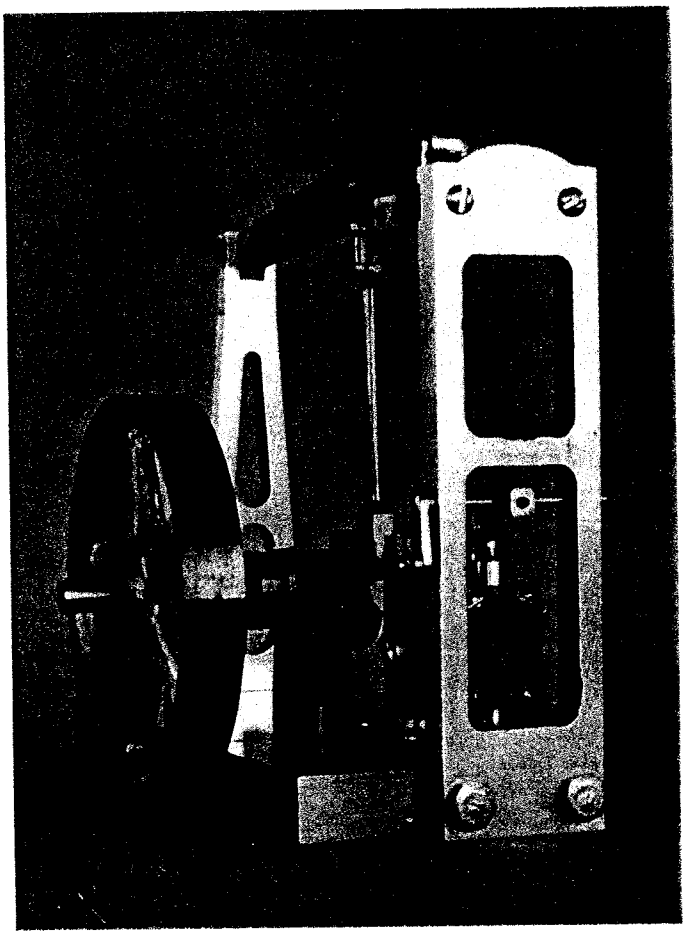
CRANK SCREW
Steel



ECCENTRIC STRAP
Brass


11/16
A
A
7/16
3/16
15/16
5/32
11/16
#2-56
#2-56
5/8
1/2
1 reference
3/4
17/32
15/32
step 1
2
3
4
5
6
7
see text
drill 1/16
B
16½° reference
1/8
AA
5/32
5/64
B
1/4
7/8
1 3/8
drill #57
1/16
1/16
1/8
#5-40
BB
5/16 r.
LAGGING
CYLINDER
Aluminum
9/32
5/32
1/4
3/16
13/64
1/16
1/16
drill #43
7/8
11/16
5/8
7/16
1/4
3/16
drill #41
SPACER
Brass
2 Required
.090
.070
1/32
VALVE
Brass
COVER
Brass
5/32
5/32
drill 1/8
12 holes
drill 3/16
6 holes
1r.
7/16 r.
option
1/2
#3-48
1/4
1/2
2 1/4
3
5/32
11/64
#5-40
3/16
7/8
3/16
11/16
11/32
7/16
3/16
5/8
1/4
17/32
drill #43
1/16 dia.
drill #41,
drill #21, depth
1/4, tap 3/16-40
STEAM CHEST
Aluminum
drill #30
1 1/4
15/16
1 1/4
1/2
15/16
1/32
1/8
3/4
drill #43 and
countersink for #2-56
FLYWHEEL
Aluminum
drill #41
drill #21, depth 1/4
tap 3/16-40
15/16
1/32
3/32
1/2
5/16
3/4
drill #43
3/16
7/8
1/16
5/8
7/16
1/16
1/16
F
G
drill #43
.100
.100
drill #57, 9 holes
11/16
VALVE PLATE
Brass
LOWER HEAD
Aluminum
UPPER HEAD
Aluminum





graphite packing. Do not turn the packing nuts too tight. Turn them in lightly with the fingers. It is not strictly necessary to use this type of packing.

At **ASSEMBLY**, spot the Piston at one dead-center position. Temporarily fasten the Steam Chest to the Cylinder with cover removed. The centerline through the Eccentric should be 90° from the centerline of the Eccentric Strap as shown. The Valve should close off all the Valve intake holes. Now fine-tune the Valve by rotating the Crank and adjusting the Fork so the Valve holes are equally exposed at each end of the stroke.

This engine is fun to watch while it is running and will reward your hours in building it with years of pleasure.

CHAPTER

38 VR 75

This engine is perhaps a bit more practical than some of the past Verburg engines as it can find more use in driving a boat or miniature machine. The bore and general proportions match somewhat the 3/4" engines on the market. This engine does not require castings.

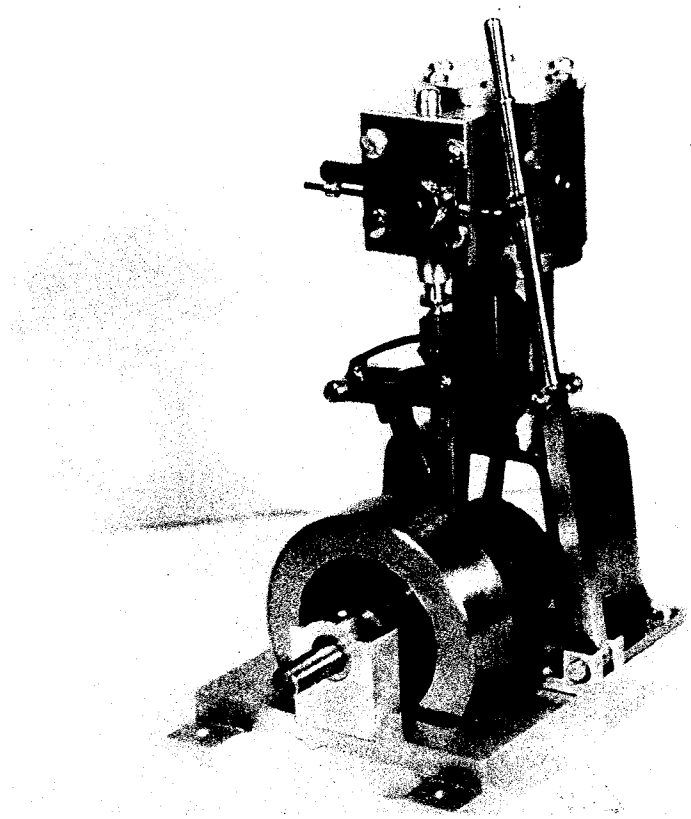
The material is up to the builder.

Only parts that need any comment will be mentioned. All the rest are considered routine machine shop practice.

The **CYLINDER** starts out as an accurate 1-3/8" x 1-7/16" x 1-1/8" block. While still square, all holes and outlines are laid out. Notice the four holes at the bottom and six for the top. Drill and tap all holes. Mill and drill all port passages. Center the 4-hole end in the 4-jaw on the bore centerline and turn the flange and bore as in **Step 1**. Take a thin skin cut off the end, only a few thousandths. This face is then square with the bore and the end that mounts on the Crosshead Guide. Reverse in the chuck and turn the second end as in **Step 2**. Make a milling setup and do **Steps 3, 4, 5** and **6**. **Step 7** is optional. It will be hidden if you make the Lagging. Fine-grained cast iron or Meehanite is great for this part.

The **LAGGING** is a cut-and-fit job. Thin black stove pipe steel is ideal for this. Make a thin cardboard pattern and transfer to the metal. The option type is easier to fit. When the fit is satisfactory, roll the piece to a diameter less than the Cylinder flanges and carefully ease it onto the Cylinder so it will cling and not require screws. The corners will catch on the Steam Chest projection and hold it in place.

The **STANDARD U, CROSSHEAD GUIDE V** and **FLANGE W** are steel on the model shown, though brass might be easier to work. The blank for the Standard is laid out on 1/8" x 1-1/4" x 5-5/16" metal and formed using the type of bending jaws developed by Paul C. Haar. The first try came within 1/64" of the required height. Make the four 1/8" anchor holes and mount on the completed

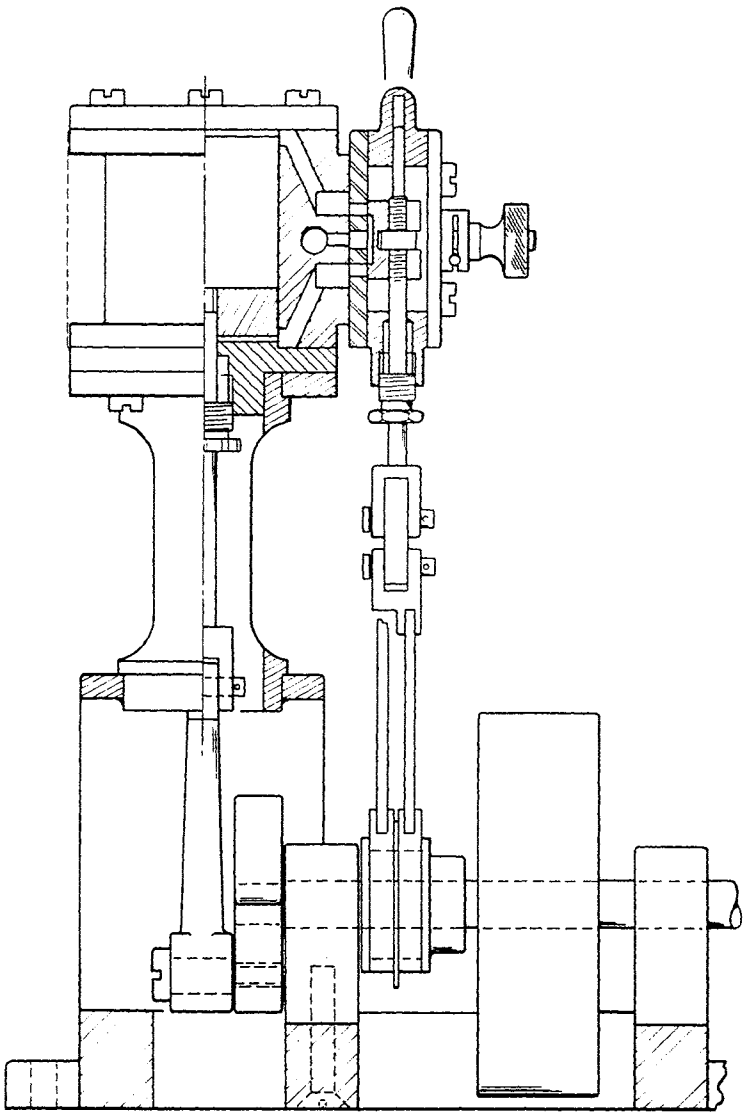


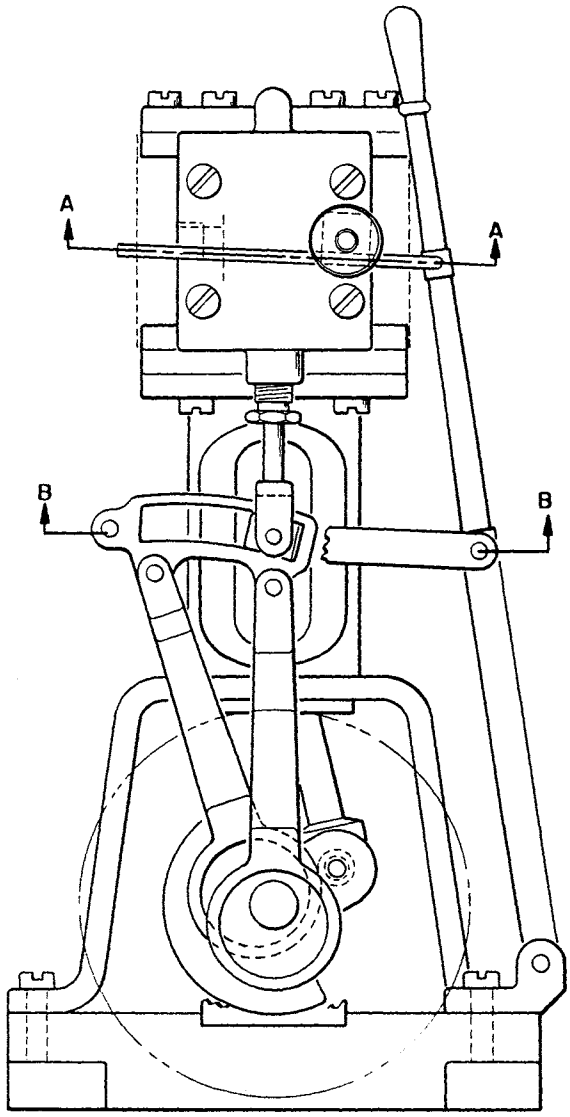
Base. Establish the center for the Crosshead Guide and center-punch. Mount Base and Standard in lathe and bore the 13/16" hole. Make a light cleanup cut on the top, making it parallel with the Base. Make the upper Flange **W**. Turn the Crosshead Guide **V** with shoulder for Flange **W**, and bore 5/8". Measure the sum of the parts to determine where to make the shoulder at the lower end. Mill the flats with a 1/2" cutter. When the total is 3-5/16", solder **U, V** and **W** together using at least 430° solder. Keep the 4-bolt-hole pattern in **W** square with the axes of the Base. Squareness and concentricity are important all through these parts to prevent binding at the Piston, Rod and Crosshead.

The **STEAM CHEST** starts out as an accurate 5/16" x 1" x 1-9/16" block. Lay out the centers for the Stuffing Box and 3/16" boss and center punch. Pick up these centers in the lathe and turn each end, doing the Valve Rod and 3/16-40 holes at the same chucking. Drill and mill out the 1/2" x 3/4" center opening.

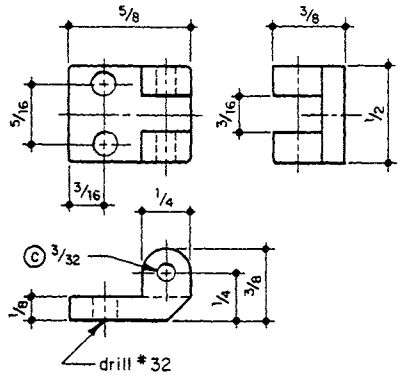
The **LINK** is purely a layout and carving job in steel. Of course, accuracy and close fit on all holes and link part will reduce clanking when the engine is running. A filing machine such as the one developed by Bob Maynard will make a neater and more accurate job.

The **ECCENTRICS** were made of 3/4" diameter free-machining steel. A piece about 2" long is centered in the chuck and each end turned to the final bright 9/16" diameter x 1/8" for the Straps. Remove from the lathe and mount in a V block with clamp. Make the two centerlines at right angles to each other. Scribe the 1/4" bore .080" off-center and prick punch. Set a protractor at 25° and scribe the

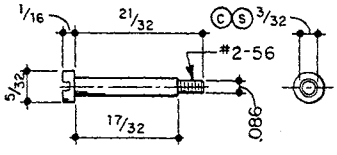




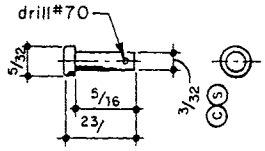
VERTICAL REVERSING 3/4 x 3/4



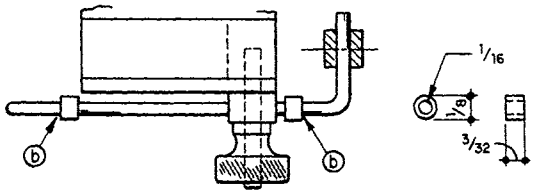
REVERSE LEVER PIVOT



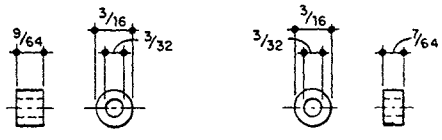
2 required



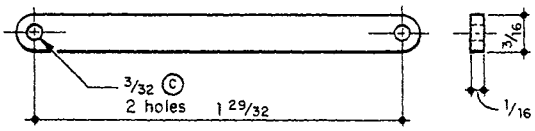
3 required



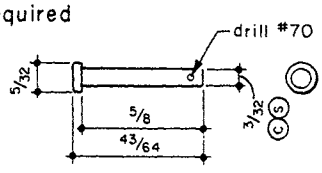
Section A-A

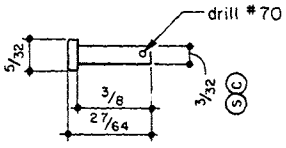


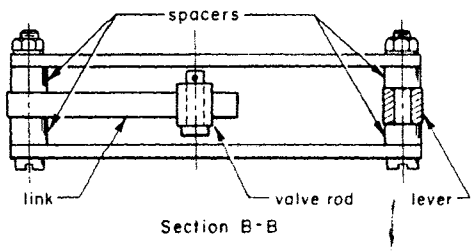
SPACERS



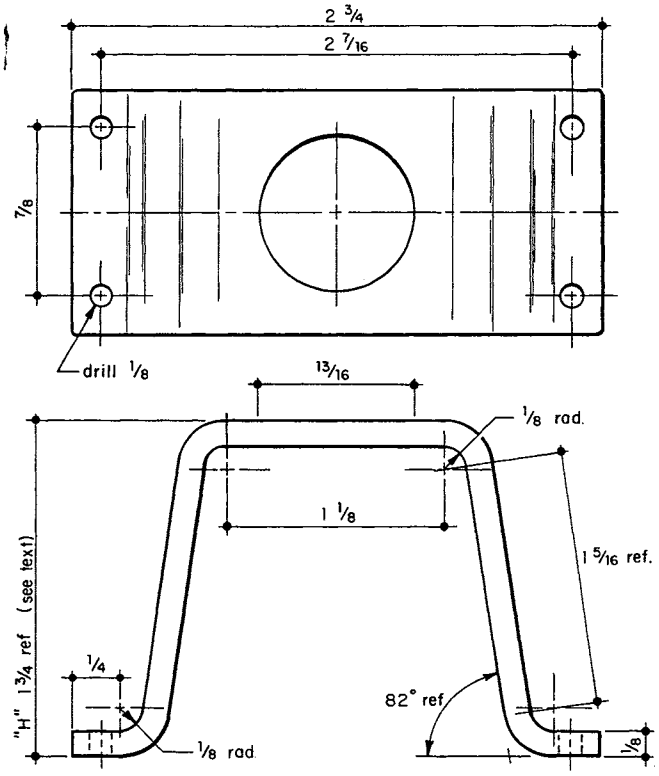
DRAG LINK
2 required



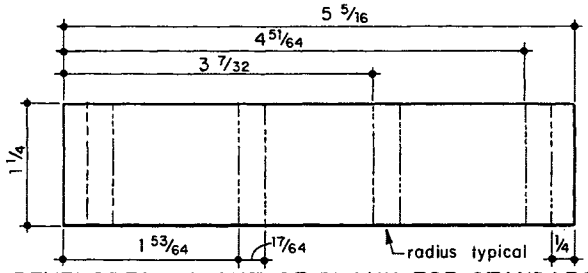




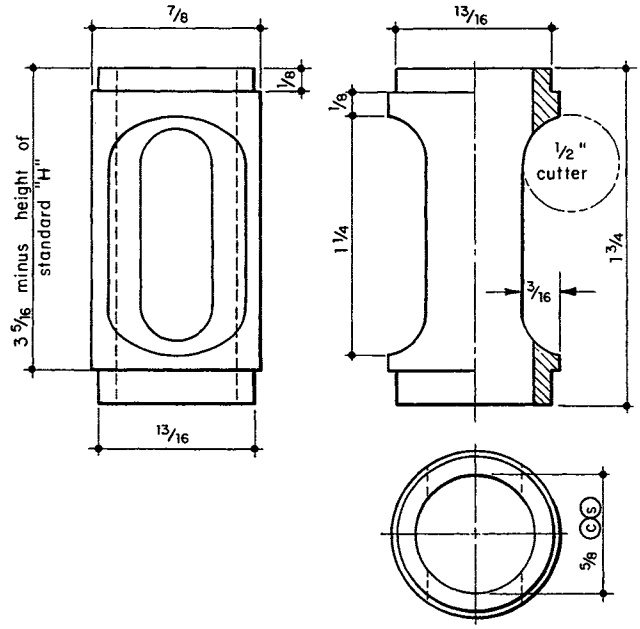
Section B-B



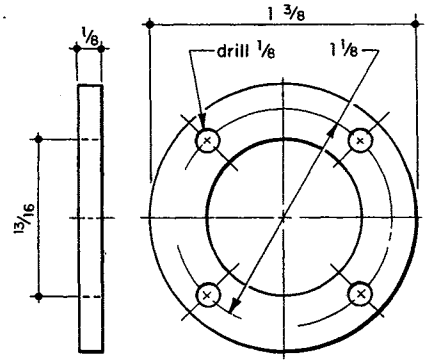
STANDARD U



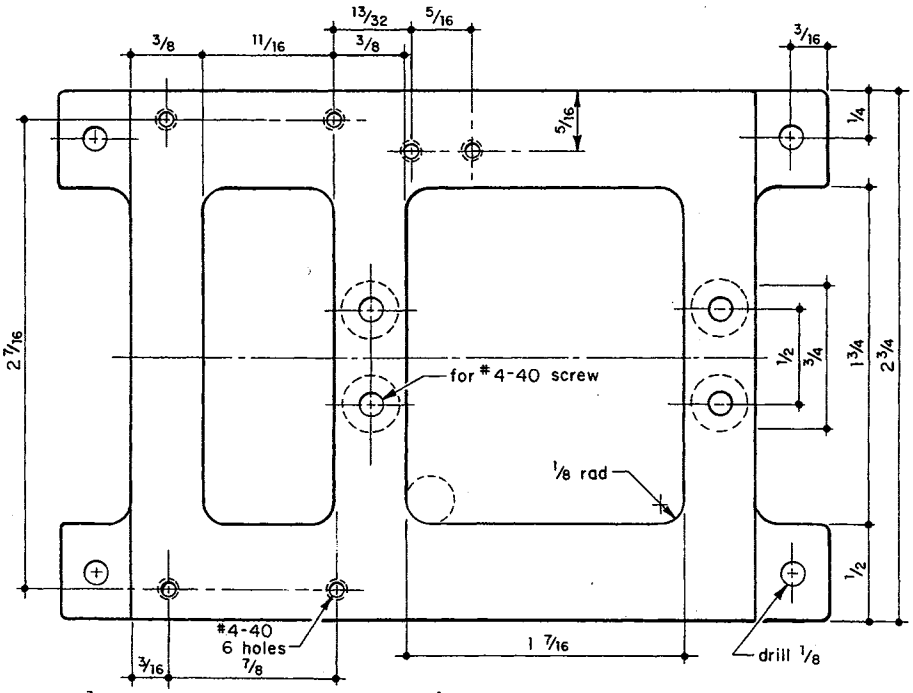
DEVELOPED LAYOUT OF BLANK FOR STANDARD



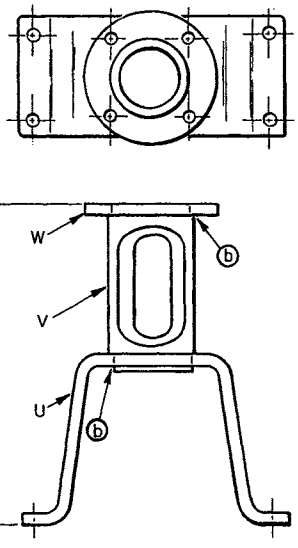
CROSSHEAD GUIDE V

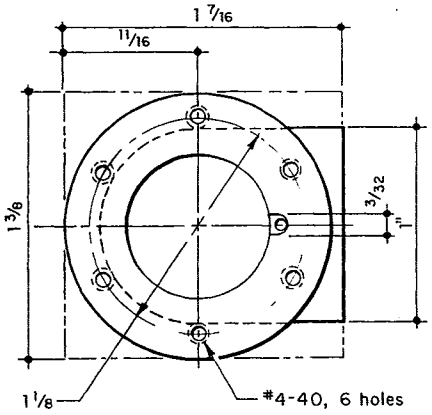


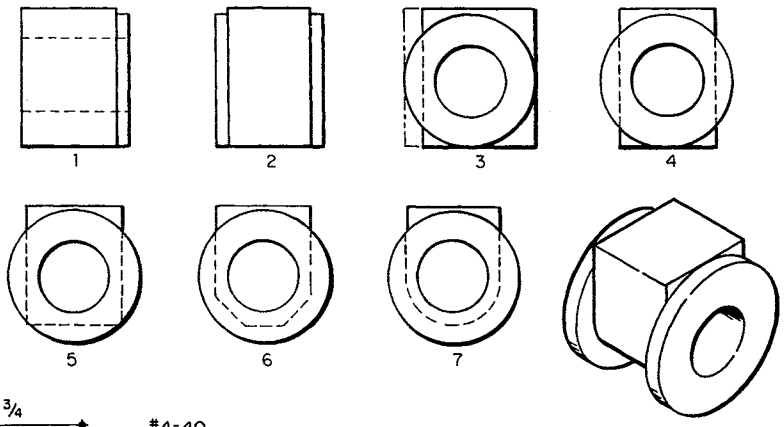
GUIDE FLANGE W

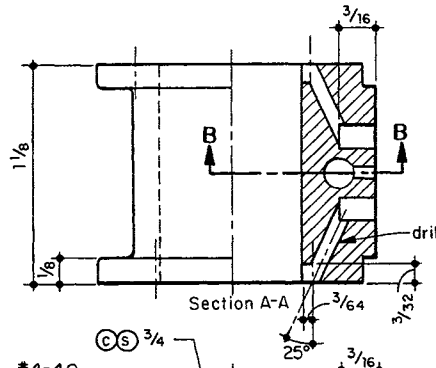


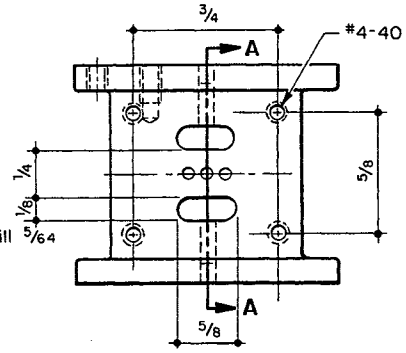
BASE

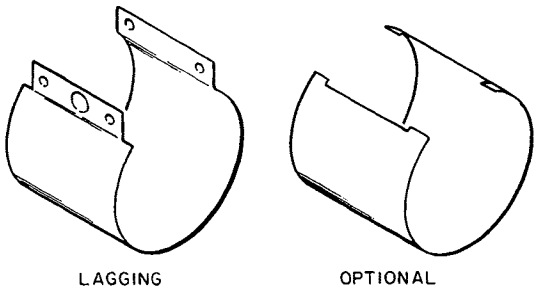


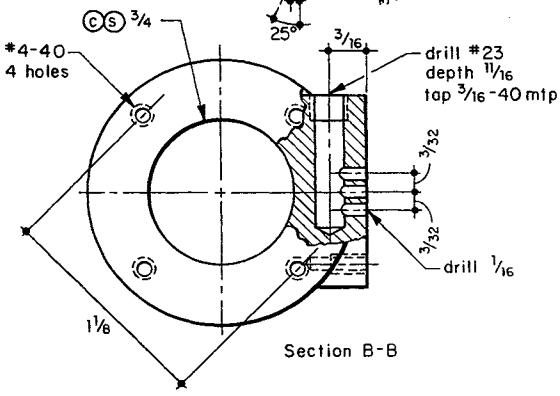




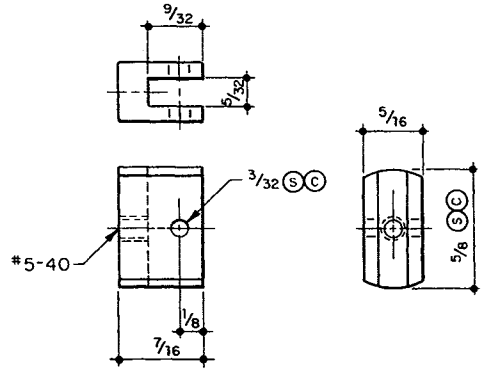






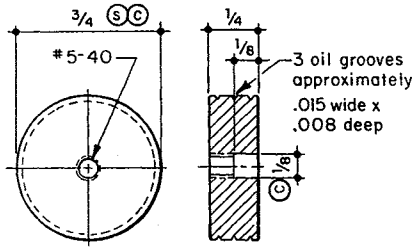


CYLINDER

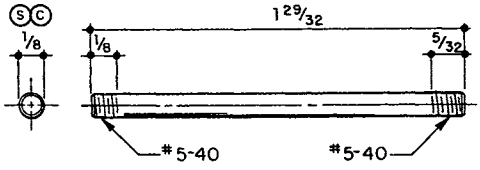


CROSSHEAD

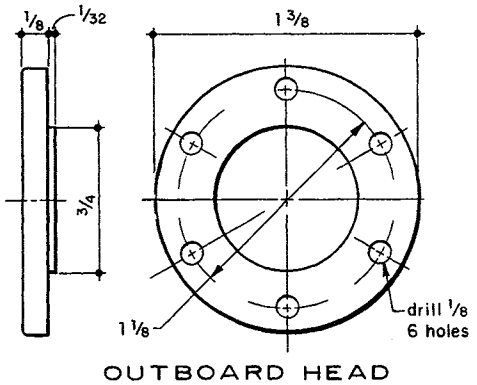
(s) smooth	(b) solder or braze
(c) close	(p) press fit or "loctite"
(f) flat	



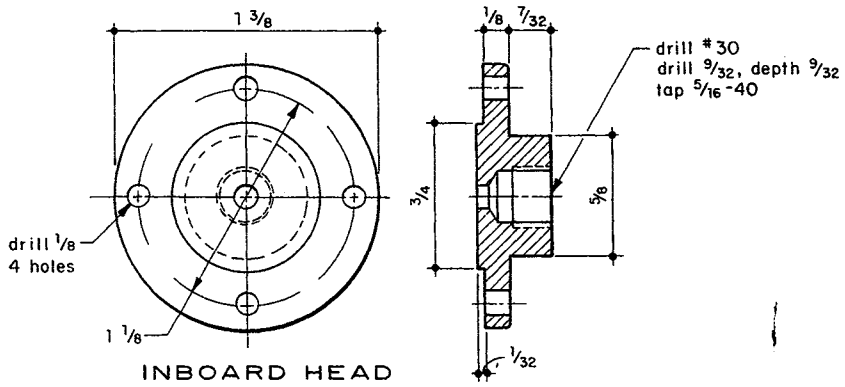
PISTON



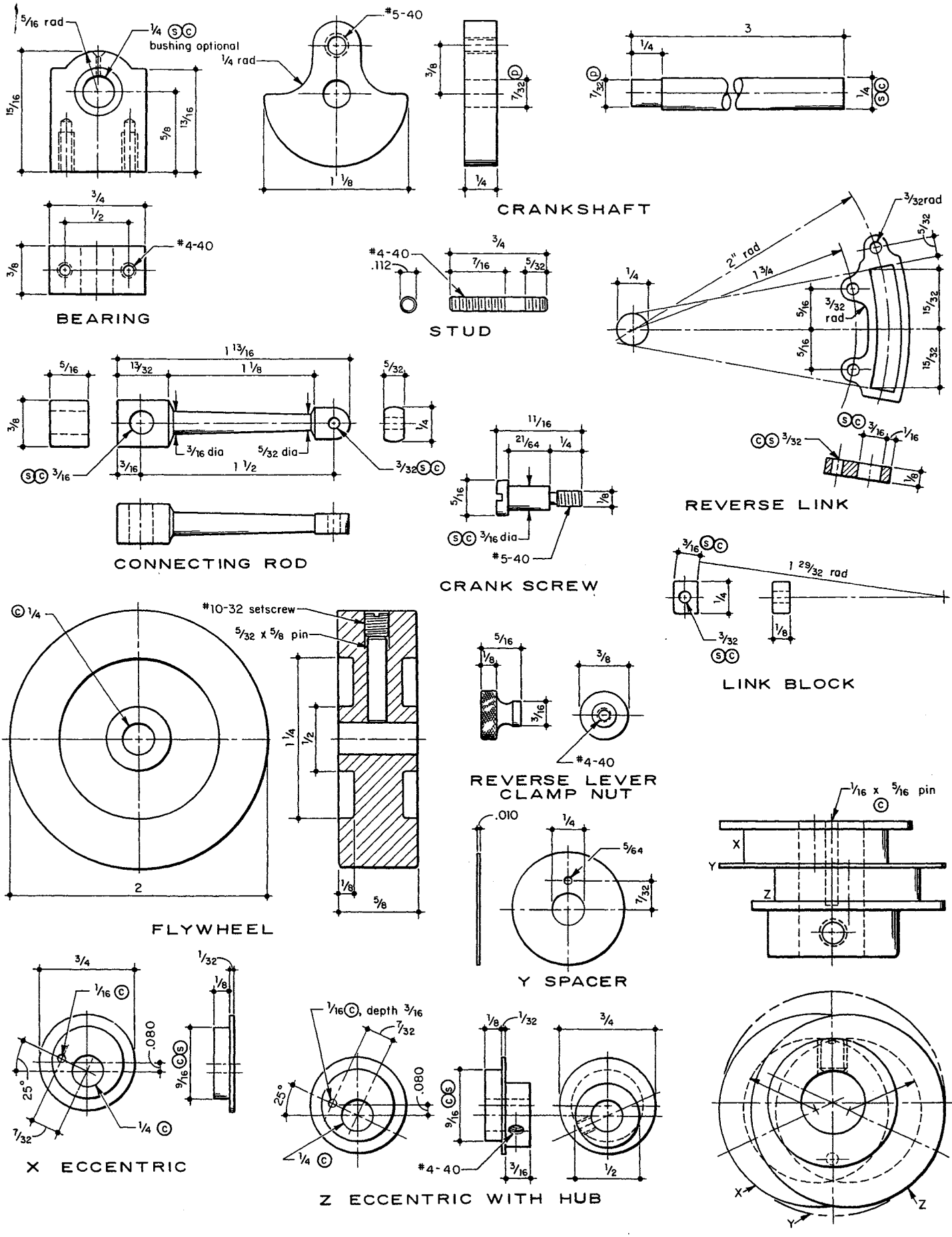
ROD

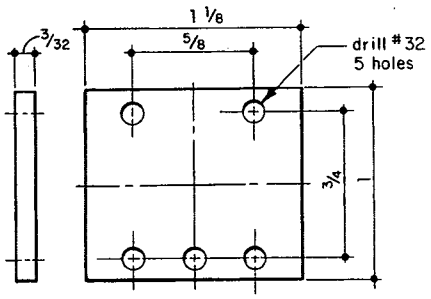


OUTBOARD HEAD

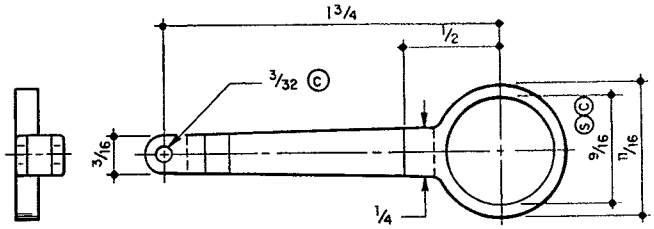


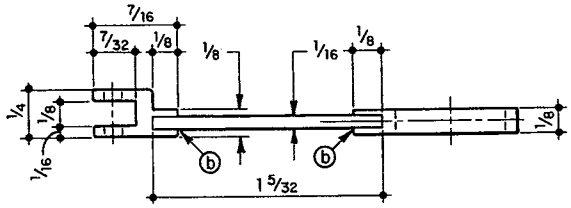
INBOARD HEAD


BEARING
CRANKSHAFT
STUD
REVERSE LINK
CONNECTING ROD
CRANK SCREW
LINK BLOCK
FLYWHEEL
REVERSE LEVER CLAMP NUT
Y SPACER
X ECCENTRIC
Z ECCENTRIC WITH HUB

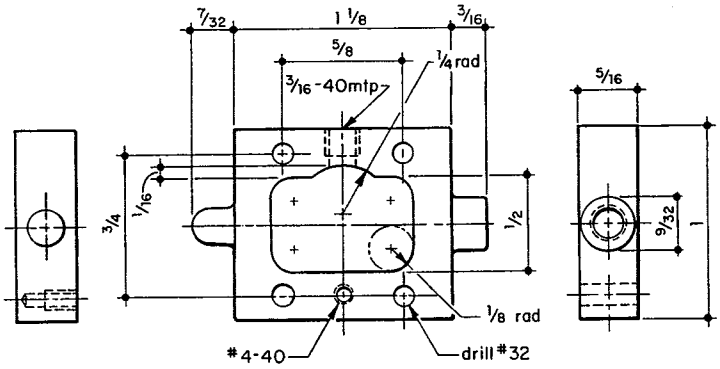


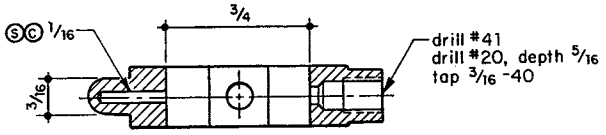
COVER



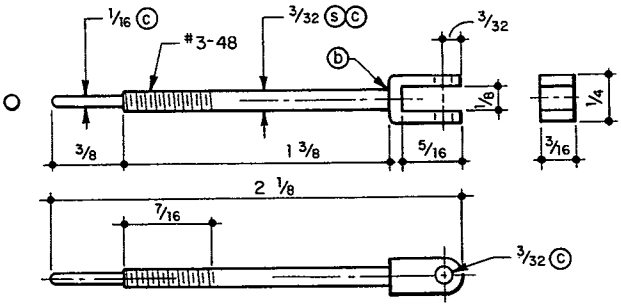


ECCENTRIC STRAP
2 Required

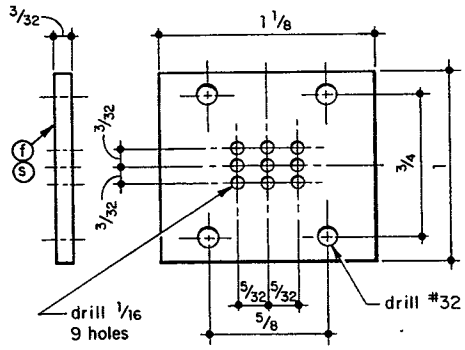




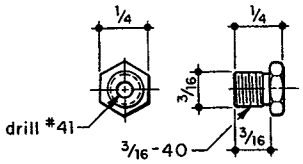
STEAM CHEST



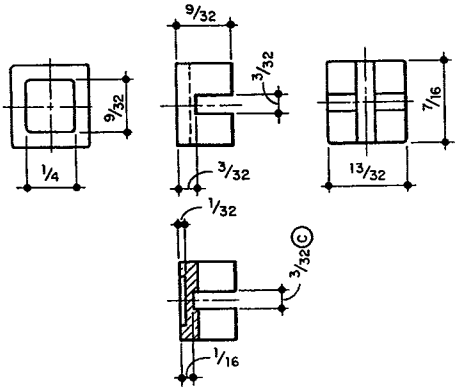
VALVE ROD



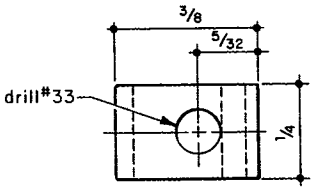
VALVE PLATE

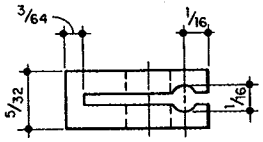


PACKNUT
(Steam Chest)

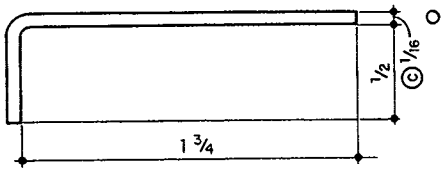


VALVE

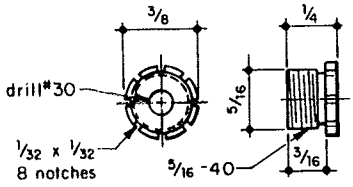




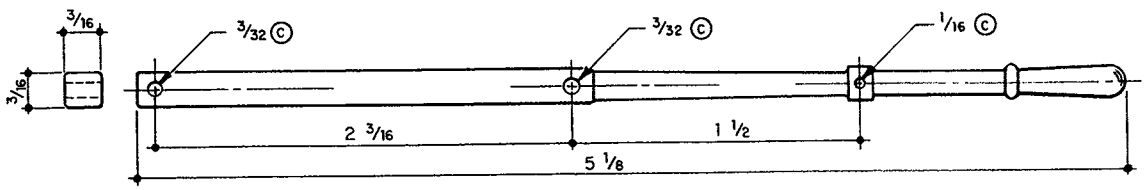
CLAMP
2 x Size



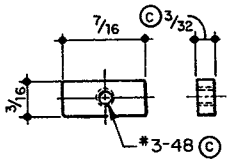
CLAMP ROD



VALVE NUT



REVERSE LEVER



VALVE NUT

centerline for the 1/16" Pin. Strike a 7/32" radius from the Shaft centerline and prick punch for the Pin. Return to the lathe, centering for the Shaft bore. Make the 1/4" bore and part off the plain Eccentric about 1/32" full. Reverse in the lathe and do the 1/4" bore and rough out the hub with a narrow tool, leaving 1/64" to 1/32" to clean up. Part off the Eccentric with the hub. Finish both Eccentrics on a close-fitting stub arbor. Drill the pin hole in the plain Eccentric. Mount the Eccentric with hub in a drill vise and make a 1/16" dimple on the pin centerline. While still anchored to the drill press table, run a close-fitting 1/4" pin in the bore and slide the plain Eccentric down over the pin and use it as a jig to complete the 1/16" hole in the Eccentric with hub. Next, spot the 4-40 set screw in the same plane as the 1/16" pin. This will help when timing the Valve. On the plain Eccentric, flow a tiny burr of metal on the rim of the 1/16" hole with a prick punch on the flange side. This will keep the Pin from scoring the Bearing during operation.

The **CONNECTING ROD** was made of a hard jig-and-fixture grade of aluminum, taking advantage of the lighter weight. Bronze would be more durable.

The **BUSHINGS** in the **BEARINGS** are "Oilite" press fit.

When making the 17/32" **SHOULDER SCREWS** for the Drag Link, try for a condition where the nuts run tight and the parts are just free but not sloppy.

Make sure the **CRANK SCREW** is tight so it won't back out when rotation is reversed.

Try for just a free but not sloppy fit at the **VALVE, VALVE ROD** and **NUT** so the Valve will float free on the Plate held by the steam pressure. Adjust the Valve so it exposes an equal amount of port holes at each end of the stroke. The Valve face and Valve Plate must be lapped flat.

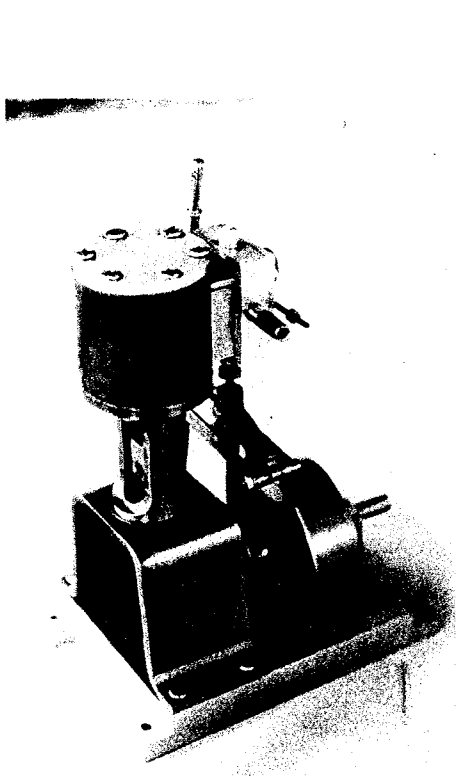
Fine copper wire is used in the #70 holes in the Pivot Pins.

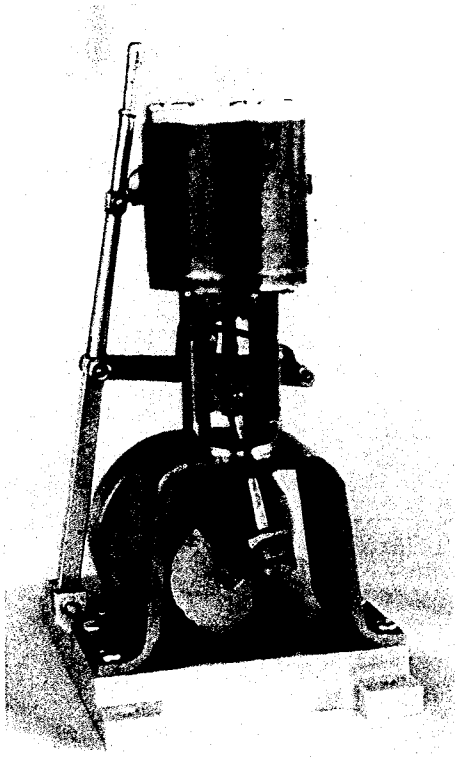
Use some 1/16" strands of unraveled graphited asbestos packing in the Stuffing Boxes. Snug up the Packnuts only finger tight and take-up as needed as they wear in. Do not over-tighten.

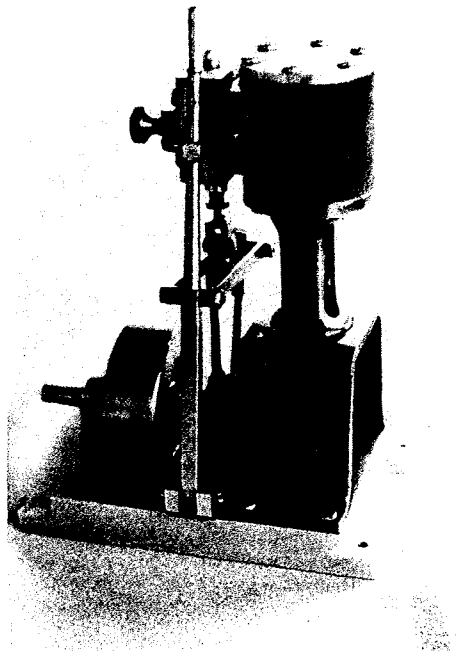
Set the crank throw at its lowest position. Use the hex wrench in the Eccentric Set Screw and aim it also straight down. After some trials, the Eccentric can be rotated a few degrees each way and trials made. When the engine runs its best in both directions, tighten the Set Screw.

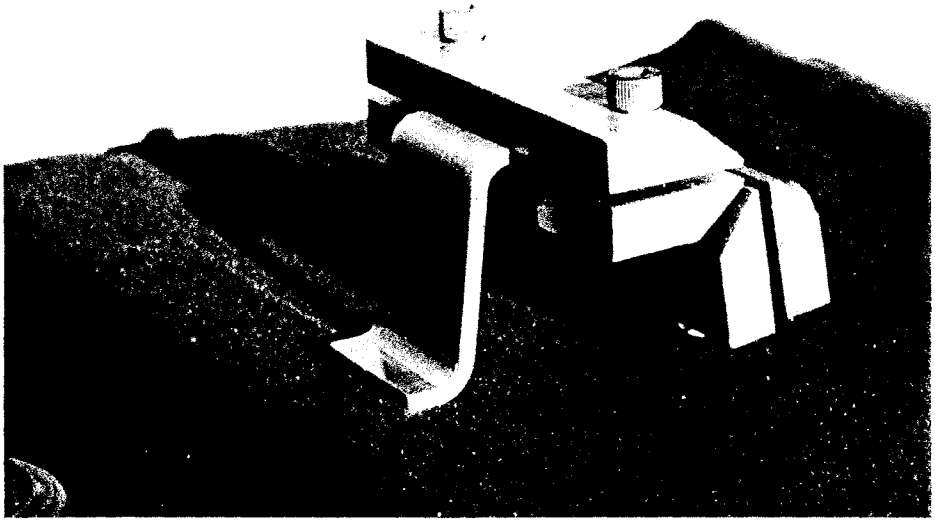
Find the best position for the reverse lever and measure so the 1/8" x 3/32" stops can be soldered in place.

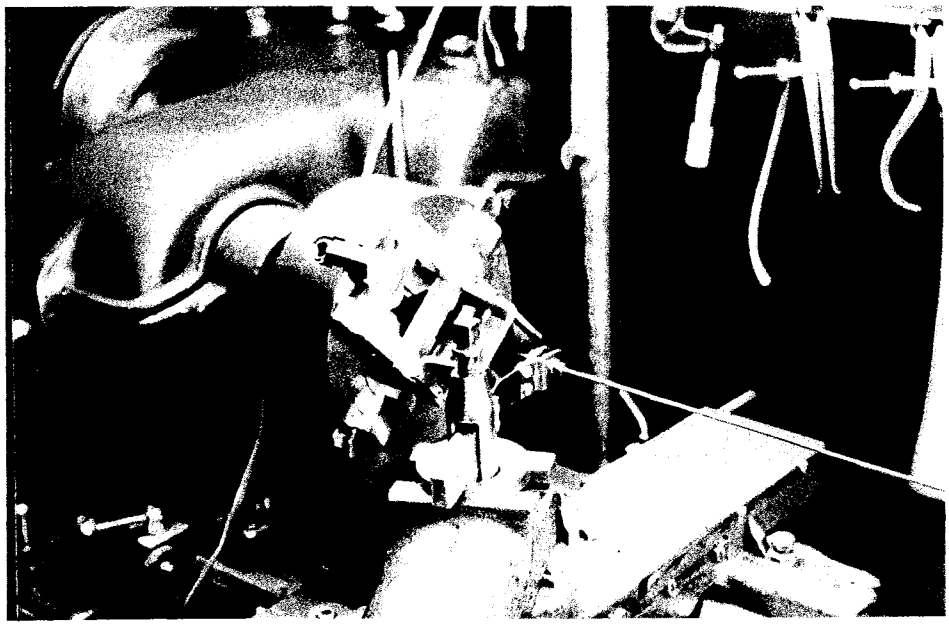
This was a first attempt to make a reversing mechanism. It turned out well, though some students of steam engine valving may be able to improve on it. It ran easily on 5 to 10 pounds of air. At about 25 pounds, it was difficult to slow it down by pinching the shaft with the fingers. It is not as compact as the commercial 3/4" models, but it has the Flywheel between the Bearings and not overhung, with the takeoff Shaft beyond that.







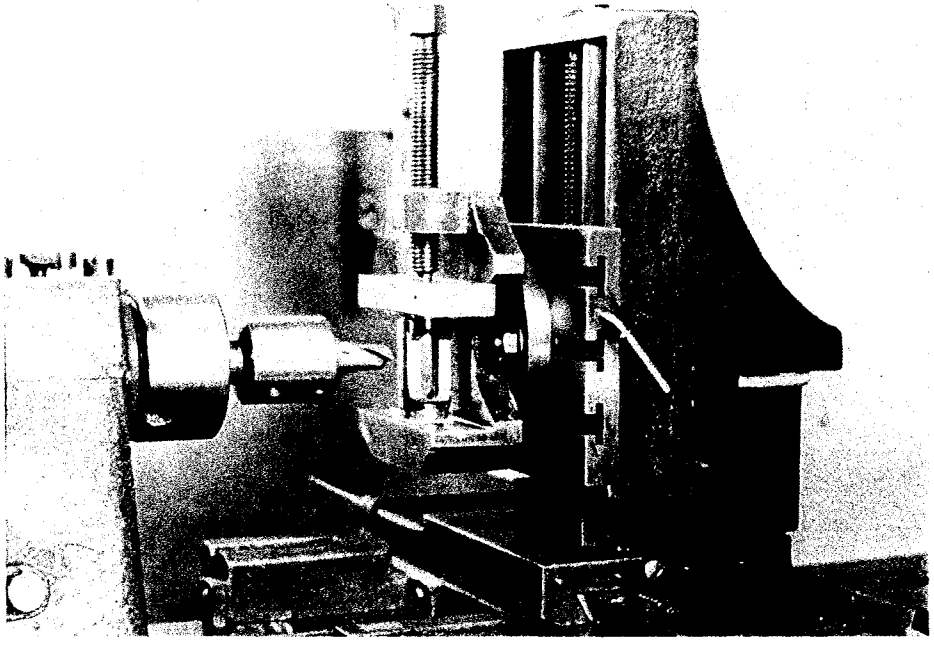




Above: Forming the Standard

Center: Using center test indicator to center Standard prior to boring for Crosshead Guide.

Below: Milling the sides of the Crosshead Guide.



CHAPTER

39 Rope Drive

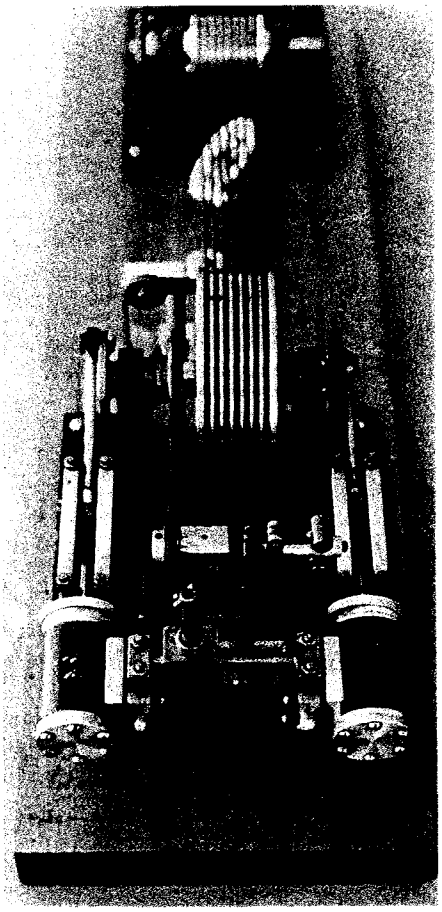
This model is a simplified twin, double-acting engine driving a jackshaft through a rope drive. It has seven ropes with the return using an idler inside the ropes between the pulleys. The Governor is simplified to avoid bevel gears. It is the spring-loaded type. The builder has the choice to make as much or little as he wishes. He can make a single Cylinder or twin Cylinder engine only, with or without Governor using a simple Flywheel. He can make a one-engine rope drive. Of course it doesn't necessarily have to drive a generator.

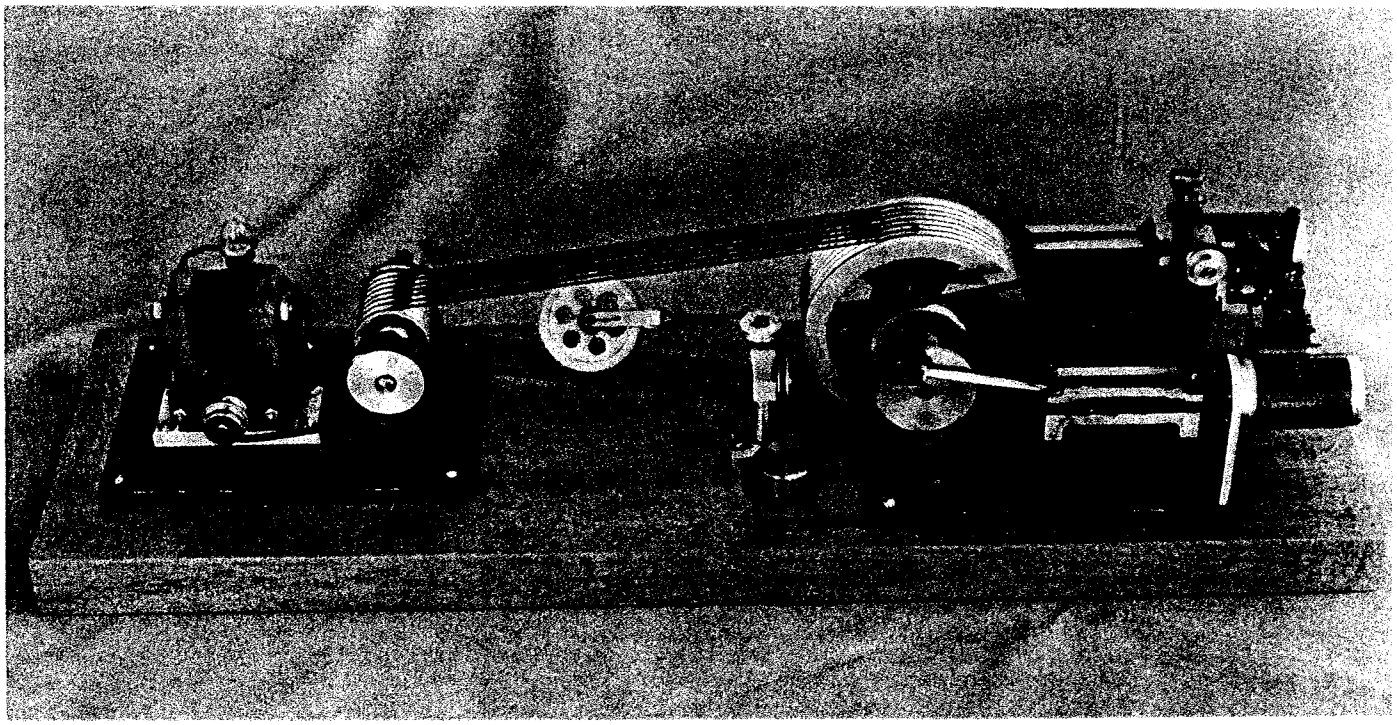
A 3-strand, .050" approximate diameter glossy fish line was used for the "Rope" and Counterweight. The Idler Pulley is plastic. The Governor Belt is 3/32" plastic belt stock purchased by the foot from Cole's Power Model Supply. It will take a little practice to cut and join with heat. If you can find a common O-ring of the right size, it will work better than this. You have a lot of leeway with material. Use your judgement and material you have on hand.

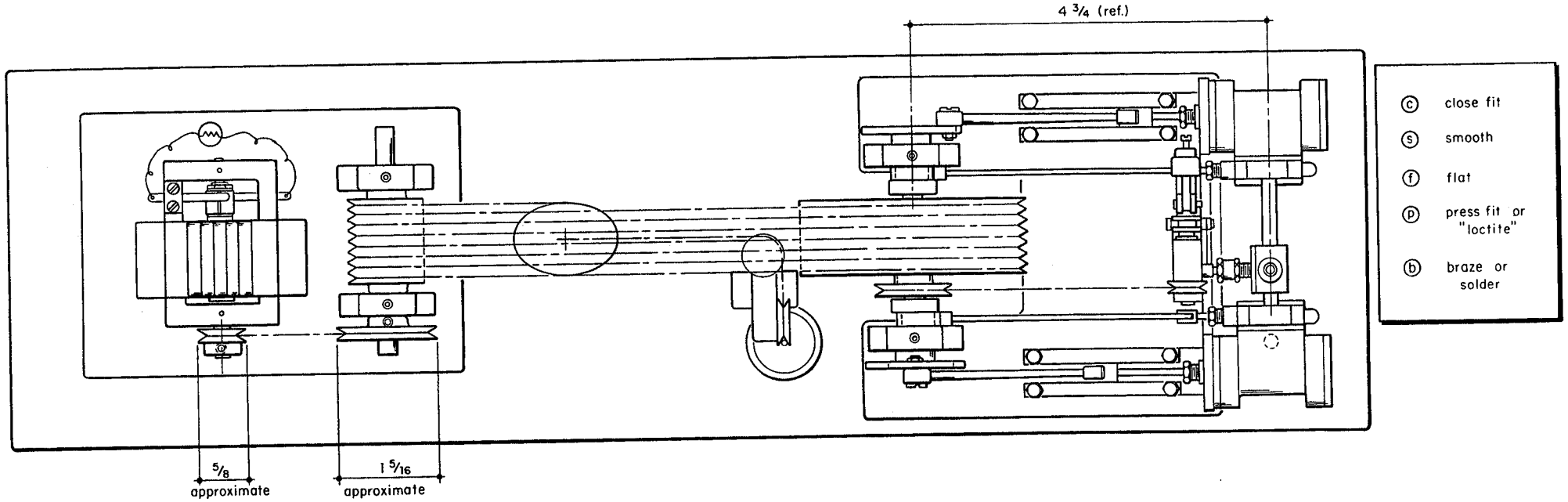
The drawings give all the details, though some parts can use some extra remarks to clear up or suggest layout and machining points.

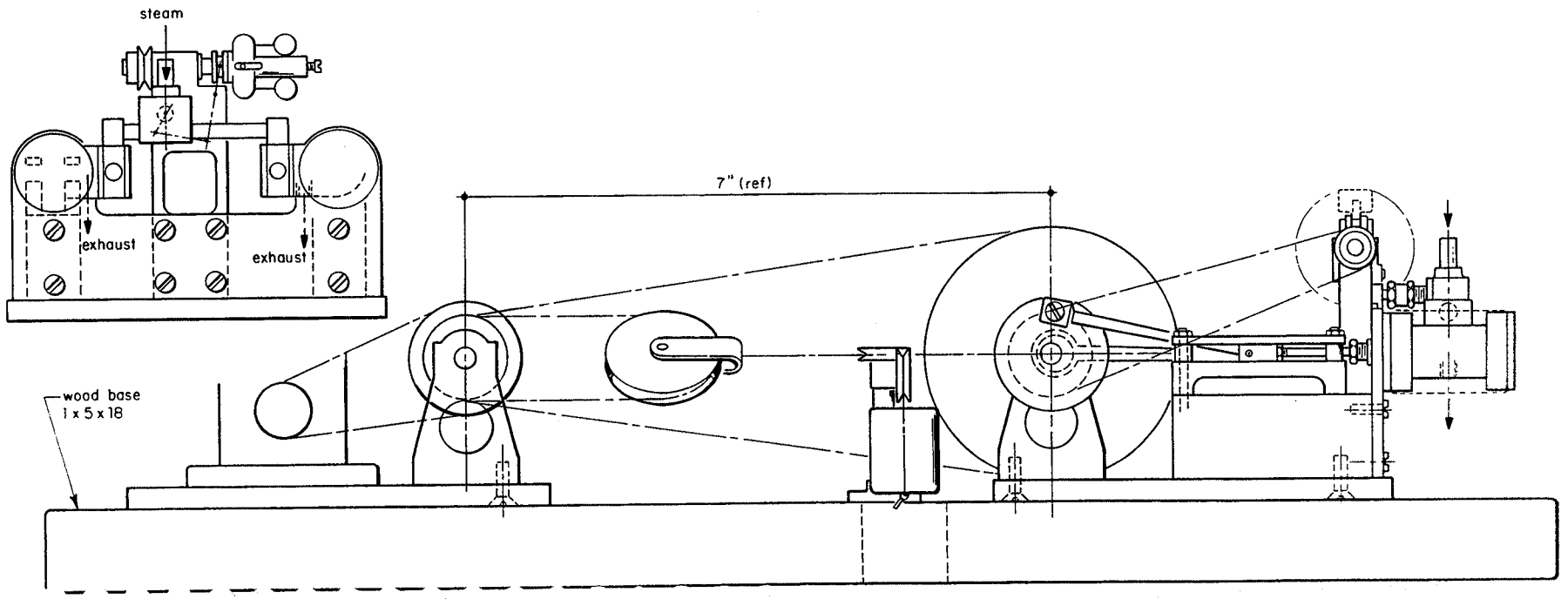
The **PULLEY GROOVES** are parallel. It is NOT a spiral thread. Use layout dye and mark the tips of the grooves 1/8" apart. Make a setup with a 60° threading tool. Start the tip of the tool by eye, a shade to the left of the 1/8" marks, and feed in .015" to .020"; then, turn until just short of the next 1/8" mark. Repeat until you clean out the space between the marks, leaving about .015" flat at the mark. NOTICE that the LARGE PULLEY has seven grooves and the SMALL PULLEY has eight.

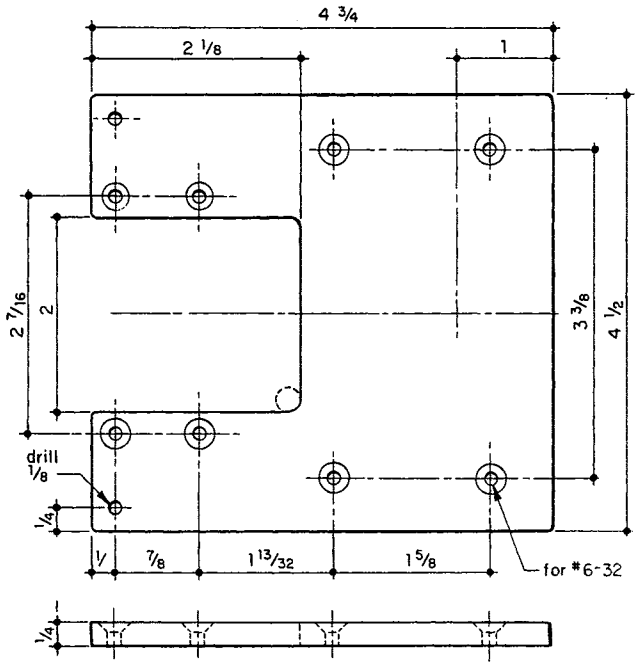
The **LARGE PULLEY** is laid out on one face of the 3" blank and all 18 holes are drilled through. Next it is chucked on the O.D. and the 2-3/8" x



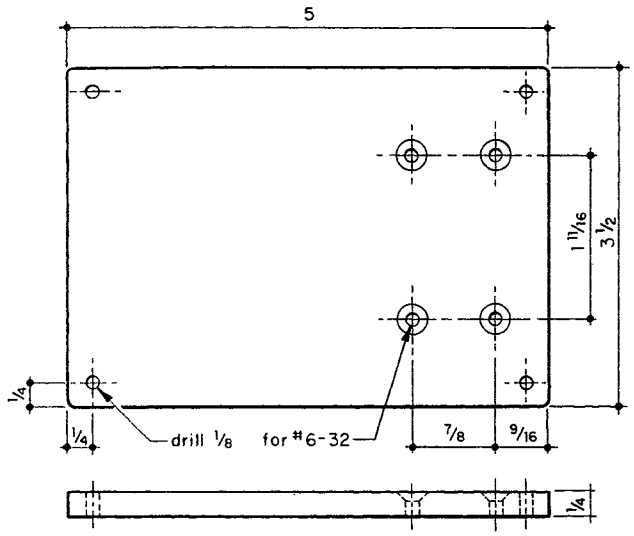



4 3/4 (ref.)
5/8
approximate
1 5/16
approximate
c close fit
s smooth
f flat
p press fit or "loctite"
b braze or solder

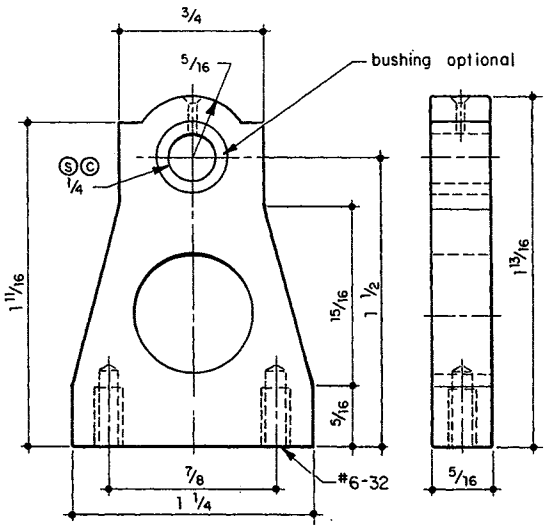

steam
exhaust
exhaust
7" (ref)
wood base
1 x 5 x 18



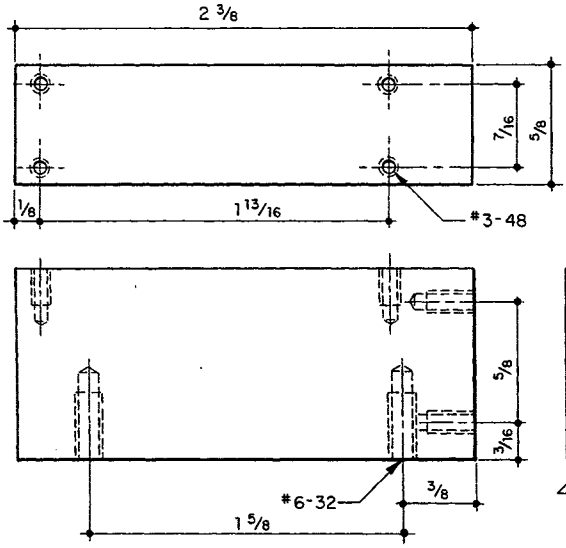
ENGINE BASE
(1/2 size)



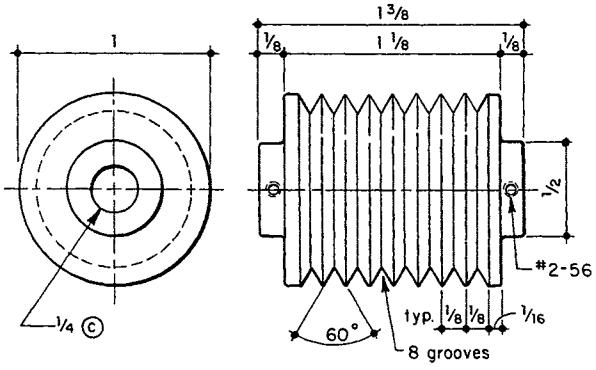
GENERATOR BASE
(1/2 size)



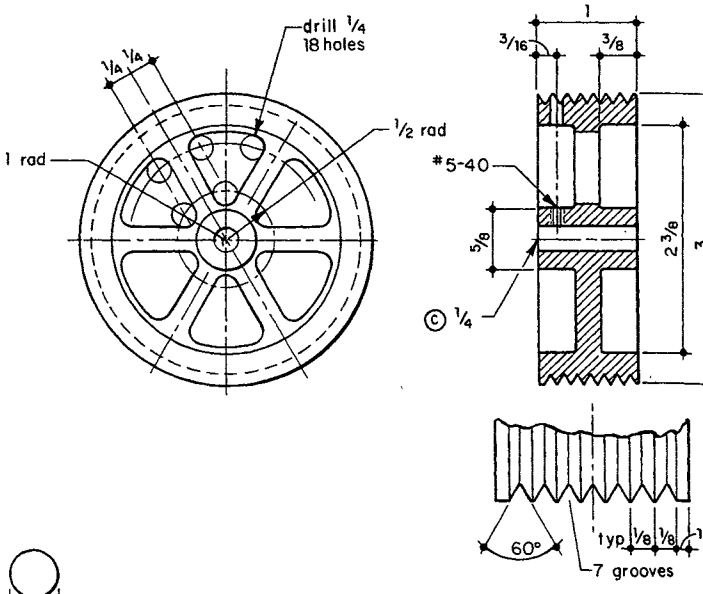
BEARING
4 Required



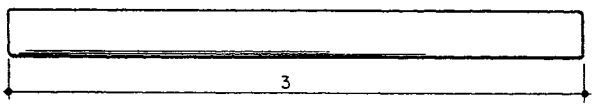
CROSSHEAD BASE
2 Required



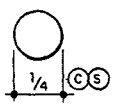
SMALL SHEAVE

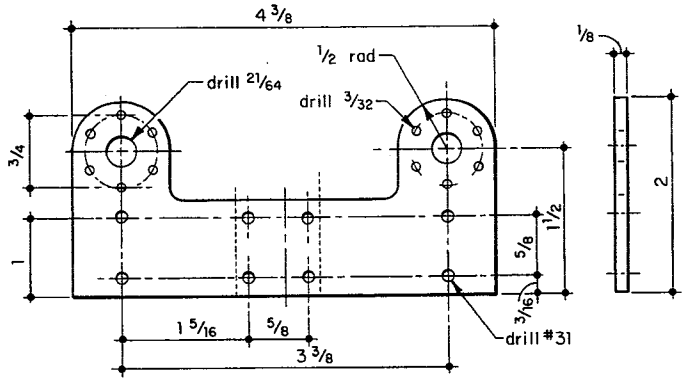


FLYWHEEL—SHEAVE
(1/2 size)

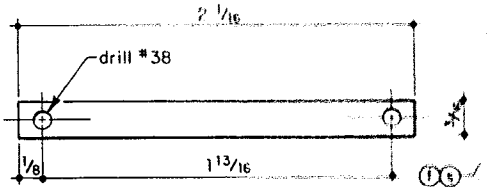


JACKSHAFT

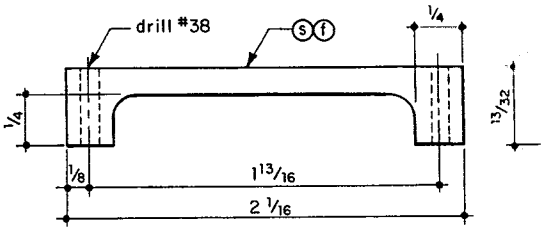




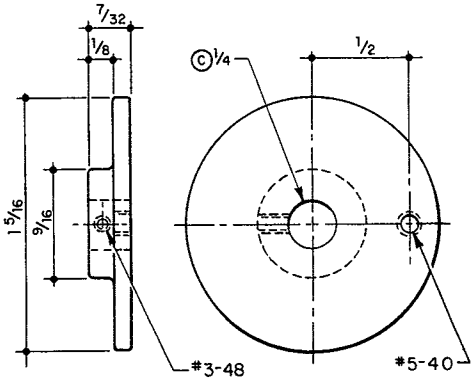
CYLINDER MOUNTING FLANGE



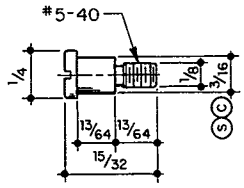
CROSSHEAD GUIDE (UPPER)



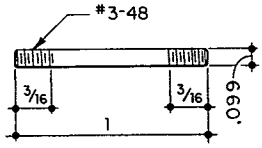
CROSSHEAD GUIDE (LOWER)



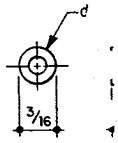
CRANK DISC



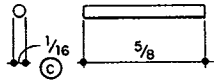
CRANK SCREW



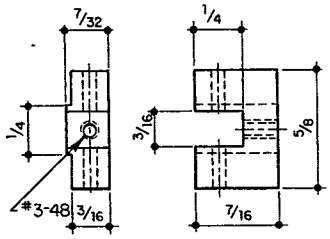
CROSSHEAD GUIDE STUD

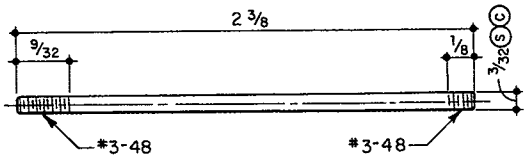


SPA

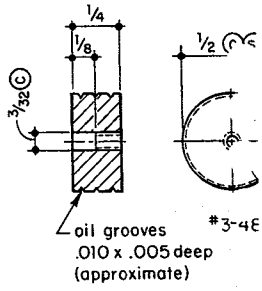


CROSSHEAD PIN

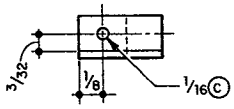




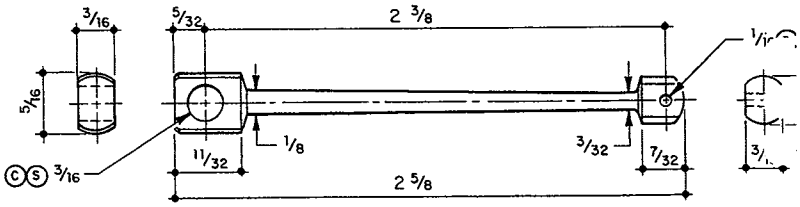
PISTON ROD



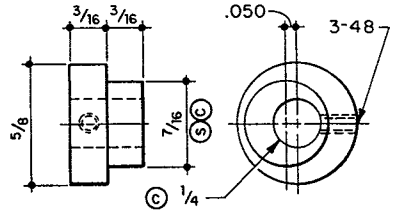
PISTON



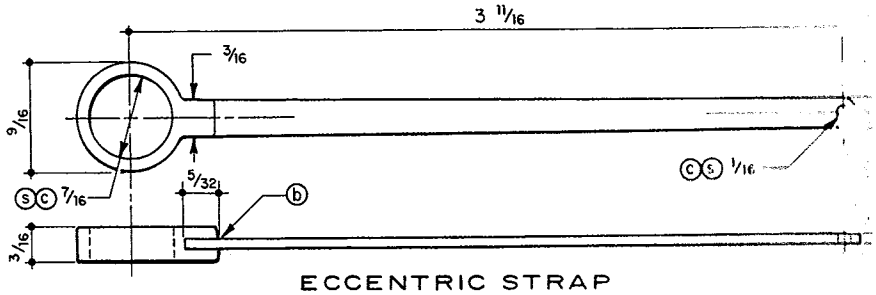
CROSSHEAD



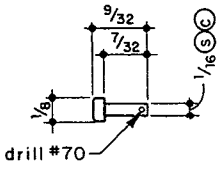
CONNECTING ROD



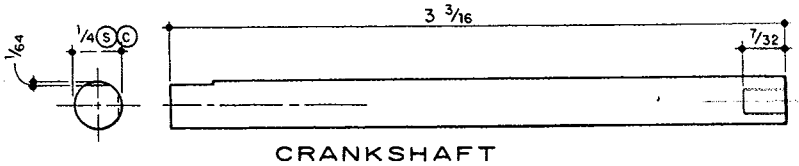
ECCENTRIC



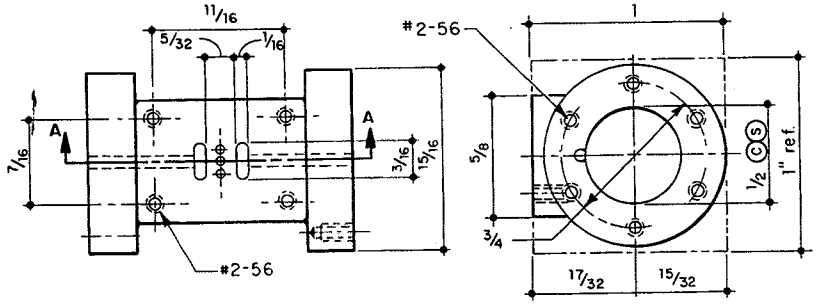
ECCENTRIC STRAP

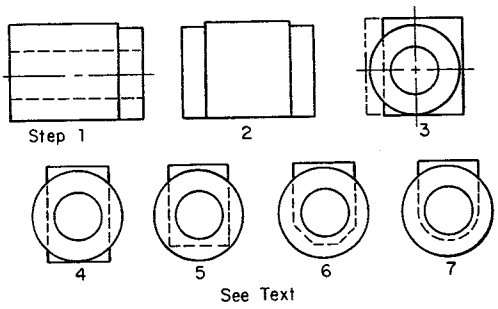


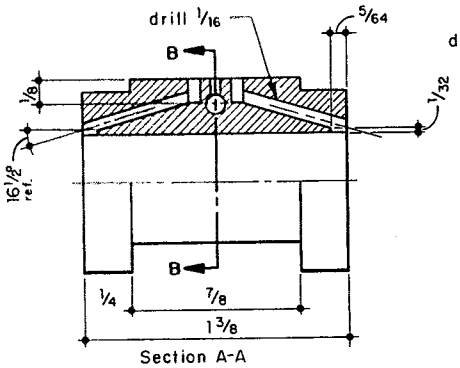
ECCENTRIC STRAP PIN



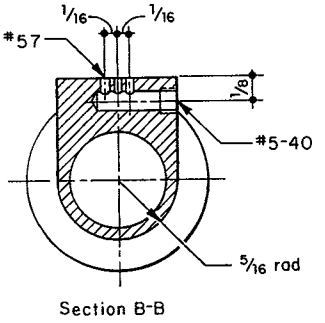
CRANKSHAFT





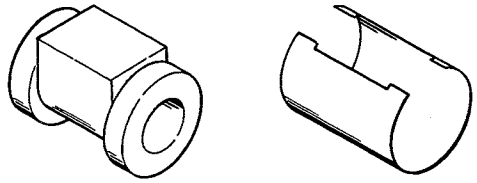


Section A-A

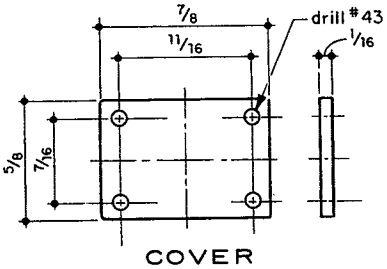


Section B-B

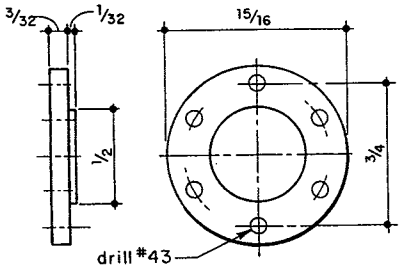
CYLINDER
2 Required



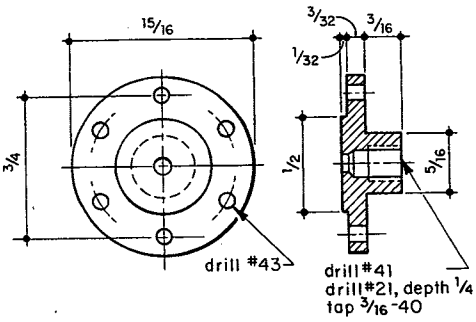
LAGGING
2 Required



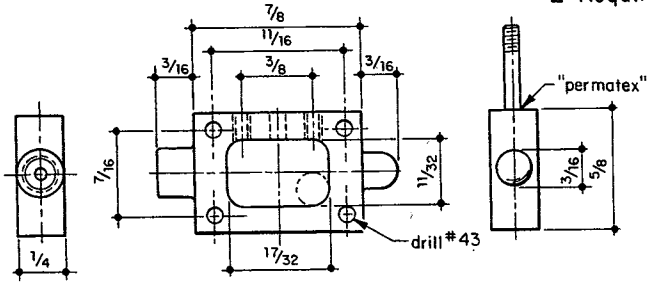
COVER
2 Required

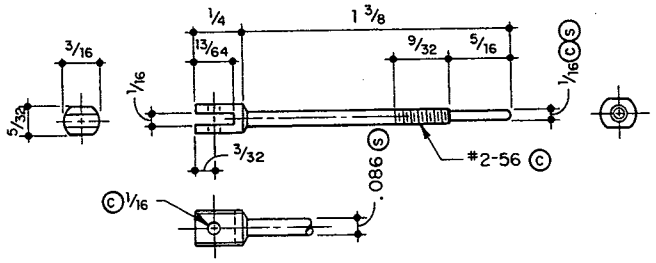


OUTBOARD HEAD
2 Required

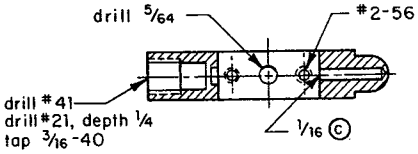


INBOARD HEAD
2 Required

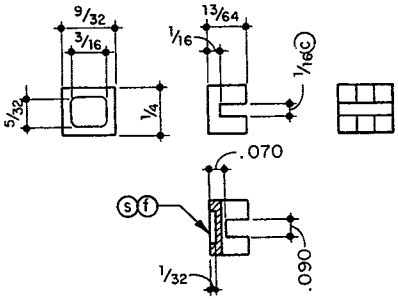




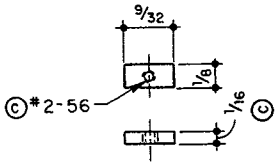
VALVE ROD
2 Required



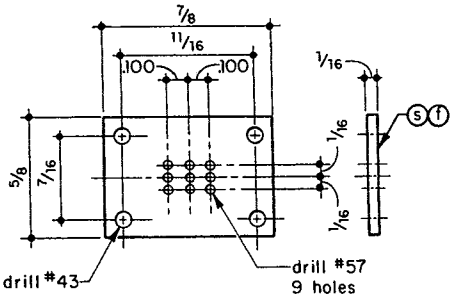
STEAM CHEST
2 Required



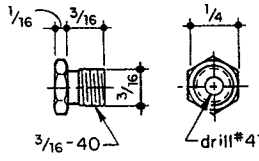
VALVE
2 Required



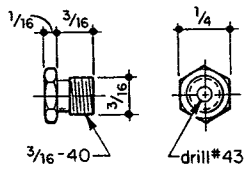
NUT
2 Required



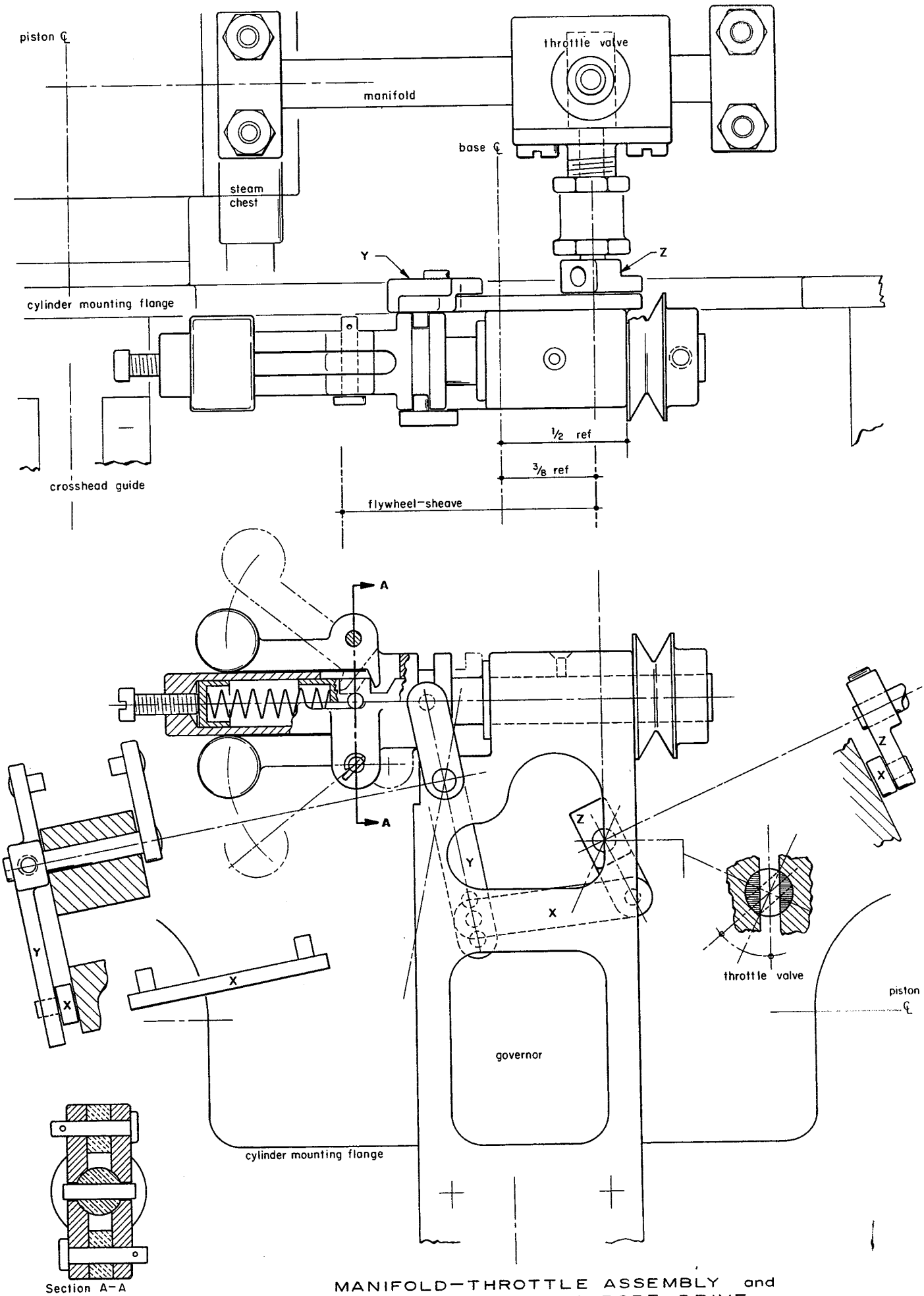
VALVE PLATE
2 Required



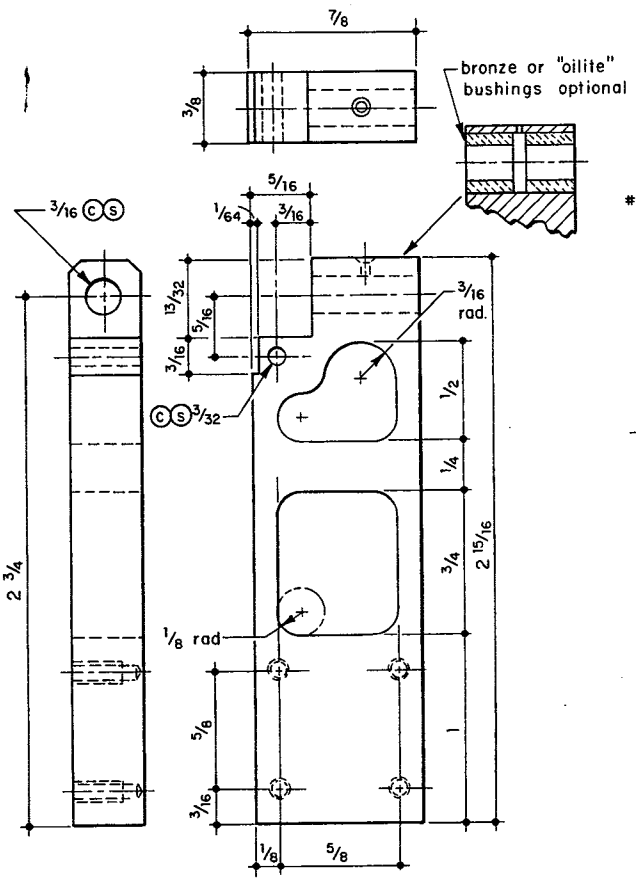
PACKNUT (Piston)
2 Required



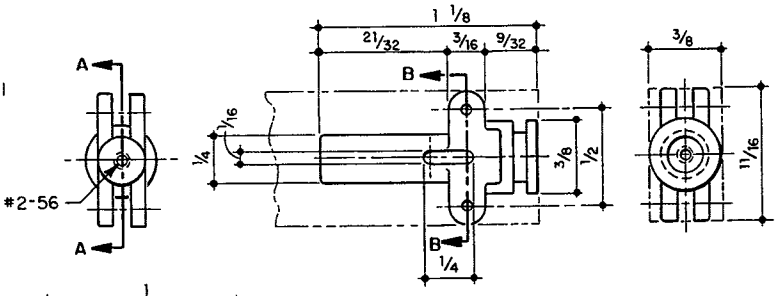
PACKNUT
(Valve Rod)
2 Required

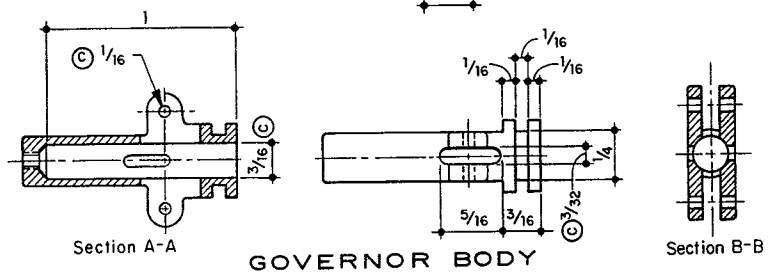


MANIFOLD–THROTTLE ASSEMBLY and GOVERNOR ASSEMBLY FOR ROPE DRIVE

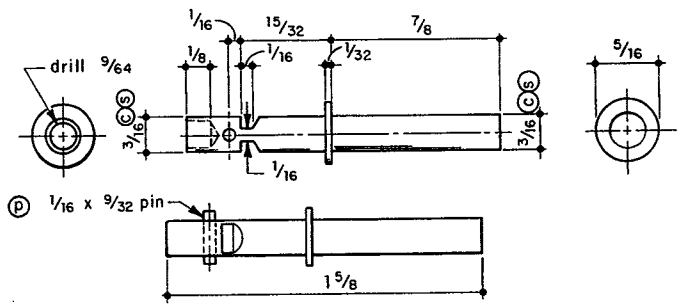


GOVERNOR COLUMN

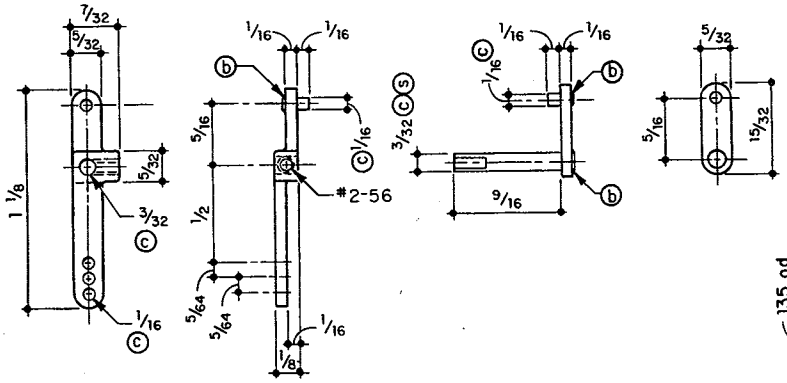




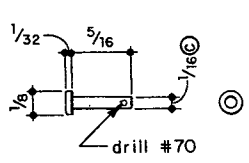
GOVERNOR BODY



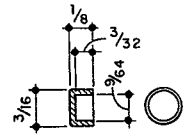
GOVERNOR SHAFT



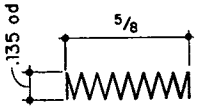
GOVERNOR FORK "Y"



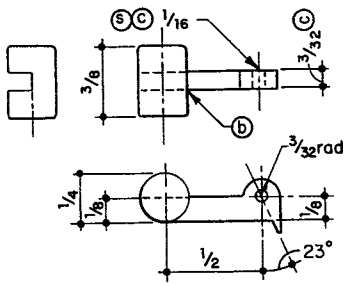
GOVERNOR ARM PIN
2 Required



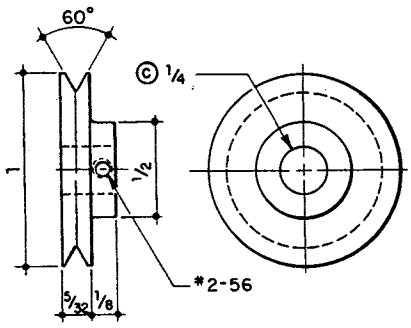
SPRING CUP



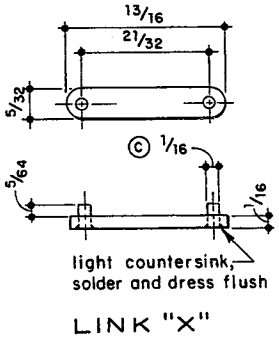
SPRING



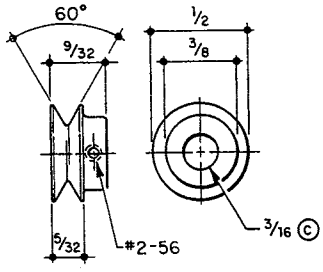
GOVERNOR ARM
2 Required



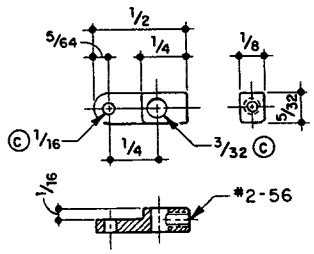
GOVERNOR PULLEY
(LARGE)



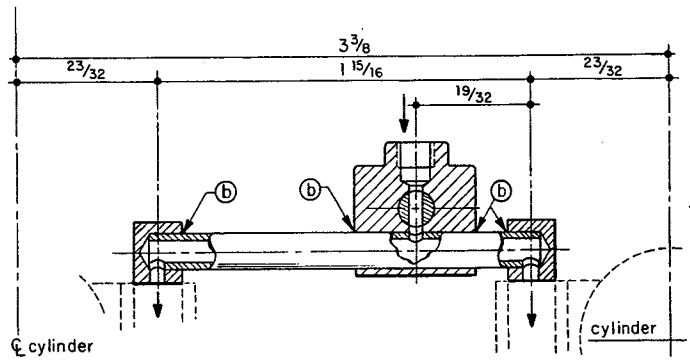
LINK "X"



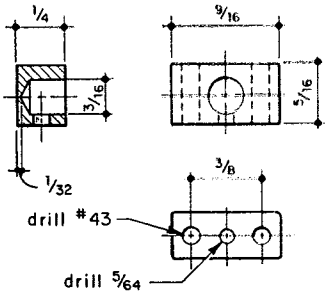
GOVERNOR PULLEY
(SMALL)



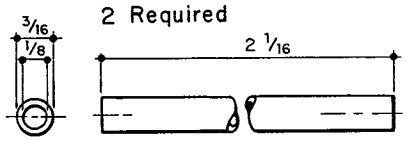
THROTTLE ARM "Z"



MANIFOLD—THROTTLE VALVE

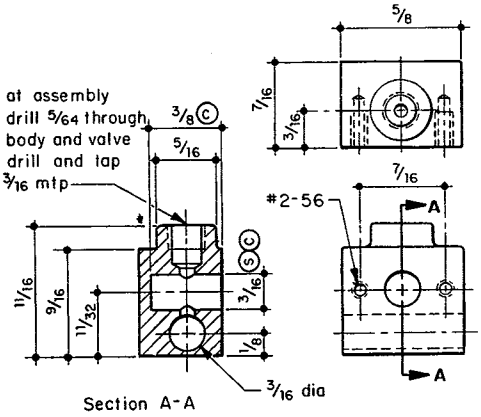


MANIFOLD BLOCK
2 Required

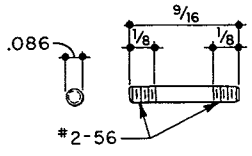


drill after assembly

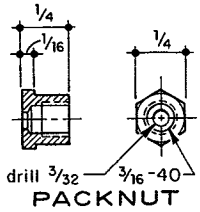
MANIFOLD TUBE



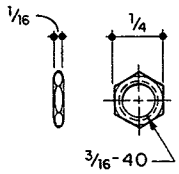
THROTTLE VALVE BODY



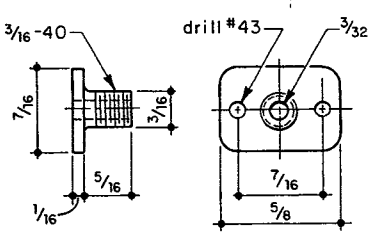
MANIFOLD STUDS
4 Required



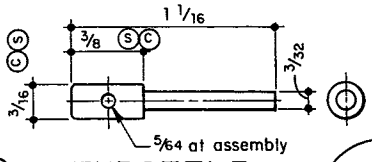
PACKNUT



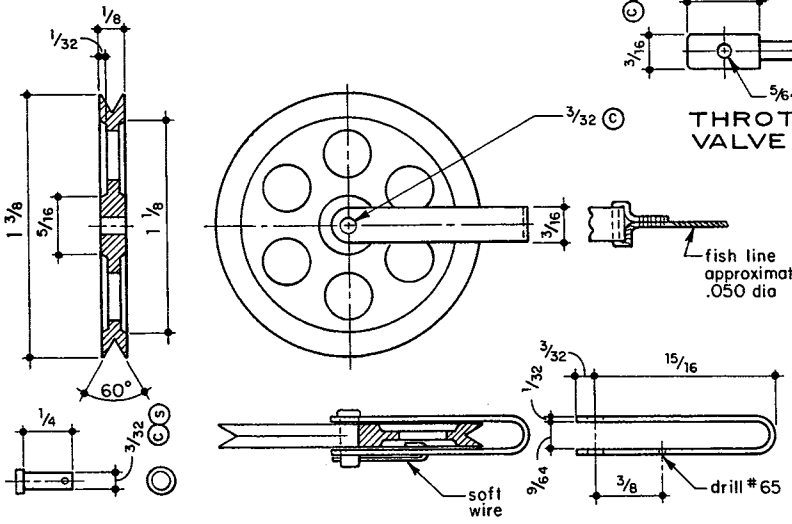
LOCKNUT



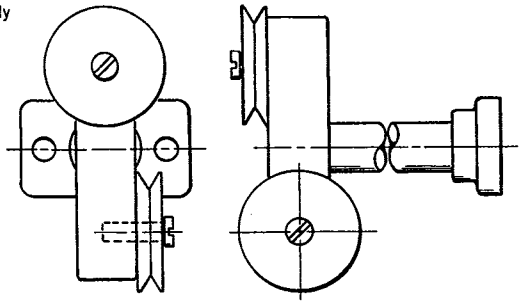
THROTTLE COVER



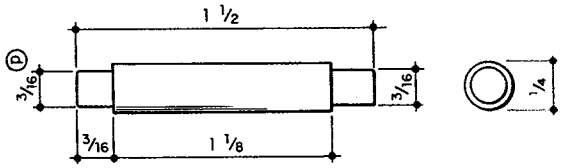
THROTTLE VALVE



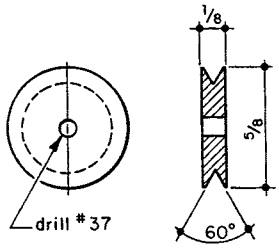
IDLER PULLEY



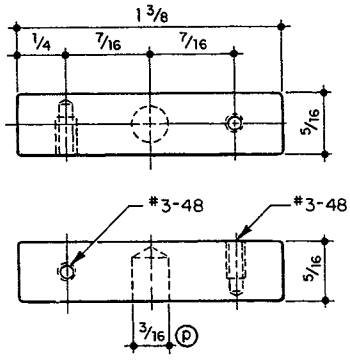
COUNTERWEIGHT STAND



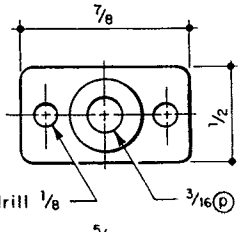
COUNTERWEIGHT COLUMN

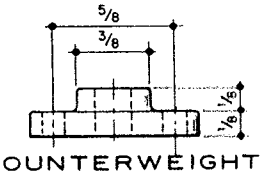


COUNTERWEIGHT
PULLEY
2 Required

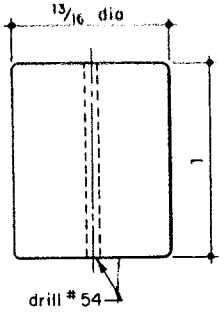


COUNTERWEIGHT
BEAM

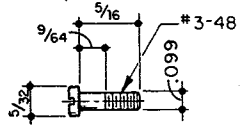




COUNTERWEIGHT
BASE



COUNTERWEIGHT



COUNTERWEIGHT
SCREW
2 Required

3/8" recess cut in the face. Drill for the set screw and tap hub. Re-chuck, gripping the inside of the rim just formed. Turn the second side and bore for the shaft. Coat the O.D. with layout dye and scribe lines (while still in the chuck) for the grooves, and machine the grooves as mentioned above. Layout lines joining the holes and saw and file the spokes.

For the **SMALL PULLEY**, chuck a piece about 3" long and make the grooves, bore and hubs in one chucking.

The **PACKING** is 1/16" strands unraveled from braided asbestos graphited packing. Do not snug up the Packing Nuts too tight. Turn them in lightly with the fingers.

The **LAGGING** is tin can stock. Make a heavy paper pattern that fits the Cylinder and transfer to the metal. The Lagging is mostly a cut-and-try job. Carefully roll over a mandrel to a diameter smaller than the 1/16" flanges on the Cylinder and spring it in place.

The **CONNECTING ROD** and **VALVE ROD** should both start out long enough for chucking and tailstock support center holes.

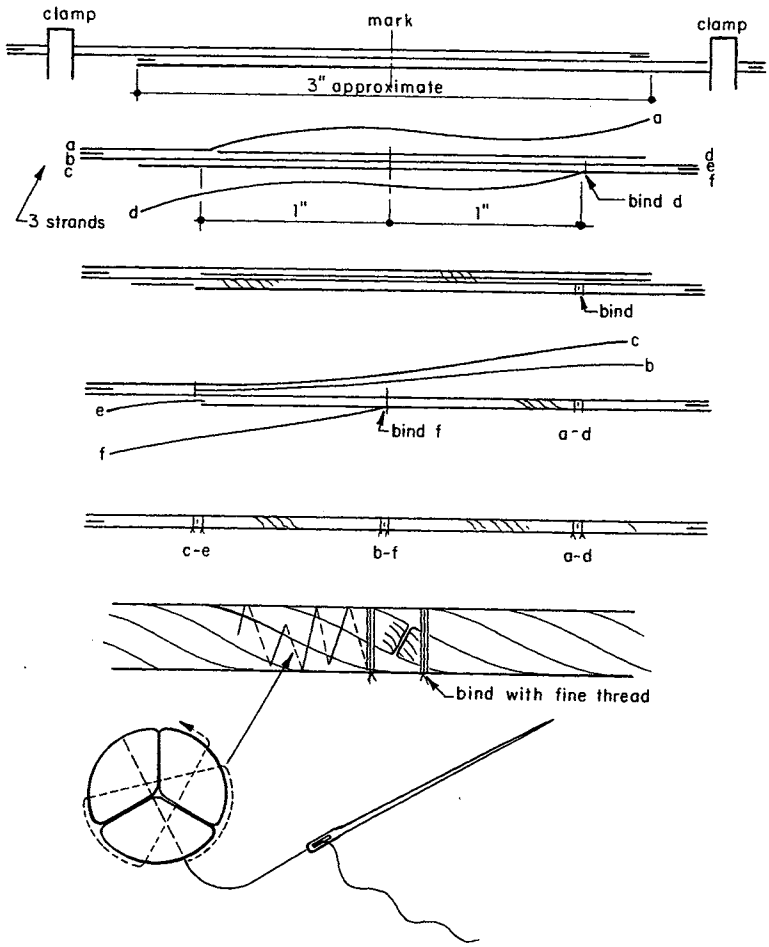
The **GOVERNOR COLUMN** is mostly layout and machining operations. The use of Bushings in the option provides an excellent reservoir for oil to feed the Oilite.

The **GOVERNOR BODY** uses 3/8" x 11/16" stock chucked in the 4-jaw, with about 1-1/2" projecting. Turn the 3/8" diameter back for 9/32" and make the 1/16" groove. Bore 3/16" 1" deep and drill #50 for 2-56 adjusting screw. Turn 1/4" diameter 7/8" long for final parting at 21/32". Make a milling setup to bring the lugs down flush with the 1/4" diameter body. Mill or drill and file the 3/32" and 1/16" slots. This body must be a close but free fit on the **GOVERNOR SHAFT**.

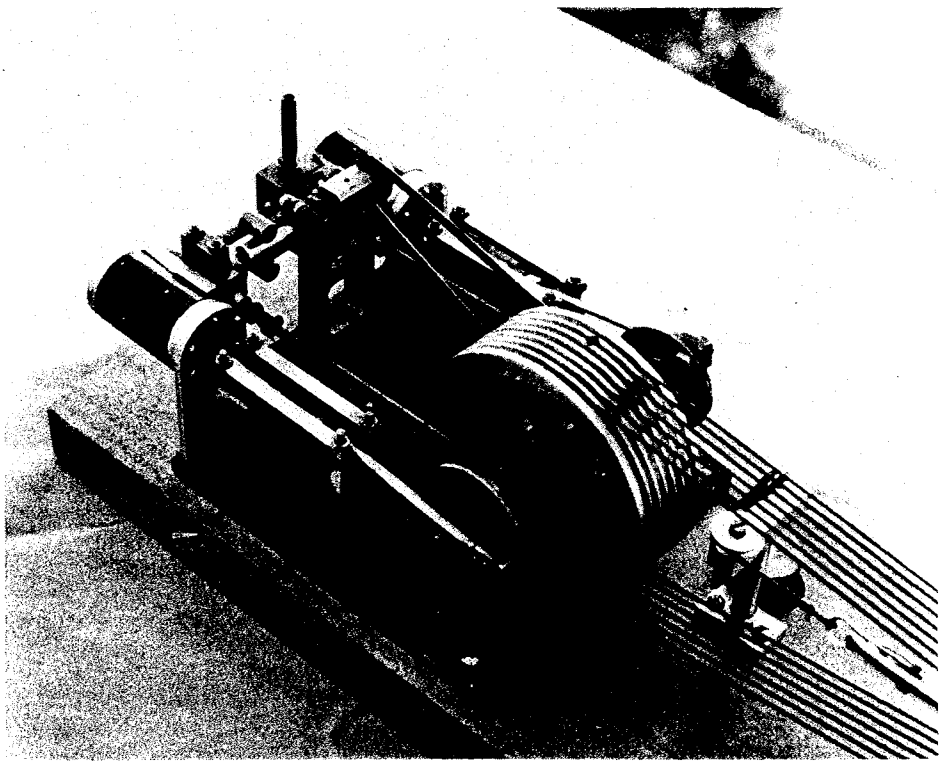
The **GOVERNOR SPRING** dimensions shown are those of a spring found in the odds-and-ends department and seemed to be just right.

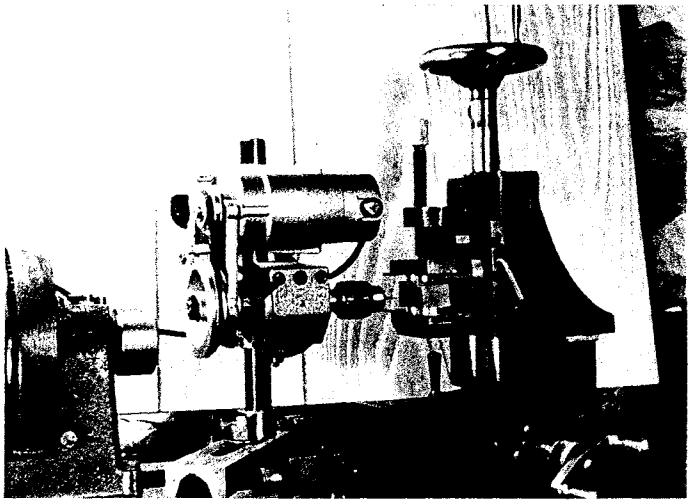
When making the **GOVERNOR ARMS**, leave the 23° point a bit full and work down at assembly with a small file, keeping the two as near alike as possible.

Make the **THROTTLE VALVE** a close but free fit in the **THROTTLE BODY**. The flyball rotation doesn't have much force to move the Valve. A thin thrust washer made from .002" to .004" steel shim stock at the Shaft

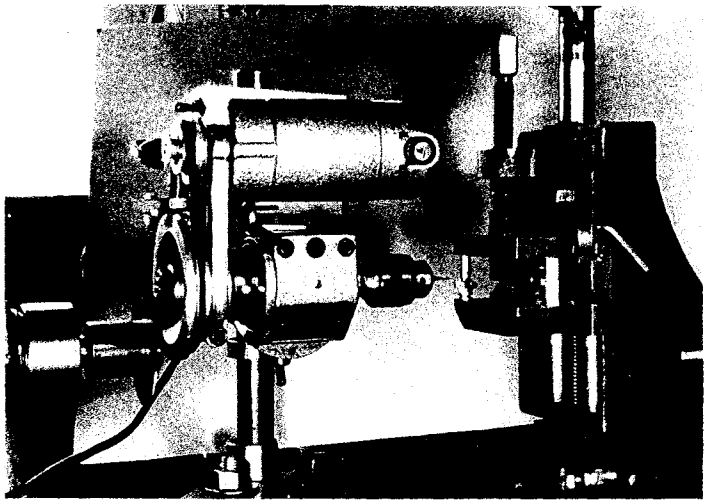


SPLICING THE "ROPE" FOR THE ROPE DRIVE





Milling the steam passages in the Cylinders.



Mlling the slots in the Governor Body.

end will reduce friction end-ways. Give this valve a thin coat of light "Molly" and oil at assembly.

The **THROTTLE COVER** was made long for Bearing support. When the **PACKNUT** was run down, it tended to turn with the Shaft. A thin 3/16-40 locknut was set when the final setting was found. Give the packing a good soaking with light oil. Avoid all the drag possible on the entire Governor assembly. At the same time avoid sloppiness.

Solder one block on the **MANIFOLD** tube. Assemble on the Steam Chest and establish the location for the other block and body and solder it. Spot the Valve Body at 19/32" and solder.

The **IDLER PULLEY** is plastic for light weight and low friction. Anchor the Pin through the Pulley with a short length of copper wire run through the pin and side of the Yoke as shown. This prevents the Pin from rotating in the thin metal of the Yoke. Avoid all the weight possible in this assembly. Bind the fish line with fine thread and add a drop of glue.

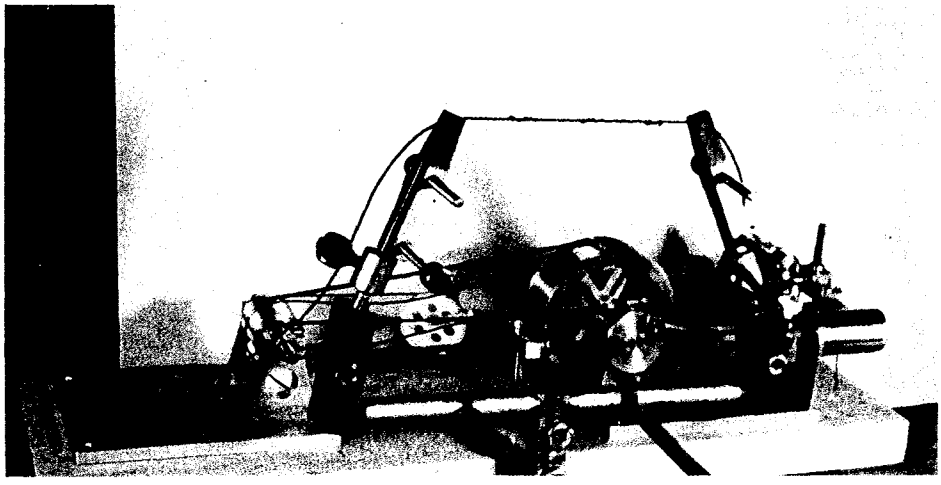
The **"ROPE"** used on this model is a three-strand fish line about .050" in diameter. Splicing this line may try your patience. After several experiments, this method was used and it made a fair joint with the least thump as it went over the pulleys. You will find tweezers handy for this job.

- Completely thread the Rope over the pulleys and bring the ends so there is an overlap. With tension about right and Counterweight high, make a mark across both Ropes with a felt pen. Hold these ends together with a spring clothes pin or such and carefully slip the outside two or three Ropes off the Pulleys so you have some slack to mount the Ropes in a work-holding fixture. Keep the marks in line and Rope reasonably tight because it maintains the length that fits over the Pulleys. Each strand is numbered. Unwind **A** and **D** as shown.
- Cut **D** and bind to prevent further unwinding.
- Wind **A** around **E** - **F** in the groove left by **D**.
- Cut **A** so it meets the end left by **D** and bind, thus we are avoiding a knot which can cause trouble.
- Unwind **B** and **C** back 1" to the left of the mark and bind.
- Unwind **F** back to the mark and bind.
- Wind **B** in the groove left by **F** and cut **B** and **F** at the mark and bind.
- Cut **E** and **C** 1" left of the mark and bind. remember to keep the slack to a minimum.

When all the ends are tied, use fine needle and thread and further bind the ends by piercing the strands in all directions back about 3/16" from the joint. Draw the thread up snug and work back toward the start so the ends can be tied with a simple square knot. A small drop of glue at the joint will help prevent the threads from loosening. Now each joint has two full strands, which is plenty for this service.

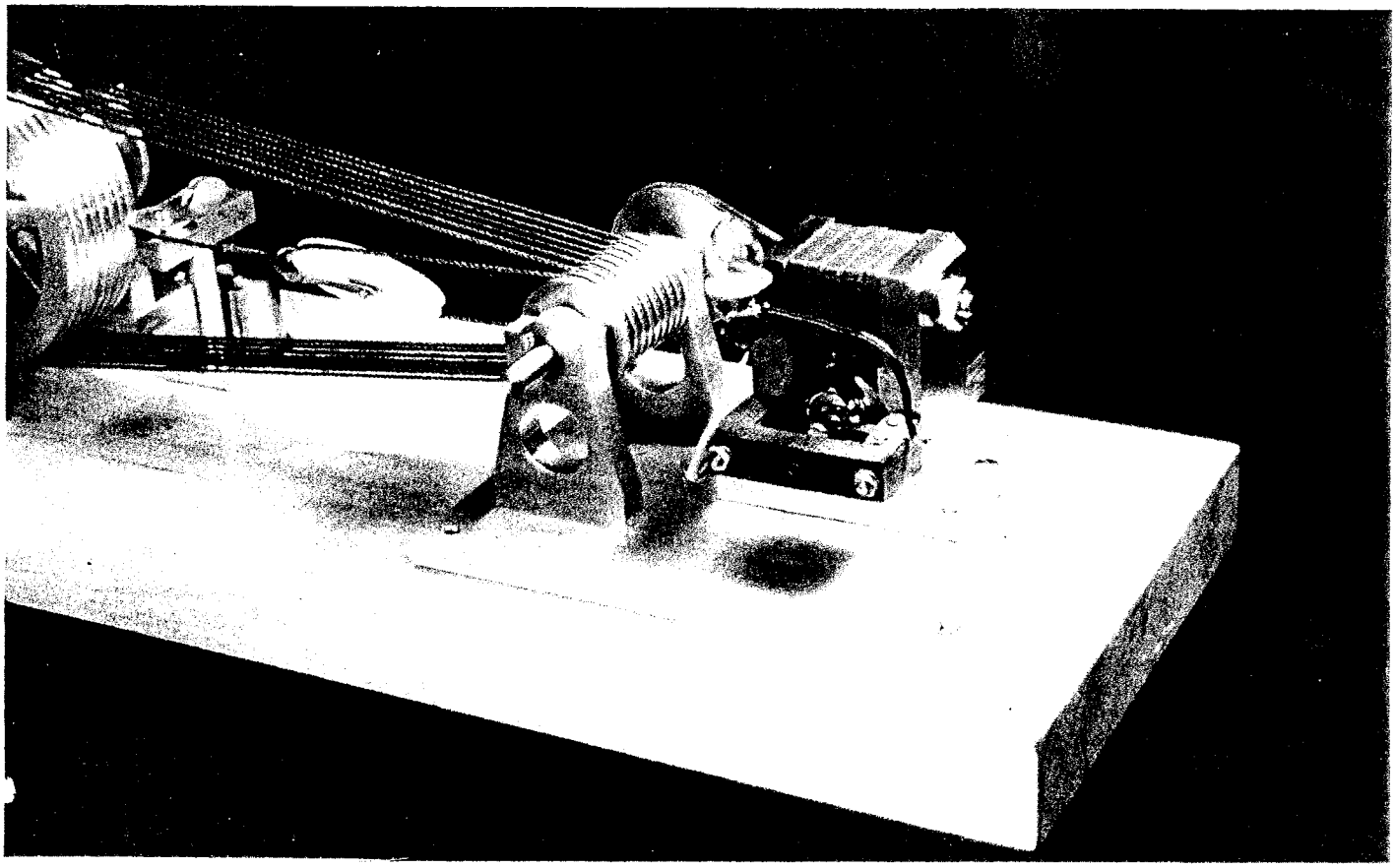
At the final engine **ASSEMBLY**, turn the Crank to one dead center position and tighten the Eccentric with its axis 90° from the centerline through the Crank. Adjust the Valve to equally expose the Valve holes at each end of the stroke. Set both Eccentrics alike to either lead or follow the Cranks.

Splicing the Rope.



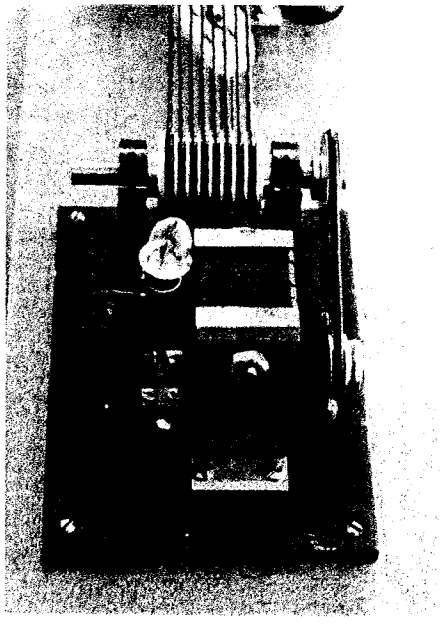
CHAPTER

40 Generator



There have been suggestions sent in to run plans for a model generator that can be driven by the model engines that have been built. Since none of the readers with electrical experience have submitted such an item, the generator shown was designed by a person with only a practical knowledge along this line. With the help of those better acquainted with the subject, clippings, and old textbooks, a generator was made that works. We're always looking for suggestions to improve this design, though it will light a flashlight bulb to a surprising degree just as it is.

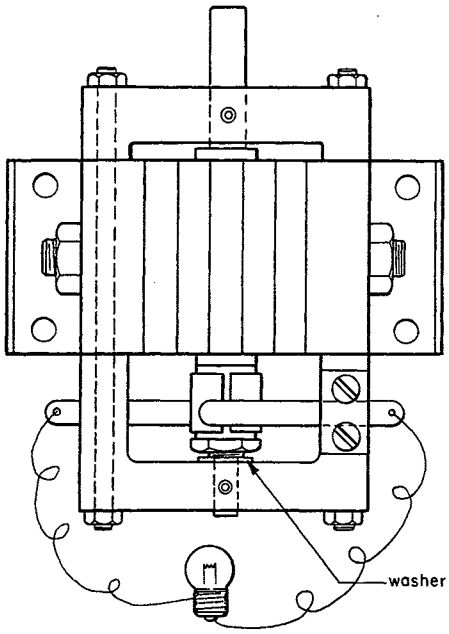
The old textbook says permanent magnets make a "magneto" and the wound-field type is a "dynamo," but both are called generators. This is the permanent-magnet type made

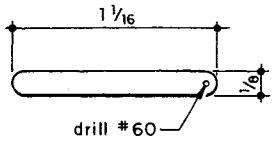


with ceramic magnets purchased from a popular scientific supply house.

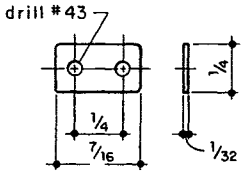
None of the material is difficult to acquire. Boring for the Armature and Shaft Bearings and Winding are the most difficult operations, but not beyond the average shop.

Measure the stack of magnets and put the magnets aside out of the reach of steel and iron chips around the bench. Make all the parts for the **MAIN FRAME**. Those are the Base, Magnet Bars less the 1/2" radius scallop, Bearings less the Shaft holes, Spacer and Tiebolts. Assemble the Bearing Tiebolts in the Magnet Bars with Loctite, with the proper amount projecting on each side. Lay out the Shaft center on the Outboard Bearing. Mount on the angle plate and center as shown. Make the 1/8" Shaft

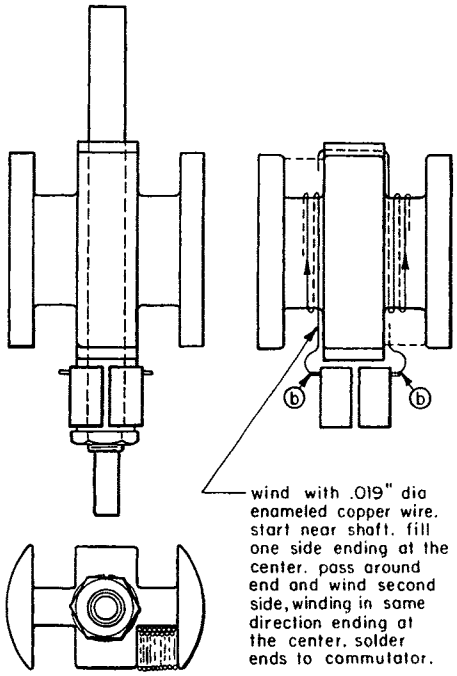


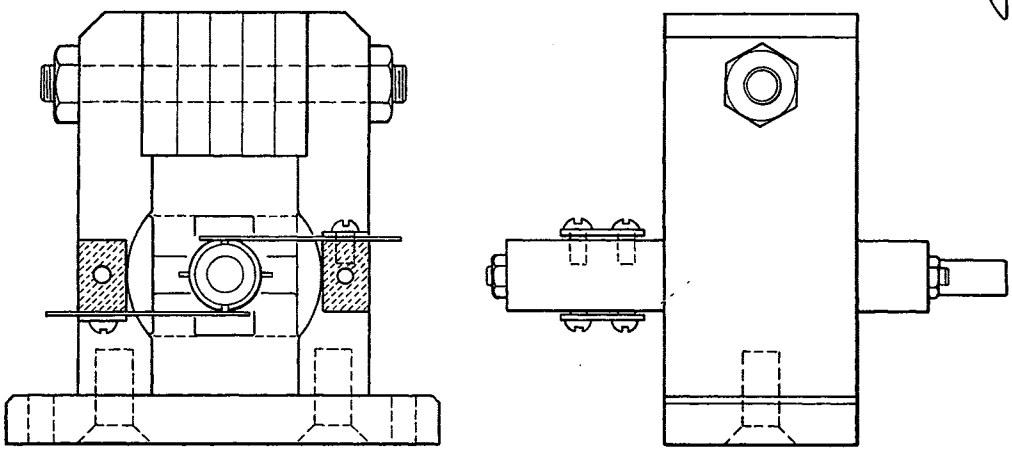


BRUSH
Spring Bronze,
2 required

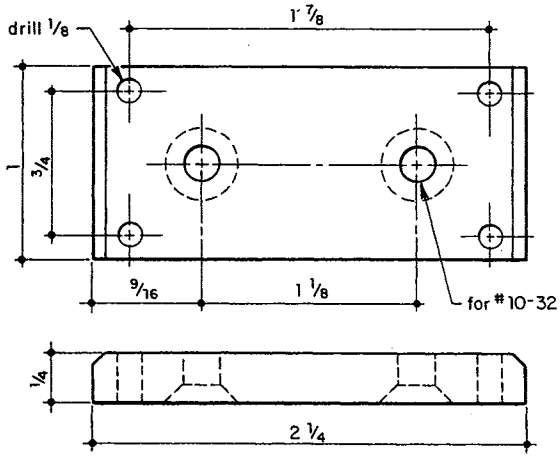


BRUSH CLAMP

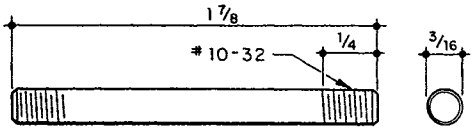




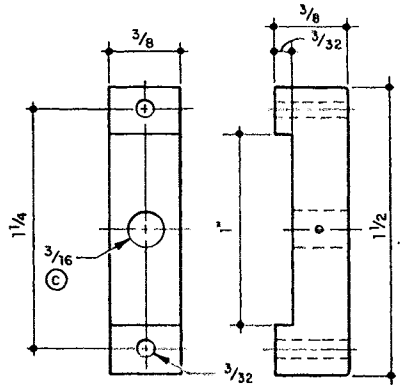
GENERATOR



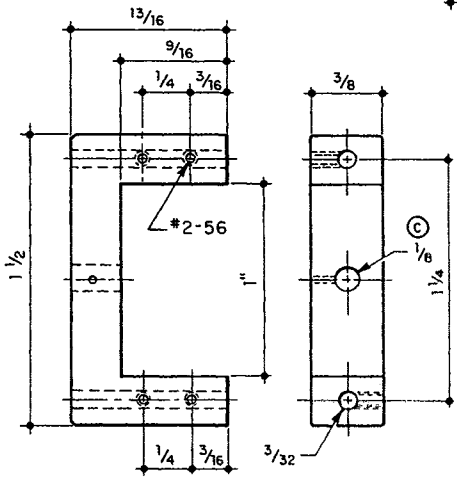
BASE
Aluminum, 1 required



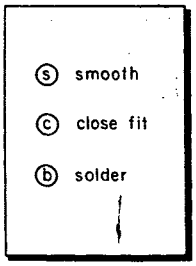
MAGNET TIEBOLT

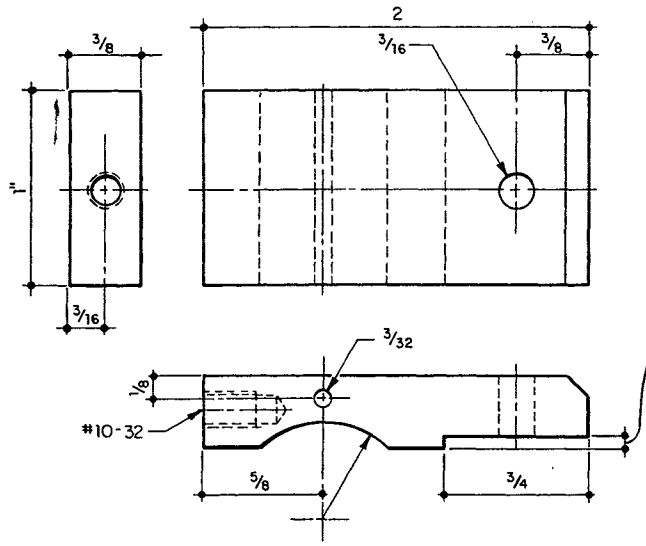


INBOARD BEARING
Canvas Laminated Bakelite



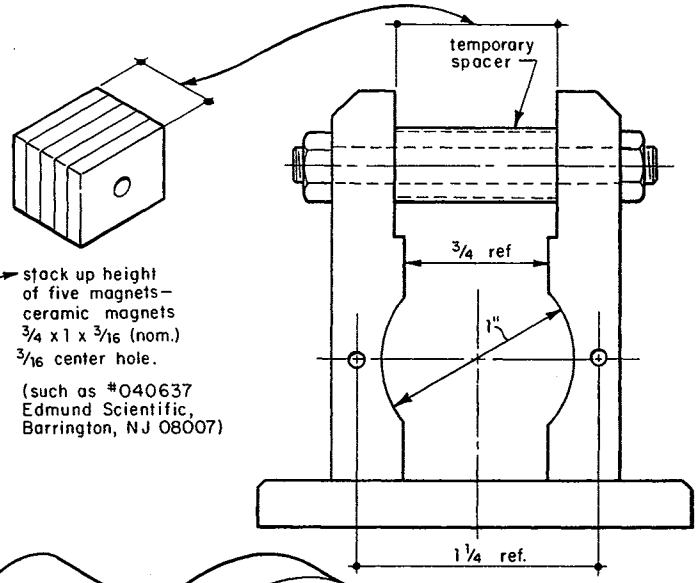
OUTBOARD BEARING
Canvas Laminated Bakelite



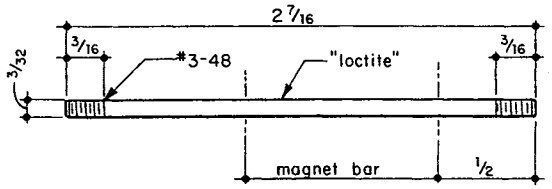


stock up height of five magnets– ceramic magnets 3/4 x 1 x 3/16 (nom.) 3/16 center hole.

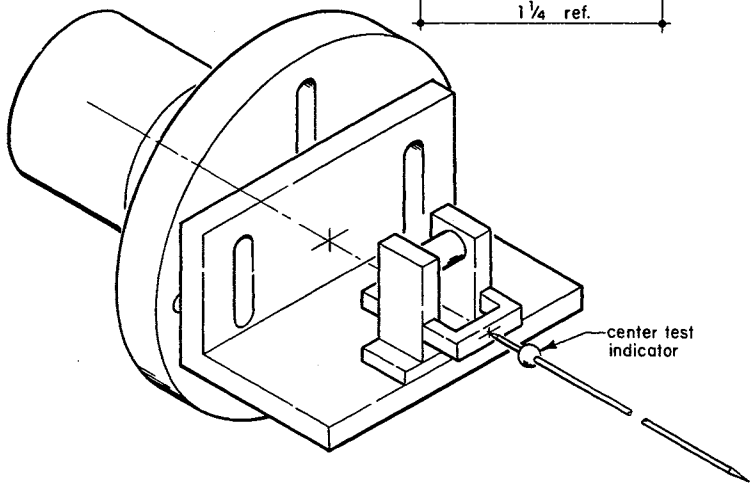
(such as #040637 Edmund Scientific, Barrington, NJ 08007)

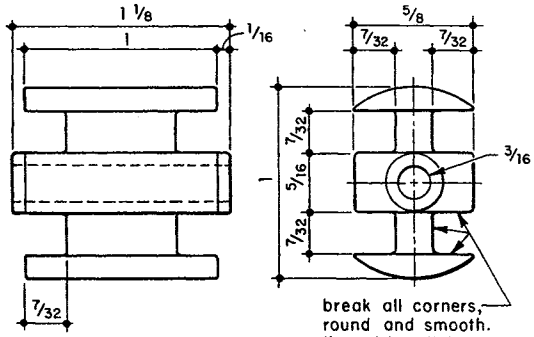


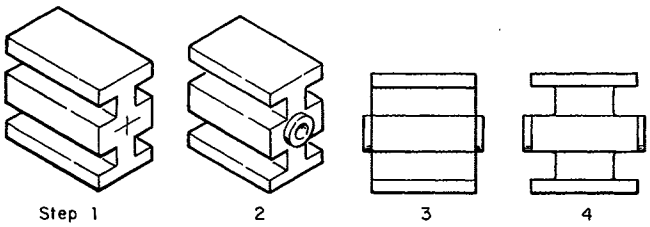
MAGNET BAR
Mild Steel, 2 required



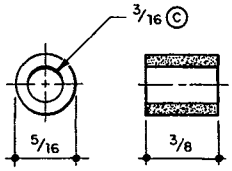
BEARING TIEBOLT
Steel, 2 required



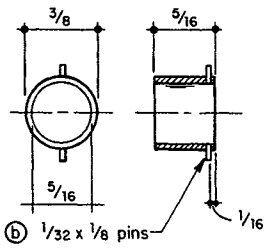




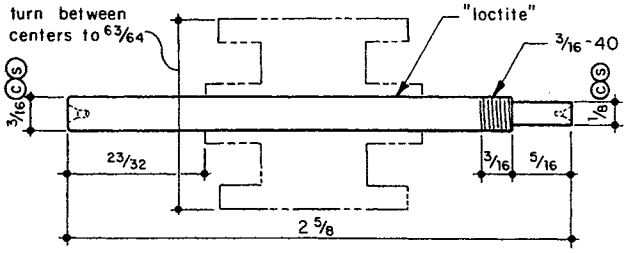
ARMATURE
Steel, 1 required



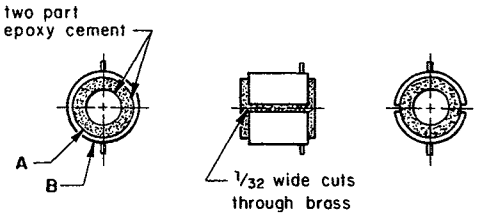
A
Canvas Laminated Bakelite, 1 required



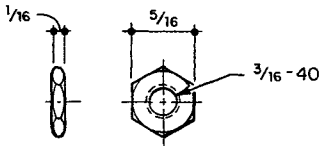
B
Brass, 1 required



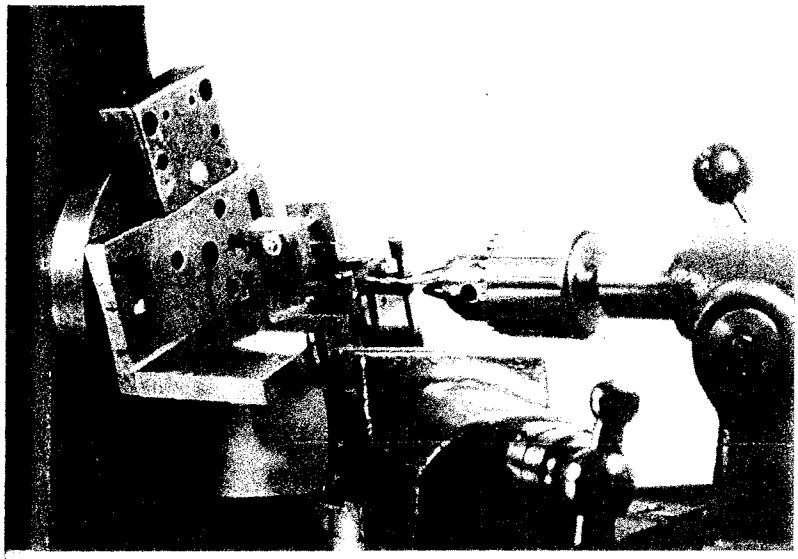
ARMATURE SHAFT
Steel, 1 required



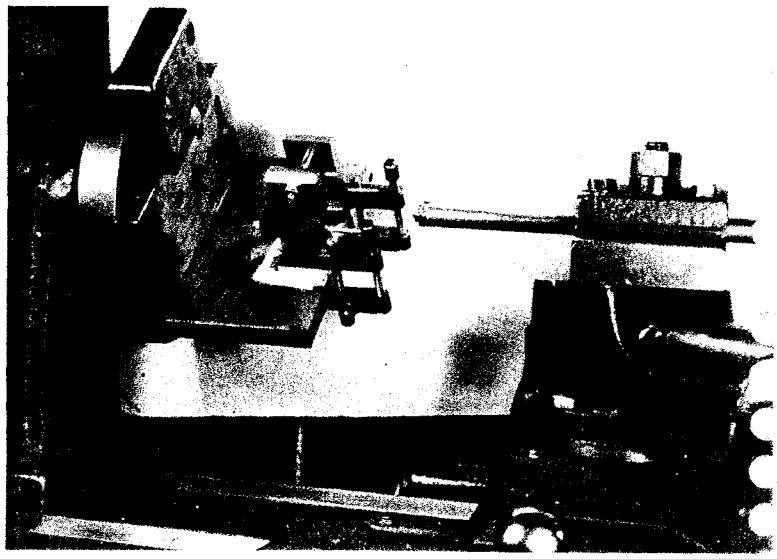
COMUTATOR



NUT
Brass, 1 required



Boring the Bearing in the Generator Frame.



Boring 1" clearance for the Armature in the Generator Frame.

bore. Remove Outboard Bearing and reach through, making the 3/16" Shaft bore in the Inboard Bearing. Set up a boring bar and turn the 1" diameter across the Magnet Bars. The ideal condition is to have the Armature clear the Magnet Bars by only a few thousandths. That is a bit fussy so the Armature is turned to 63/64" making it about .008" clearance. This works OK though it is close enough to cause considerable trouble with fine steel chips, attracted by the magnetized parts and wedging between the Armature and the Magnet Bars. Wipe everything clean before final assembly with the Magnets. This was learned the hard way.

The **ARMATURE** starts as a 5/8" x 1" x 1-1/8" block. Lay out all the outlines and mill the four 7/32" x 7/32" grooves as in **Step 1**. Center in the 4-jaw and turn the 1/16" x 5/16" hub and bore 3/16" as in **Step 2**. Reverse in chuck and turn the other end as in **Step 3**. Make milling setup and do **Step 4**. The **ARMATURE SHAFT** is made between centers and set in Armature with Loctite.

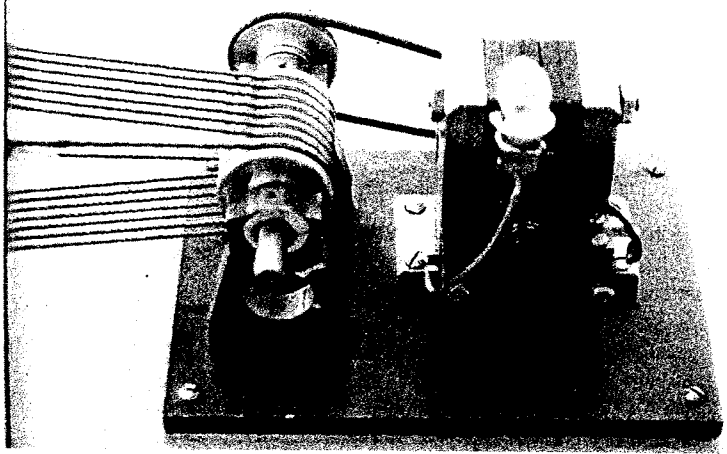
The **COMMUTATOR** is an insulating body with a brass Sleeve cemented to the outside. Two 1/32" Pins are soldered to the Sleeve before cementing. These provide an easier soldering operation when attaching to the Winding Wire. It is less apt to overheat the "Epoxy" cement. Make the 1/32" cuts, just barely cutting through the brass. If a section should loosen, a thin coat of cement and a spring clothes pin can anchor it back in place. True-up the Commutator in the lathe for smooth contact with the brushes.

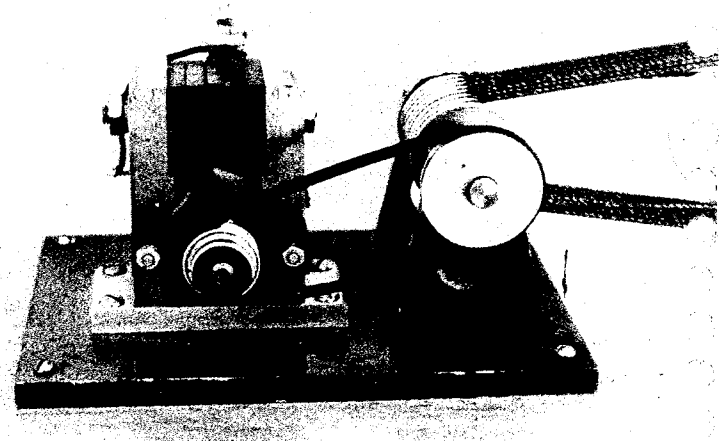
The **MAGNET WIRE** is the coated type rather than the old cotton-covered. Care must be taken that no sharp edges cut through the varnish, thus the rounded corners and cellulose tape insulation. Wind as shown, trying for the same amount of turns on each side to keep the Armature balanced. Remember to wind the second side in the same direction as the first. A washer 1/8" I.D. may be necessary on the Commutator end at assembly. The **BRUSHES** are already insulated away from the other metal since the Bearings are non-conducting "Bakelite." The material for the Brushes can often be found in car distributors and abandoned electronic assemblies. Bend the Brushes so they ride the Commutator a bit firmly. Make sure the 2-56 screws holding the Brushes do not touch the Tiebolts.

Unfamiliarity with such electrical equipment made this a cut-and-try dead-reckoning project, so no calculations or data can be supplied such as proper proportions, wire diameter, number of turns, stress, output, etc. The only thing is the flashlight bulb "LIT UP"!

This generator made a good unit to drive with the Twin-Cylinder Rope Drive. It makes a great conversation piece.

The completed Generator





CHAPTER

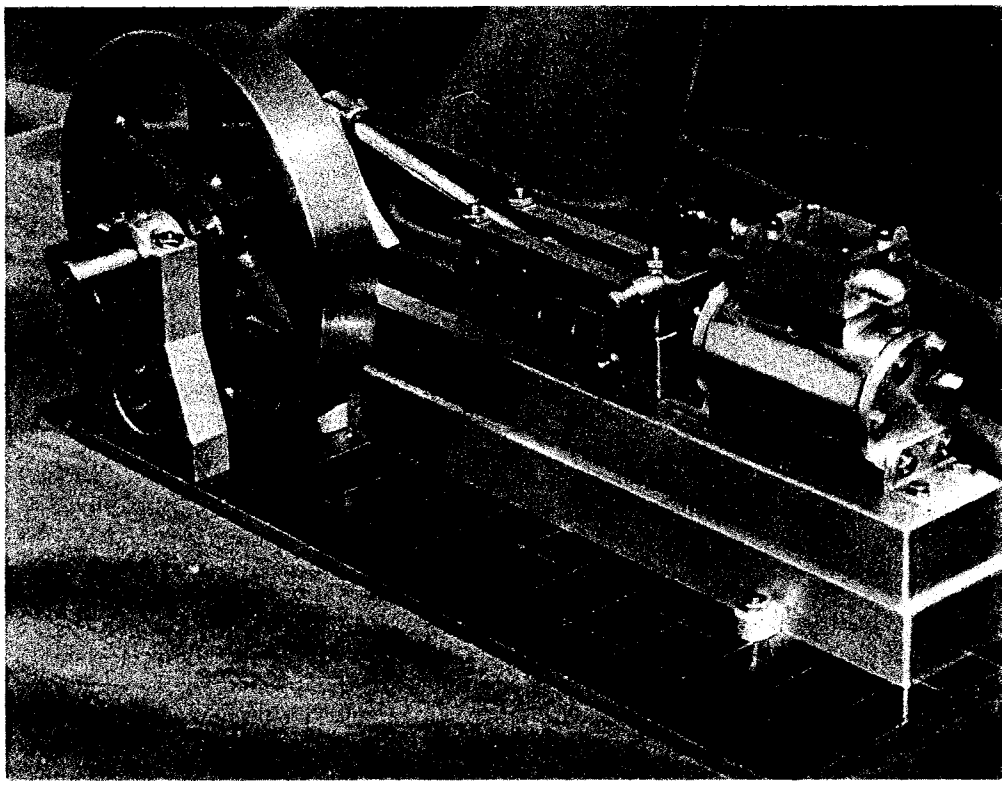
41 Factory Engine

This is a sister engine to the Mill Engine which, by now, you may already have completed. Many parts are common to both engines so, if you have finished the Mill Engine, you will have the benefit of past experience in this project. This Factory Engine has a 1/2" bore x 1" stroke with the Steam Chest on top actuated by a Rocker Shaft.

No castings are required and most of the material can come from your scrap box. On the model shown, most of the parts are made of a fairly hard jig-and-fixture grade of aluminum.

The **FLYWHEEL** shown in the photo is a 3" Stuart Turner from a 10H engine. Drawings and instructions are given in the Appendix for a Flywheel made from 1/2" flat stock.

For the **BEARINGS**, start out with accurate blocks, 5/16" x 3/4" x 13/16" and 5/16" x 1-1/4" x 1-13/16". Scribe the outlines on the faces of each Bearing. Lay out and tap the bearing mounting holes. Lay out the centerline for the shaft hole on the Tall Bearing and mill to outline. Assemble the Bearings to the Floor, Sub-Base and Base, all snug and well-aligned. On the model shown, the assembly was mounted in the cross-slide milling attachment. The shaft center was picked up with a wiggler and the bearing holes line-drilled in easy stages to avoid strain on the setup. The last few thousandths were taken out with a reamer, in this case 3/8", since "Oilite" bushings were to be used. If you do not choose to use bushings, work up to a 1/4" reamer. A 1" long, flat head bolt with a thick nut was used as a jack between the Tall Bearing and the Base to take some of the drill thrust. This operation might be done in a drill press, using an angle plate or a deep-jawed drill press vise. Mark each Bearing so it can be returned to its own position where it was machined. If you wish, you can actually make Split Bearings, but you must plan for this at the start. On this model, a deep scored line was scribed to represent a Split Bearing, and fake Studs were added in spot-faced holes. The 5/8" hole is optional.



For the **CYLINDER**, make an accurate 1" x 1" x 1-3/8" block. Lay out all the centers and lines on all six faces. Note that the bore is centered one way on the 1" square and 15/32" from the other face. In **STEP 1**, turn the **X** end, face and bore and ream it 1/2". For **STEP 2**, reverse, and turn the second end. Make a milling setup and complete **STEPS 3, 4, 5** and **6**. Rounding, as in **STEP 7** is optional, since Lagging will cover it. Next, complete all machining, drilling and tapping. Actually, you may prefer to do some of these while the block is still square. Watch the head bolt pattern location so the Cylinder will set squarely upright when the feet are attached.

Make the **FEET**, taking care in drilling for the head bolts so, when the Feet are attached, they rest down squarely on the Base. See, too, that the Steam Chest is parallel to the Base and that the shaft height matches the Crosshead drilling.

The **CONNECTING ROD** is made from 5/16" x 3/16" stock, drilled, reamed and turned. Add extra length for a center hole for tailstock support when turning.

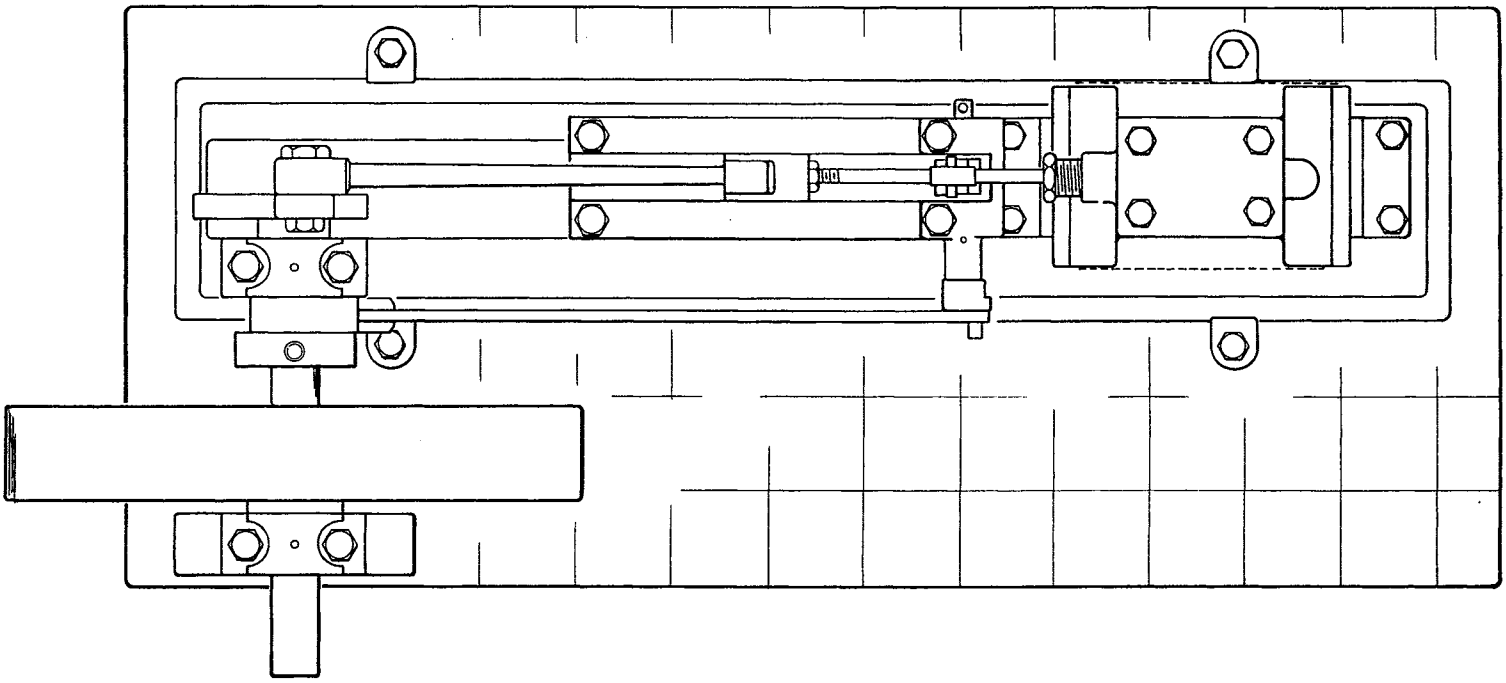
Try for good concentricity on the **PISTON** and **ROD** to avoid binding at the inboard head.

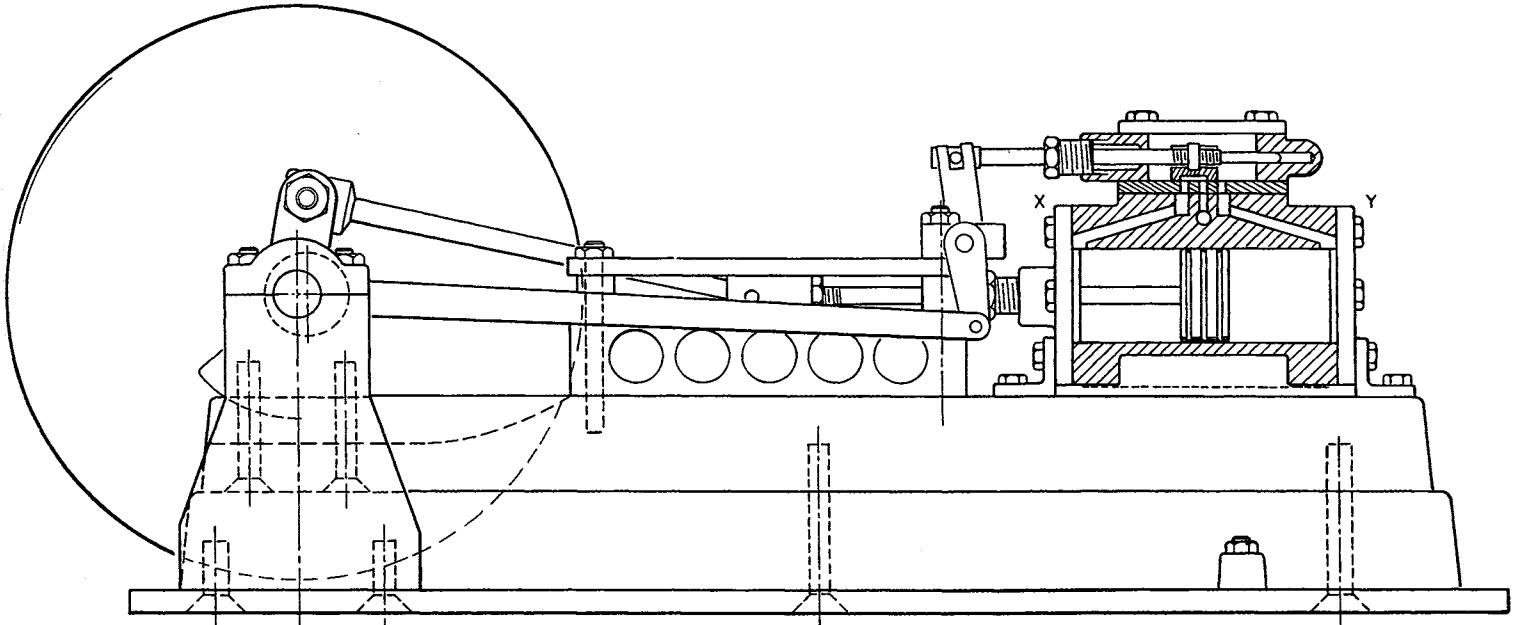
The **VALVE ROD** is 1/8" stock, turned with tailstock support. Mount in the cross-slide mill attachment and mill the flats. It is well that the Nut fit the 2-56 thread closely to reduce pounding at the Valve. Fit the 1/16" x 7/32" Cross Pin.

The **ECCENTRIC STRAP** is a machined bearing end, soldered to a flat bar.

The **FLOOR** on the model shown is salvaged blue-colored anodized aluminum and 1/2" squares were easily scribed to represent tile. The scribing is optional. The metal can be left bright or painted. Perhaps deep scribed lines can be filled with enamel and the surface wiped clean to leave some color in the lines. There are dyes on the market for coloring metal and they should make a background for the lines.

When making the **BASE** and **SUB-BASE**, make the beveling (which is





optional) the last operation. You will have more accurate edges and corners for layout and holding. Mount the Guides, Brackets and Cylinder on the Base before beveling so you can see which areas can be beveled and which corners can be rounded. The fake **LUGS** are set in the Base with Loctite. Short trimmings from #2-56 screws plus hex nuts complete the fake anchor bolts.

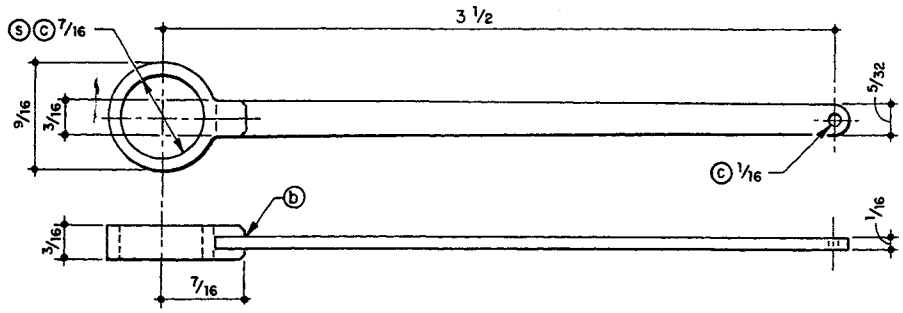
The lower **CROSSHEAD GUIDE** can be simple solid pieces or drilled out or arched as shown. The Piston Rod hole in the **CROSSHEAD** should match the Piston centerline height in the Cylinder. Use a 1/16" x 5/8" pin in the Crosshead.

For the **PACKING,** use 1/16" strands unraveled from braided asbestos graphite packing. do not snug up the packing nuts too tight; turn them in lightly with the fingers.

Make the **ROCKER SHAFT, ROCKER BEARING** and **FORK** of brass. A tiny bit of solder is the best way of assembling the Shaft, Arm and Pin. Use a short piece of soft copper wire in the #70 holes as retainers. Make the Fork a close, but free, fit on the Valve Rod Pin.

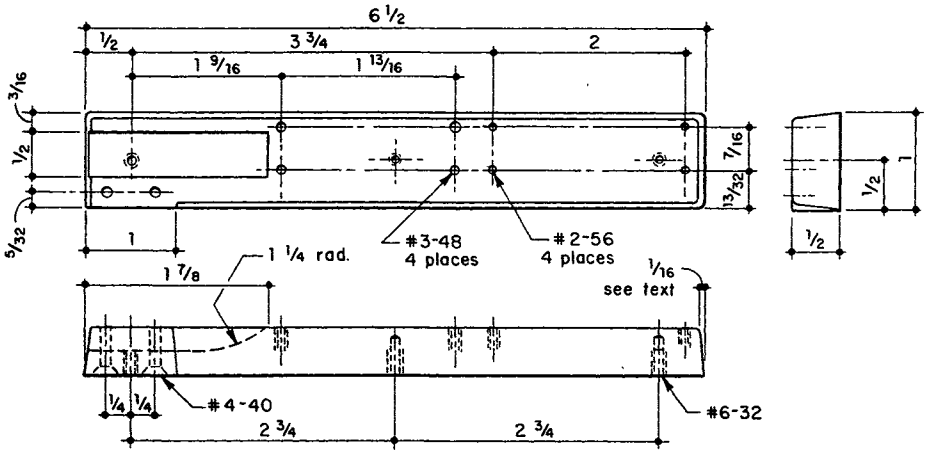
The **LAGGING** is tin can stock. Make a heavy paper pattern that fit the Cylinder, and transfer to the metal. The pattern is a cut-and-try job. Spot two #2-56 countersunk screw holes in the bottom of the Cylinder. Bind the Lagging to the Cylinder with soft wire and drive the Lagging metal into the countersink with a cone-shaped punch. This Lagging is optional since this Cylinder is fairly presentable without Lagging if the milling and filing are neat. If the screw heads strike the Base, make a couple of shallow drill dimples in the Base for clearance or file the heads extra thin. Pan head screws are used here.

At the final **ASSEMBLY**, turn the Crank to one dead center position and tighten the Eccentric with its axis 90 degrees from the centerline through the Crank. Temporarily hold the Steam Chest in place while adjusting the Valve to equally expose the Valve holes at each end of the stroke. You now have the companion to your Mill Engine and the two will make a very complimentary couple.

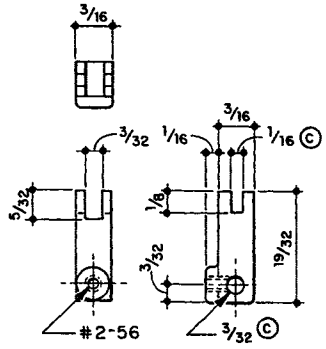


ECCENTRIC STRAP

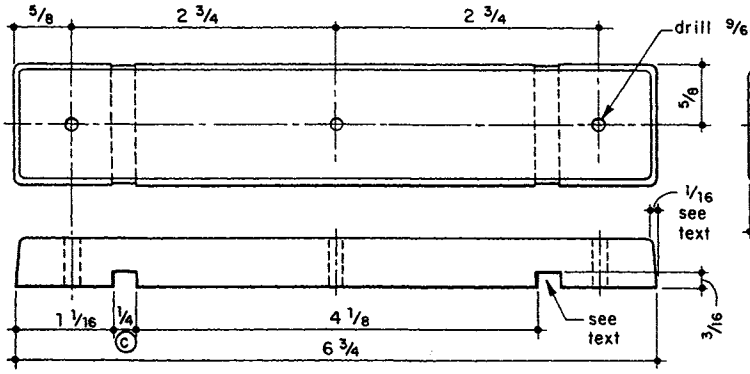
CYLINDER FOOT
2 Required



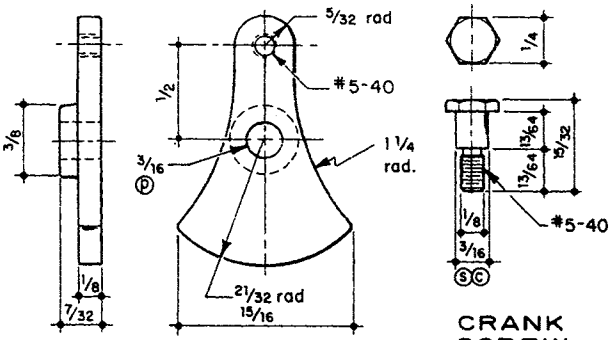
BASE



FORK

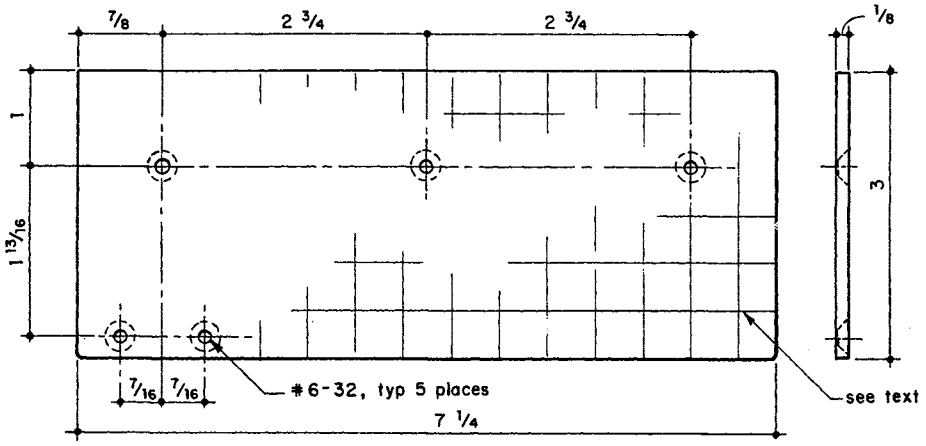


SUB-BASE

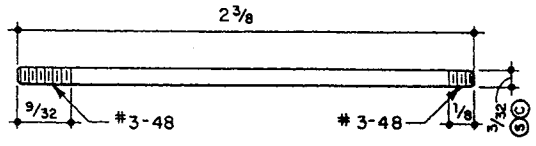


CRANK

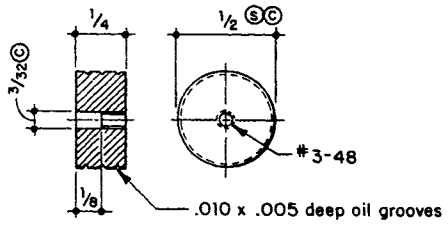
CRANK SCREW



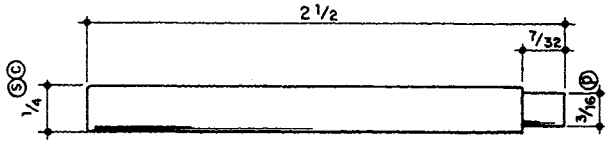
FLOOR



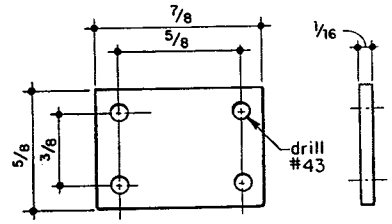
PISTON ROD



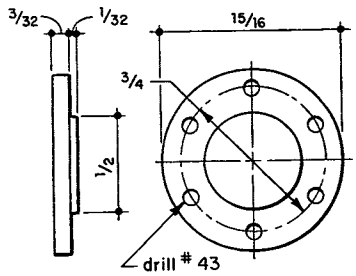
PISTON



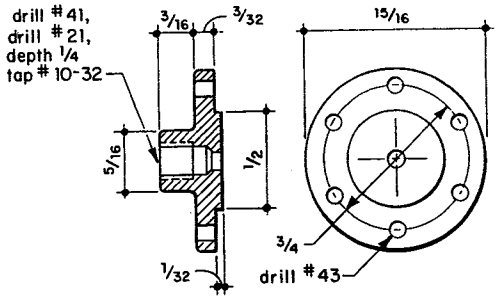
SHAFT



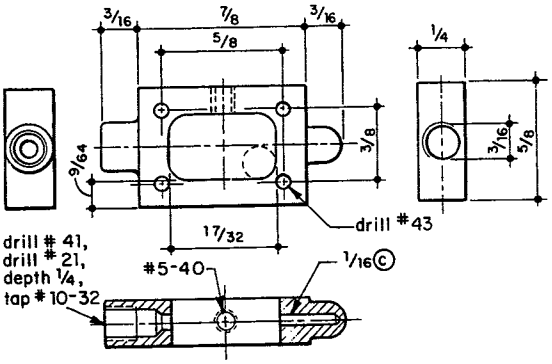
COVER



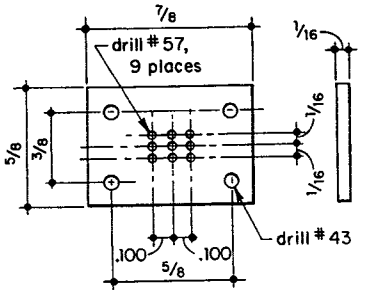
OUTBOARD HEAD



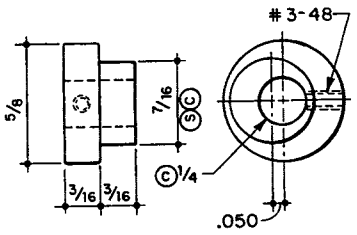
INBOARD HEAD



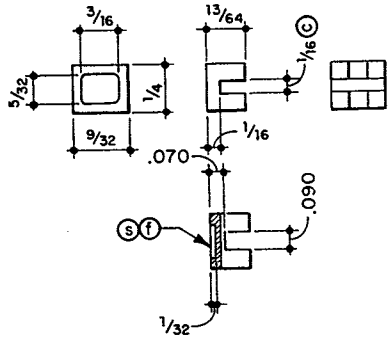
STEAM CHEST



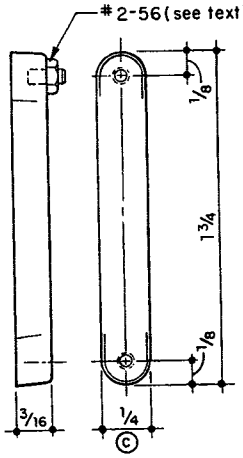
VALVE PLATE



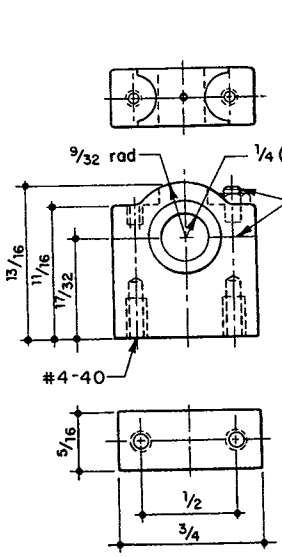
ECCENTRIC

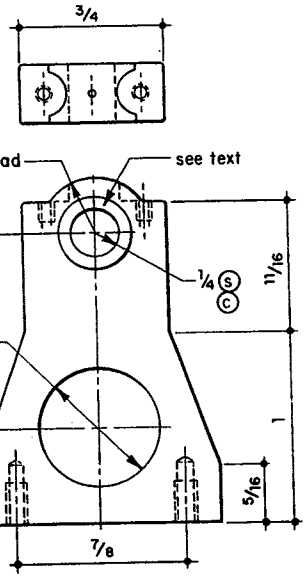


VALVE

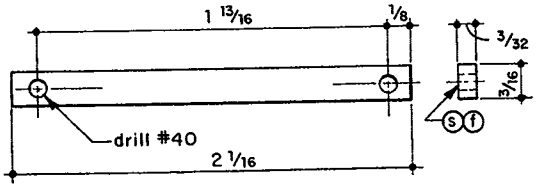


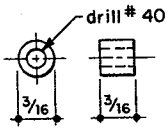
ANCHOR LUGS
2 Required



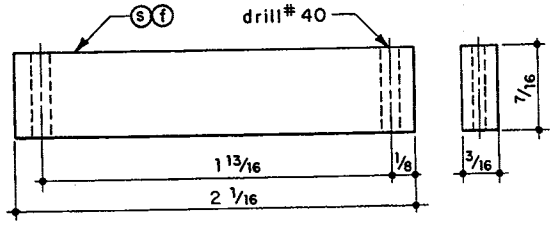


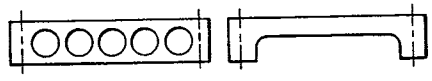
BEARINGS



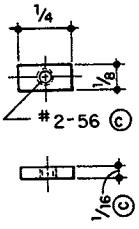


SPACER
4 Required

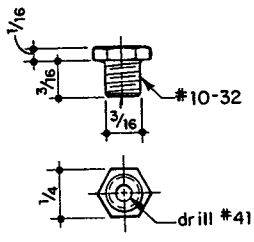




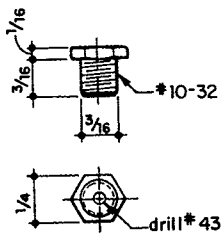
CROSSHEAD GUIDES



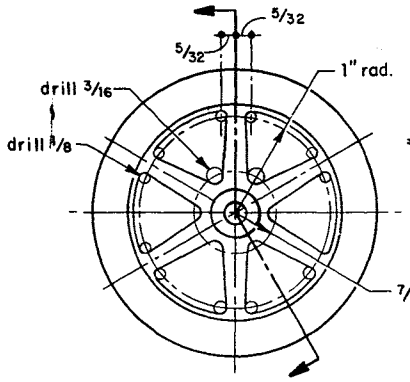
NUT

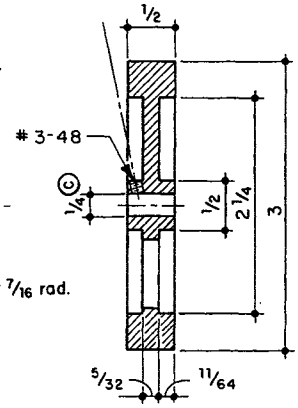


PACKNUT
(Piston)

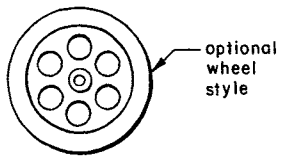


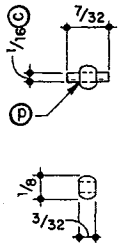
PACKNUT
(Valve)

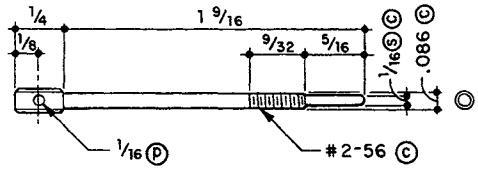




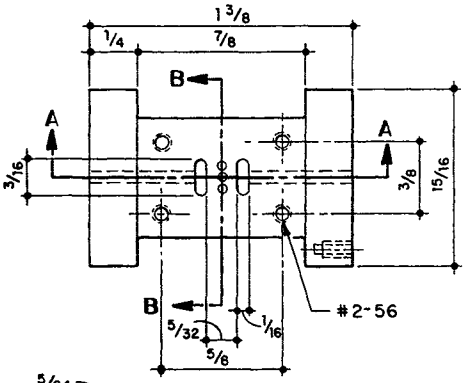
FLYWHEEL

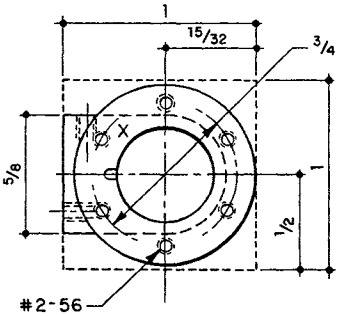


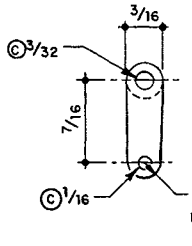


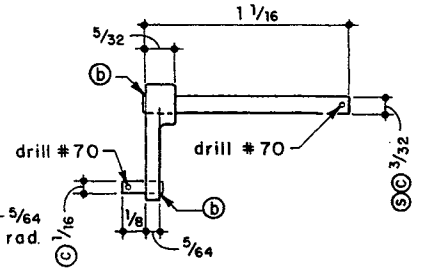


VALVE ROD

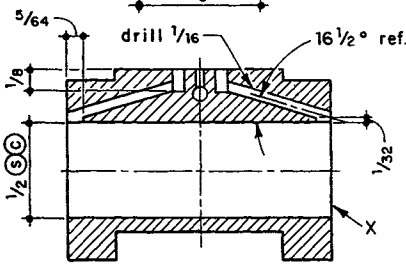




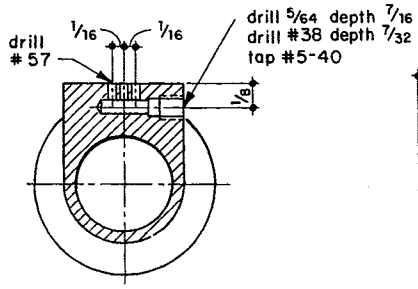




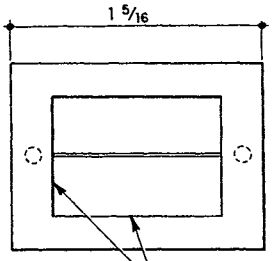
ROCKER SHAFT

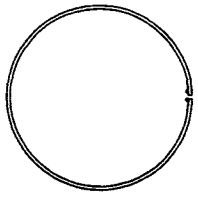


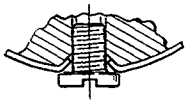
Section A-A

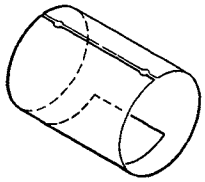


Section B-B



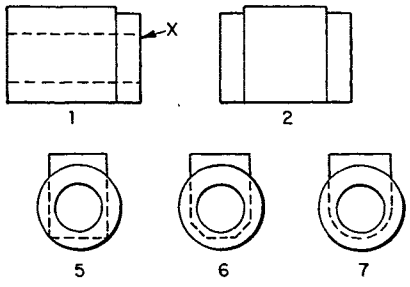






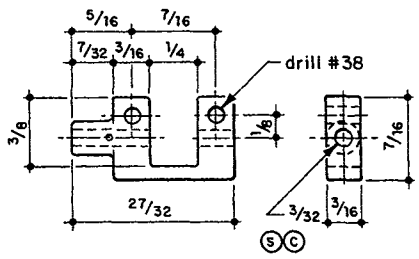
(see text)

LAGGING

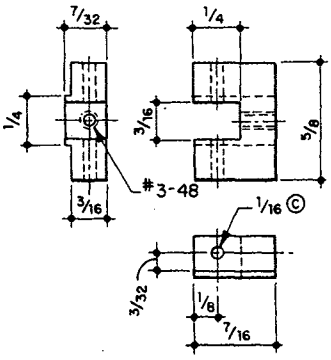


CYLINDER

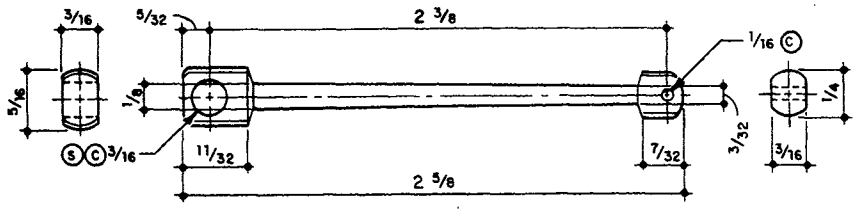
Ⓢ	smooth
Ⓕ	flat
Ⓒ	close fit
Ⓑ	solder or braze
Ⓟ	press fit or loctite



ROCKER BEARING



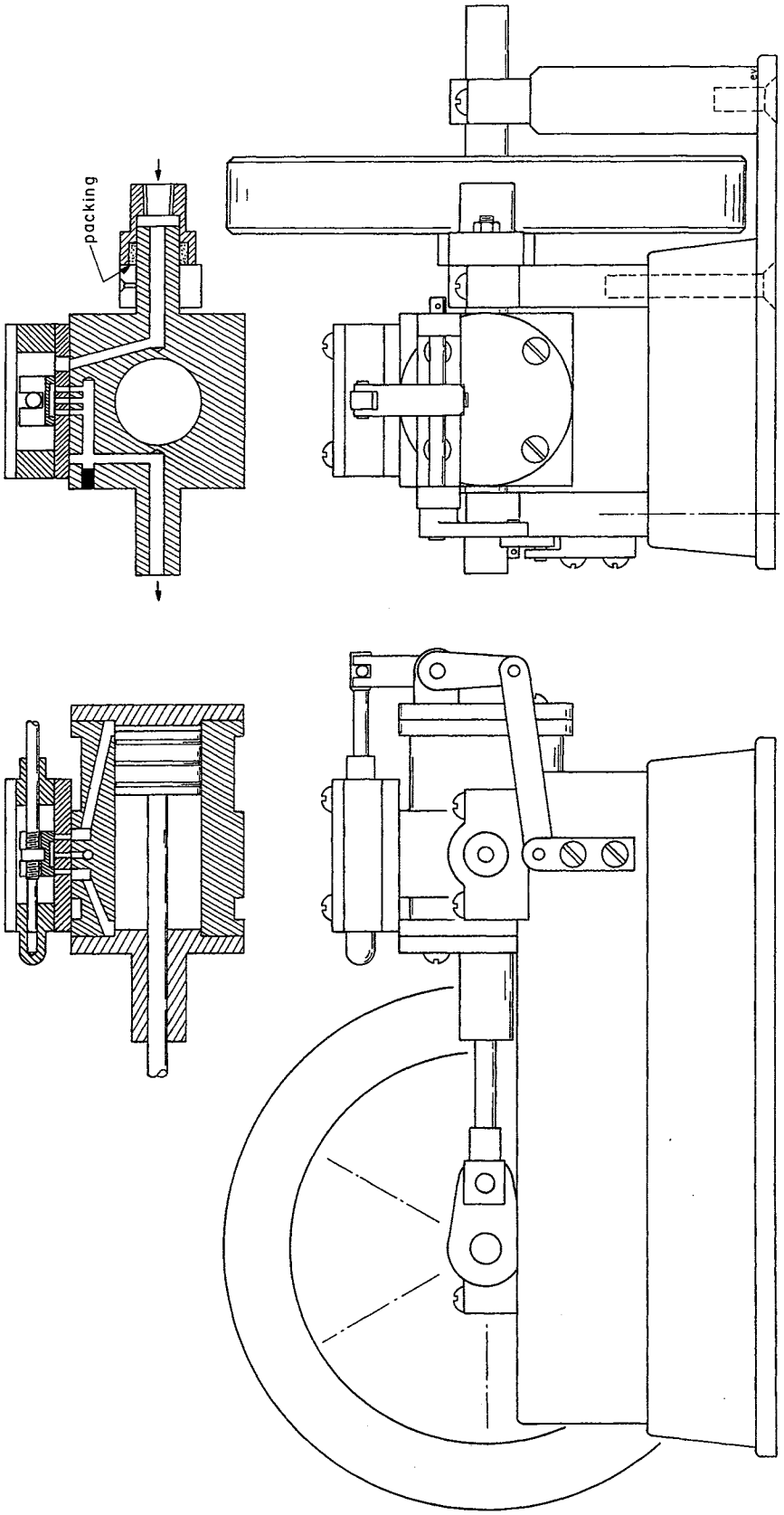
CROSSHEAD



CONNECTING ROD

CHAPTER

42 Oscillating-Cylinder Engine



OSCILLATING-CYLINDER ENGINE

The idea for this engine was submitted by C. W. Sleppy of Troy, Ohio. He sent a photograph of an illustration in an old book and this is a miniature patterned after it. There were no details, but the principle was pretty well shown and the result is quite an interesting engine. It is an oscillator, but it has a conventional slide valve.

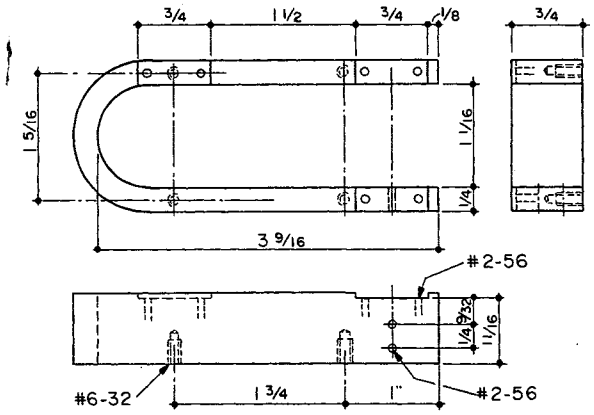
The material used in the model shown is aluminum for the Sub-Base, Base, Frame, Flywheel, Steam Connection, Steam Chest, Outboard Head and Bearing Bracket. They can all be made of other material, such as steel. The Flywheel and Base could be cast iron. A 3" cast iron Stuart-Turner H10 Flywheel from Cole's Power Models is excellent for this engine. The Crankshaft and Spacer are steel. All the other parts are brass or bronze.

The **SUB-BASE** is simple, straight and no problem. The **BASE** is shown tapered as most cast bases are for easy molding in the foundry. This draft or taper is optional.

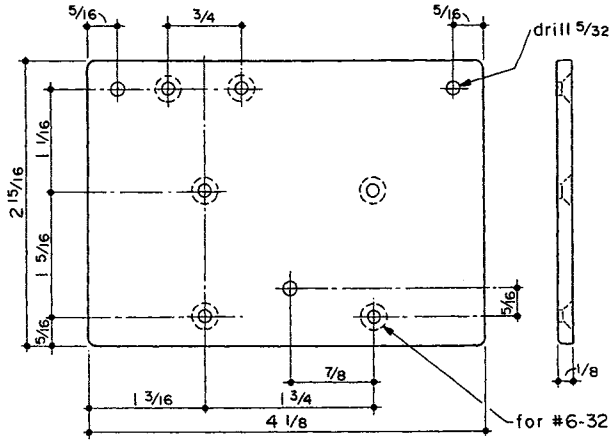
The **FRAME** on the model shown is aluminum. The illustration shows a closed "keyhole" shape for the Frame. Here it is simpler and uses less expensive metal. The aluminum was an industrial grade and quite hard to bend. It was heated with a torch and bent around a 1" diameter bar. Steel might be easier to use by heating to a red heat and then bending. Start with a piece about 9-1/4" long and trim after bending. Dress the top and bottom flat. Make the notches for the Bearings 11/16" from the bottom. Your cleanup may have made the height less then 3/4"; no problem. The **BRACKET** is simple and should match the 5/8" height of the Base plus the 11/16" on the Frame.

The **FLYWHEEL** can start out as a square or a round plate. The spoke-type is an interesting layout and filing job, using the drawings and instructions found in the Appendix .

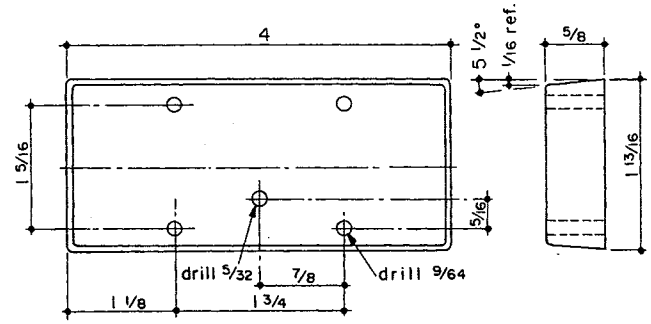
Make the **CRANKSHAFT** of steel. The **PISTON** and **ROD** require no comment except that concentricity is important. The **CRANK END** is a soldering job. The four **BEARINGS**



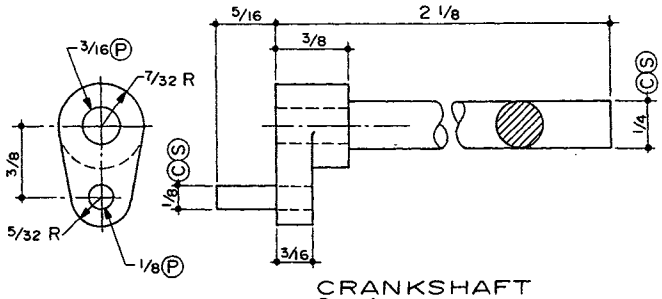
FRAME
Aluminum



SUB-BASE
Aluminum



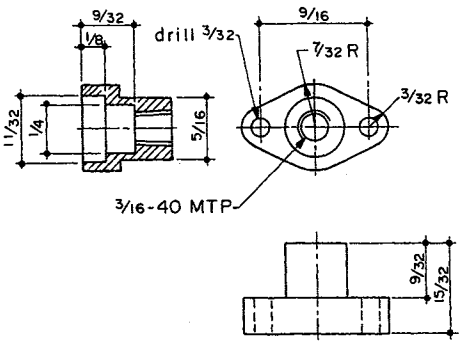
BASE
Aluminum



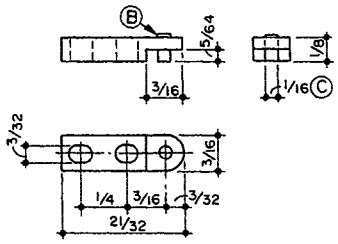
CRANKSHAFT
Steel

are alike except one is fitted with threaded rods or studs. Since the engagement is so little, these are soldered in place. The **STEAM CONNECTION** uses 1/16" strands of graphited asbestos packing. The **VALVE LINKAGE** is simple, requiring a bit of soldering. The **INBOARD HEAD** is two pieces soldered to avoid making chips out of valuable metal. Turn a shoulder on the 5/16" hub and a matching hole in the disk, then solder and finish turning and boring.

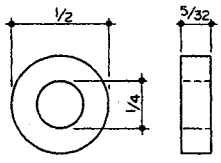
The **CYLINDER** is probably the most difficult part to make. Square up a block of brass 1" x 1" x 1.260" long. Lay out the pivot hole in the block making it 15/32" plus about .010" from the end. Make the 1/4" diameter hole for the Pivot Pin about .003" to .005" larger than the Pivot Pin and use a pyramid punch to raise four burrs at each end of the hole. Make light trial punches until the Pin is a push-fit past the burrs. wDon't make them so high that they score the Pin which is a bearing surface at the outside. Take care on all future operations that this pivot surface is not damaged. Solder, using tiny bits of solder, applying heat with a torch



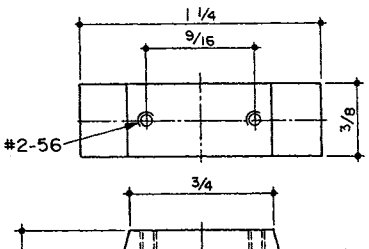
STEAM CONNECTION
Aluminum or Brass

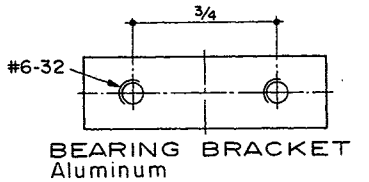


LINK PIVOT
Brass

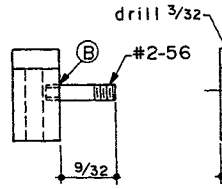


SPACER
Brass

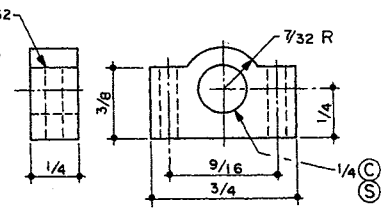




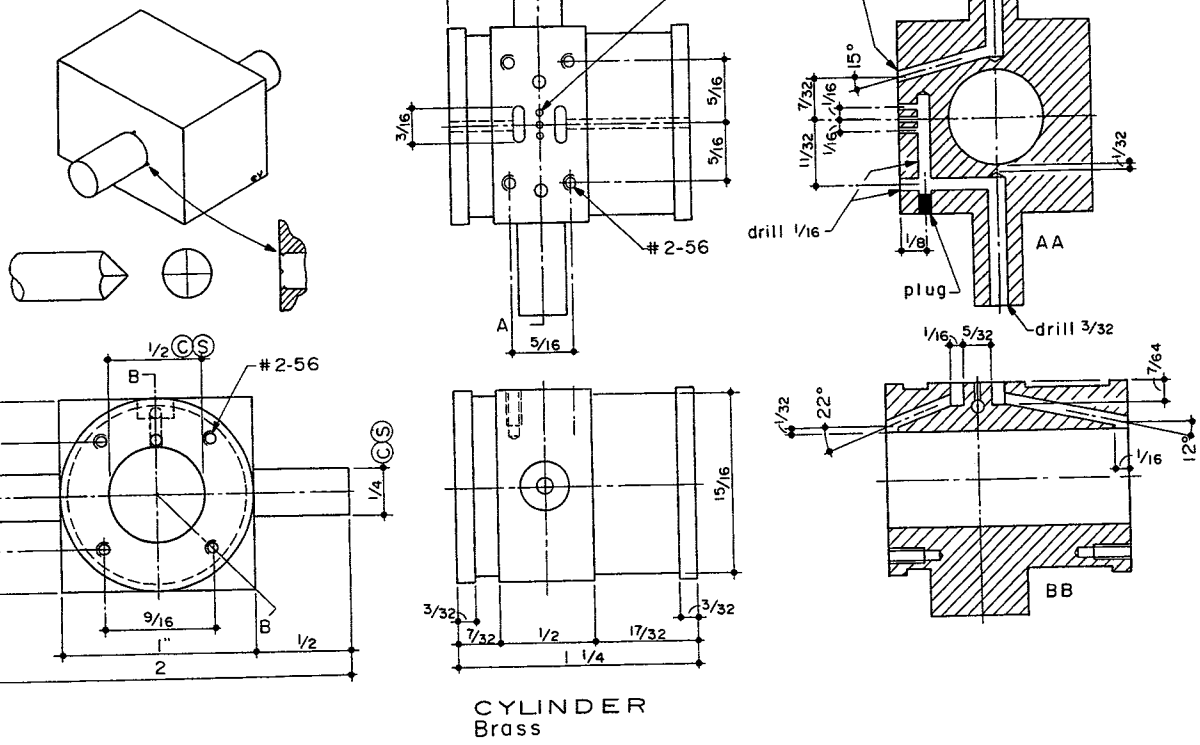
BEARING BRACKET
Aluminum

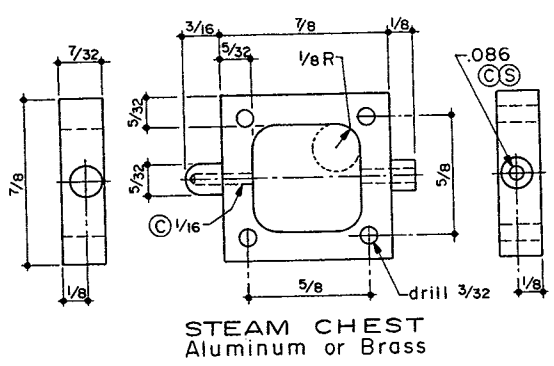


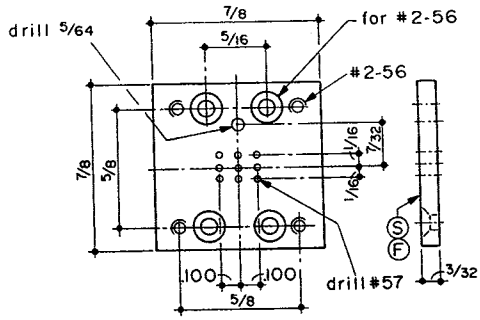
Add 2:#2-56 studs to one bearing spot from steam connection

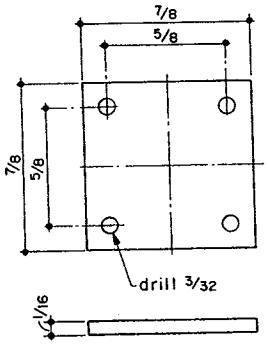


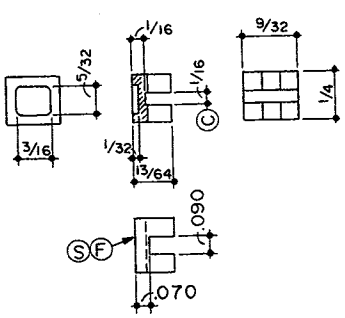
BEARING
Brass
4 Required

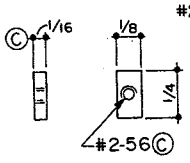


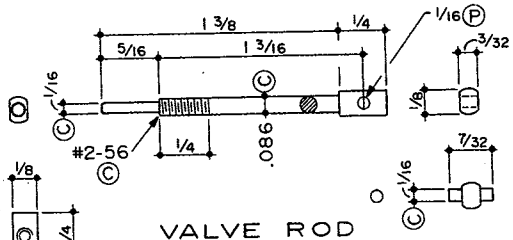


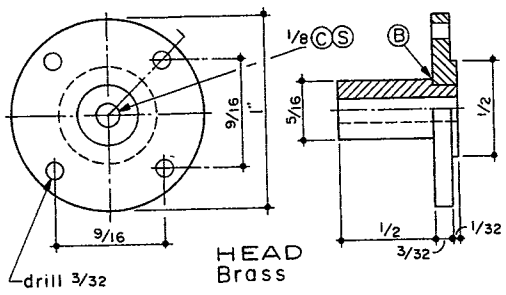


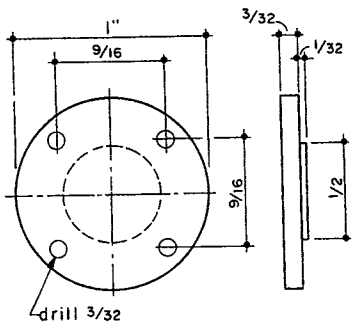






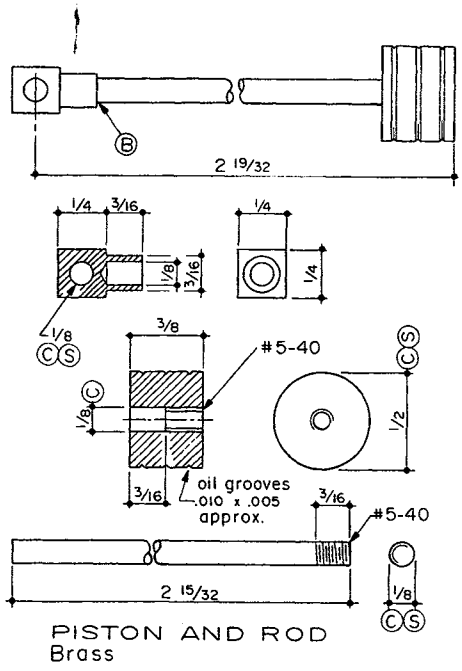




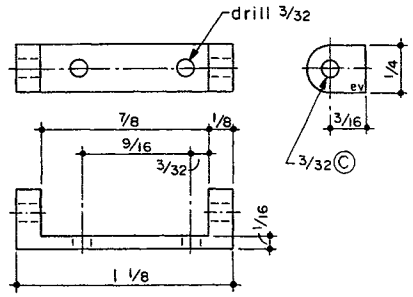


onto the block. The solder will flow into this clearance formed by the burrs. Apply the solder at both ends.

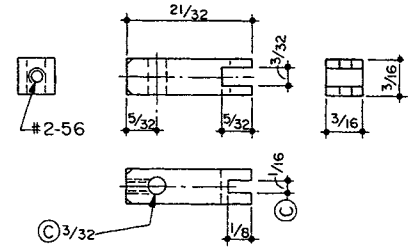
Chuck the workpiece on the long end and bore and ream 1/2", face of about .008" to .010" on the end and turn the flange O.D. and neck. Reverse in the chuck and turn the flange and neck on the other end. This is probably a place to use an arbor, but take care not to score the finish in the bore. On the model shown, thin copper was wrapped around the jaws of a 4-jaws and the block gripped on the corners. Light cuts were used to form the flange and neck. No cut was made on the end since there is no alignment problem. Brighten the face that is to be the Valve area and lay out all the holes. Drill and tap the



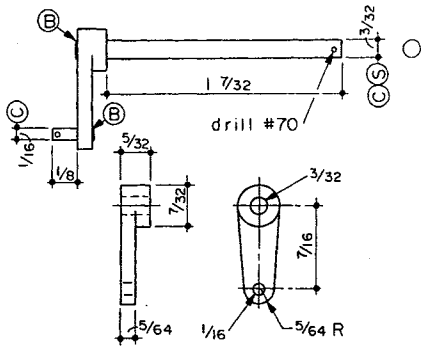
PISTON AND ROD
Brass



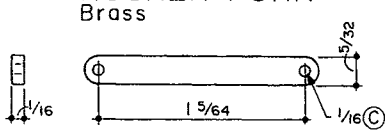
ROCKER BRACKET
Brass



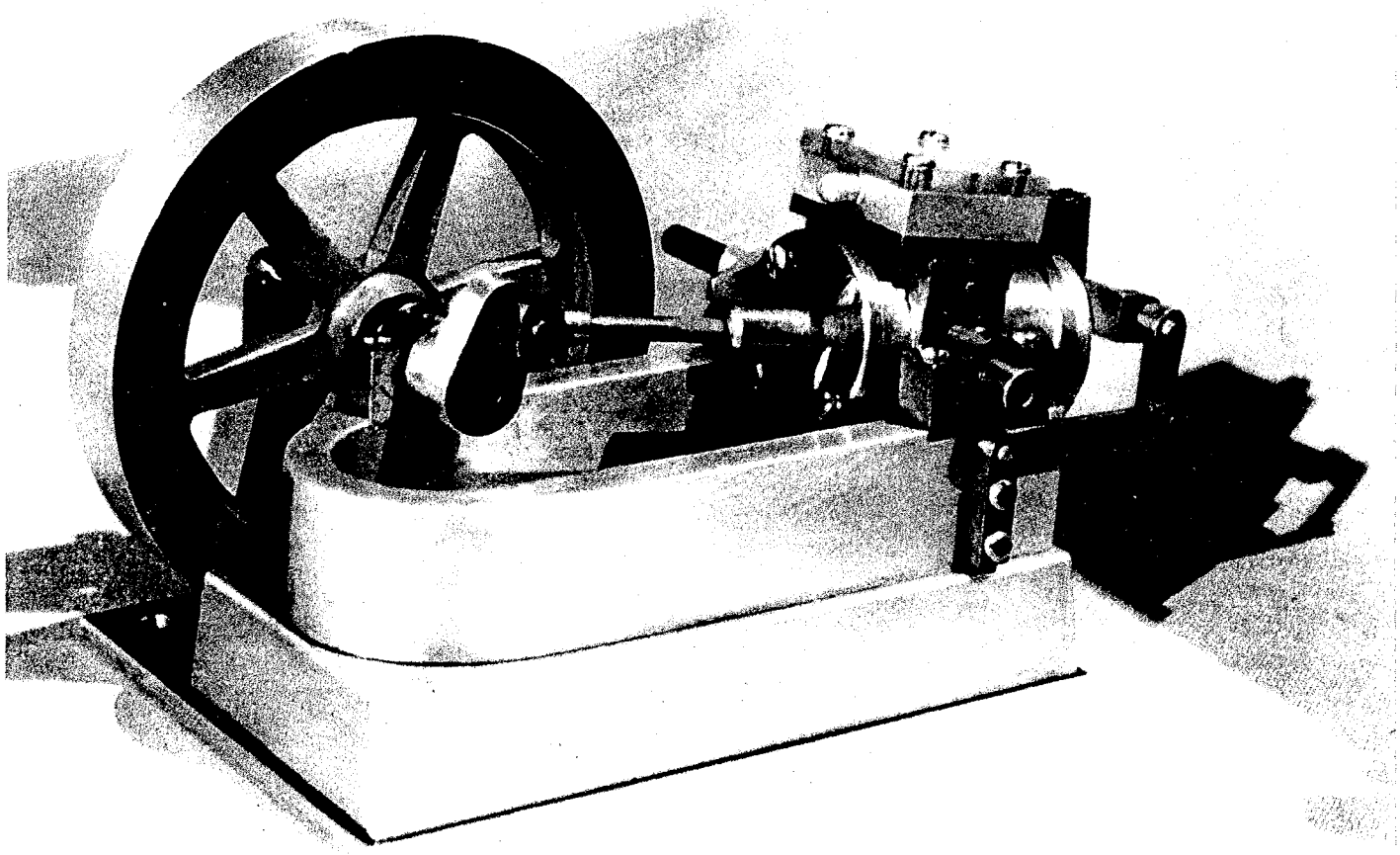
ROCKER FORK
Brass



ROCKER SHAFT
Brass



LINK
Brass



four 2-56 holes. Chuck on one pivot projection using thin copper to avoid jaw marks. Drill the steam passage on the opposite side. Reverse and repeat. Drill the 1/16" intake hole at 15°. Drill the three #57 holes later, using the Valve Plate as a jig. Drill the 1/16" exhaust holes at 11/32" and 1/8". Add the plug after final cleanup. Mill the two 1/16" x 3/16" x 7/64" deep recesses and drill 1/16" at 12° and at 22°. Mill the connecting notch to the bore 1/16" deep. Lay out the 2-56 holes for the Heads or use the Heads as jigs. Dress the Valve surface flat with fine emery paper on a flat surface.

The **VALVE PLATE** and **COVER** are straight layout, drilling, countersinking, and tapping operations. The important things are flatness and the careful location of the 9 #57 holes.

For the **STEAM CHEST,** start with an accurate block 7/32" x 7/8" x 1-3/16". Lay out the end bosses and prick-punch. Note that they are offset 1/8" from one face. Chuck in the 4-jaw, centering with a center test indicator, and turn the blind boss. Do the same with the opposite end, making an accurate 1/16" hole 1/32" short of breaking through. Enlarge this to .086" about half-way through the block. Lay out and drill four 3/32" holes. Lay out four centers for a drill to provide the 1/8 radius in the center opening. Start with a 7/32" drill and, if it doesn't reach the layout lines, enlarge with a 15/64" or 1/4" drill.

Make the **VALVE, VALVE ROD** and **NUT** of brass. This Valve should float on the Valve Plate. The steam pressure holds it down. That is, there should be a few thousandths freedom to rise off the Plate with close clearances in the fit of the Nut in the Valve and on the Rod threads. There should be no binding between the Valve and Valve Plate or Valve Rod, and a minimum of play at the Nut. The Valve Rod is made of 1/8" stock, long enough to add a center hole for tailstock support (later cut off) and to grip in the chuck.

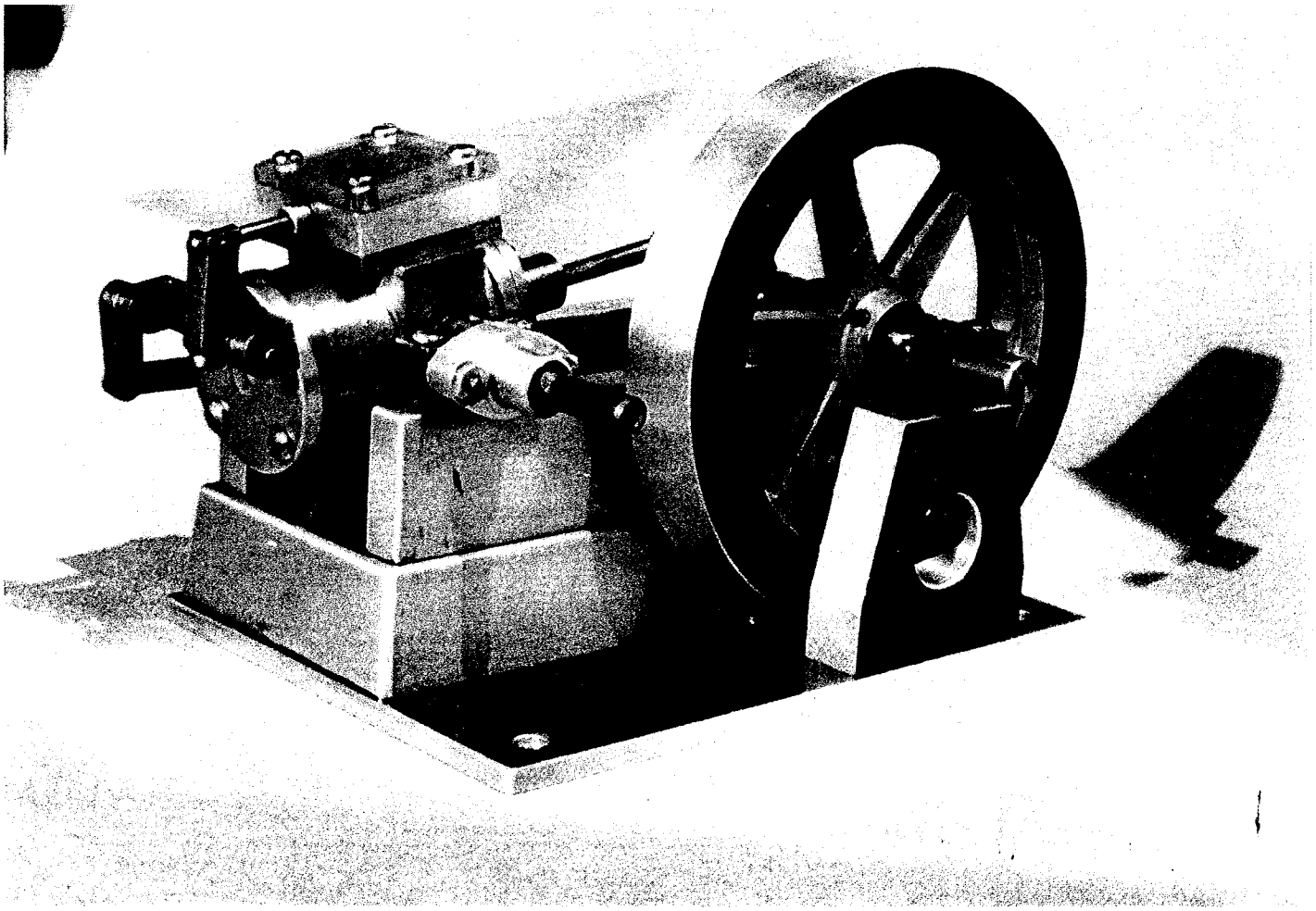
On each side of the Cylinder, about three plastic washers were added to center it in the Frame. These were punched from a plastic billfold calender card to 1/4" I.D. x 3/8" O.D. If live steam is used, these should be metal. More or less than three can be used as needed.

Small bits of fine copper wire can be used in the #70 holes in the Linkage. Set up so there is no binding of the Valve Rod in the Steam Chest. In fact, the Rocker Shaft should float and not bear tight against the Valve Rod, with minimum clearance between the 1/16" pin and the fork, without binding.

At assembly, the Valve should be located so as to give equal exposure to the three #57 Valve holes at each end of the stroke. The enlarged holes in the Link Pivot permits some fine adjustment at this point.

The model shown ran good on as little as five pounds of air.

If you feel as one reader does, a PackNut can be added to the inboard head — thread the hub head 5/16-40 or tap out at 1/4-40. The hub on the Steam Chest should be longer if you plan on a PackNut here. The Nut would be made of 1/4" hex brass threaded a modelmakers 5/32-40.



CHAPTER

43 Horizontal Mill Engine

This simple horizontal double-acting engine uses a sliding block reverse. There are no complicated linkages or precision cut-off, lead, etc., so let's get right to the construction.

The **BASE** is a simple, straightforward piece so no comments are needed.

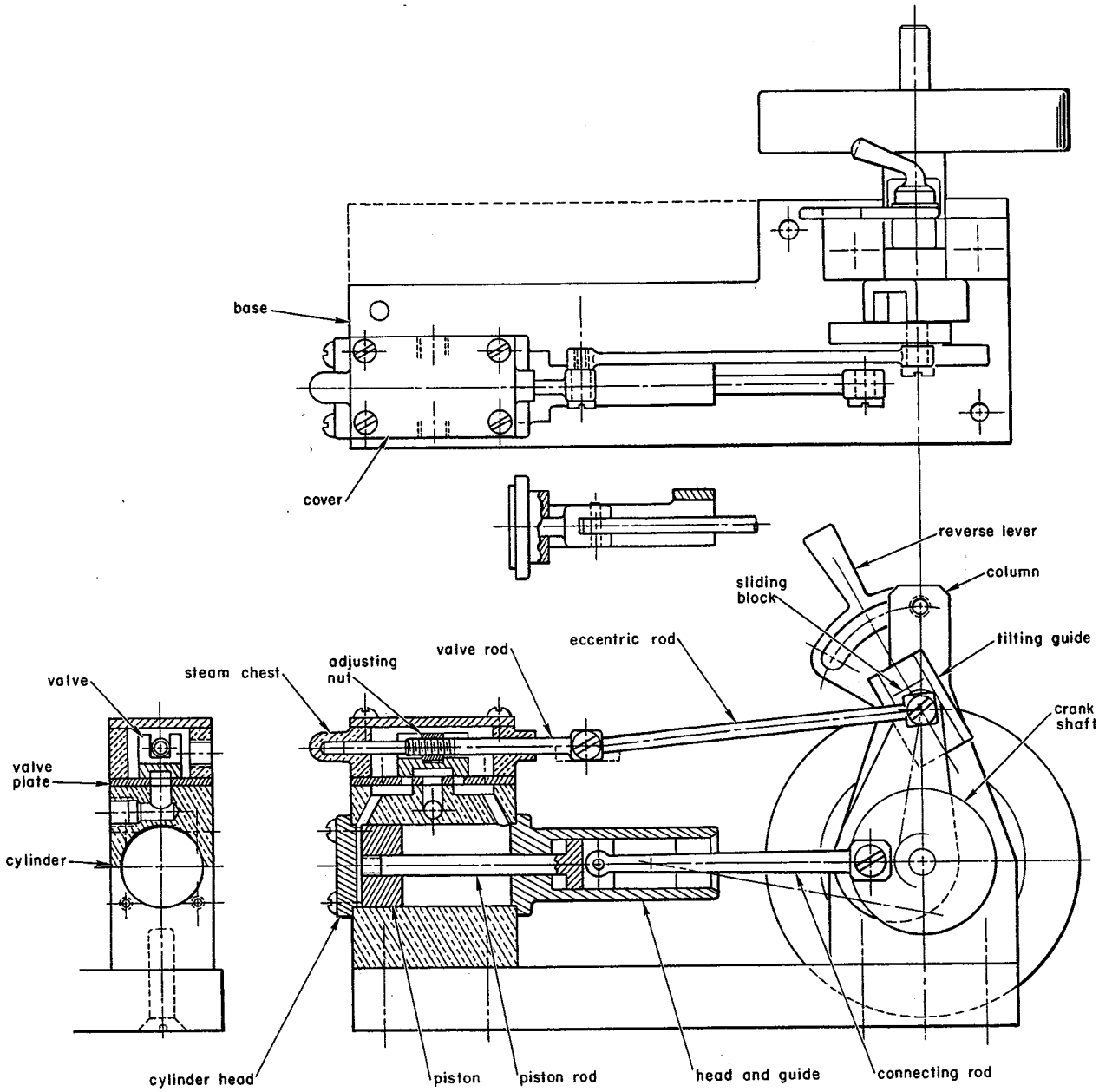
On an accurate block for the **CYLINDER,** apply layout dye and lay out the centers for the two 6-32 holes, the bore and the port openings. Mount in a 4-jaw and use a center test indicator and make the 1/2" bore. Mill and drill the port openings, drill and tap the 6-32 holes and steam connections.

Make the **STEAM CHEST COVER** and **VALVE PLATE**. Lay out and drill the four screw holes in the cover and use it as a jig for the Valve Plate, Steam Chest and Cylinder Block.

The off-center bosses on the **STEAM CHEST** are laid out and centered in a 4-jaw using the center test indicator.

The **PISTON** and **ROD** need no mention except the importance of concentricity.

The **CYLINDER HEAD** and **CROSS SLIDE GUIDE** are used to spot the holes in the Cylinder. The Cross Slide Guide starts out with 5/8" square stock about 2" long. Lay out and prick punch the center of one end



and center in the 4-jaw. Then turn the 7/16" diameter and 5/16" bore. Next, cut off and leave approximately 1/16" for finishing the face and dowel. Chuck in the 4-jaw on the 7/16" diameter, leaving enough room to use an indicator for centering to .001" or less. Finish the face, dowel and hole for the Rod. File or mill the Guides to the 1/4" dimension.

Make the **VALVE, VALVE ROD** and **NUT** of brass. This Valve should float on the Valve Plate. The steam pressure holds it down; there should be a few thousandths freedom to rise off the ValvePlate with close clearance in the fit of the nut in the Valve and on the Rod threads. There should be no binding between the Valve and Valve Rod and a minimun of play at the nut. The Valve Rod and **CONNECTING ROD** are made from stock long enough to hold in the 4-jaw and a little extra for a tail center hole. On the Connecting Rod, before parting, mill to 3/32" thick at the small end, then lay out the 3/16" diameter end and file to the line. The only comment necessary on the **COLUMN** is importance of squareness on the bottom and the Shaft holes.

The **CRANKSHAFT** is simple and straight-forward with a press fit and peening at the joint.

The **TILTING GUIDE** is a turning job which can be speeded up by sawing out the corners instead of making them into chips. Make the 1/4" slot using the tool post milling attachment.

The **SLIDING BLOCK** can be "oilite" or bronze.

The **ECCENTRIC ROD** can be turned from the solid or soldered. The 2-1/32" dimension and the parallelism of the .125" and 3-48 holes are important here.

The **REVERSE LEVER** can be turned out of the solid or a hub can be soldered to 1/16" stock. This is a layout and a filing job. The curved slot can be a series of drilled holes filed out or milled by rotating the piece by hand around a 3/16" pin held in the milling vise.

The **ECCENTRIC** is first turned in the four-jaw to 3/4" diameter and the .625 x 1/8" is turned to a fine finish. Offset the piece in the four-jaw .156", using the crossfeed collar to measure the distance. As a final check, clamp a smooth square-ended piece of stock in the tool post and bring it up against the high point of the offset. Rotate the spindle 180 degrees. A .312" diameter piece of round stock should just pass between. Bore for the Shaft and turn the hub. Add a set-screw at the low point.

The **ECCENTRIC STRAP** is first laid out and prick-punched. While in the rough, chuck the part in the 4-jaw and bore the .625" hole to a close fit on the Eccentric. If you are working close and the metal is already narrow at this bore, ease off the chuck jaws so the bore will not be distorted on the final cut.

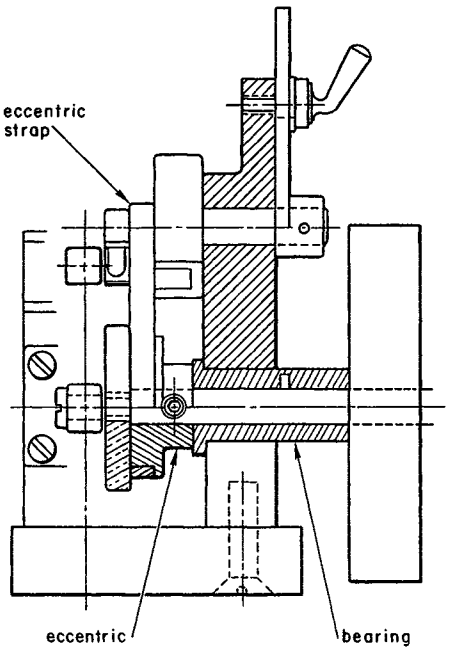
Make the **FLYWHEEL next,** about 1-3/4" diameter by 3/8" wide, fitted with a set-screw. The one shown is 1-1/2" and seems to be o.k.

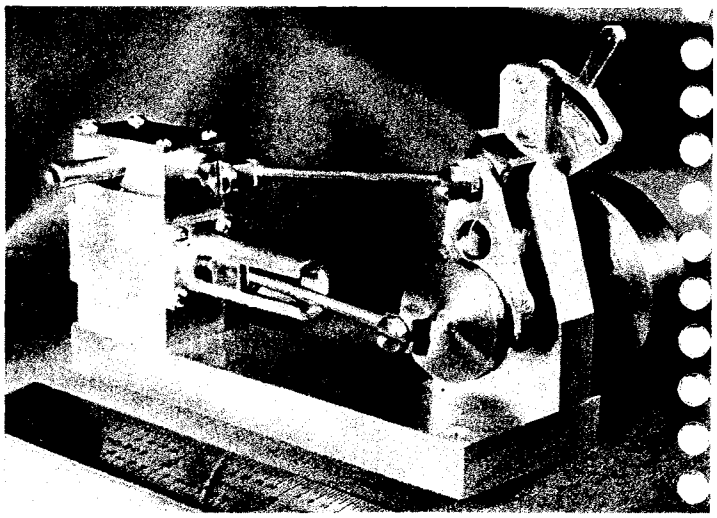
The **STEAM CONNECTIONS** are shown as 3/16" model taper pipe or 10-32 thread, but you can make them whatever is convenient.

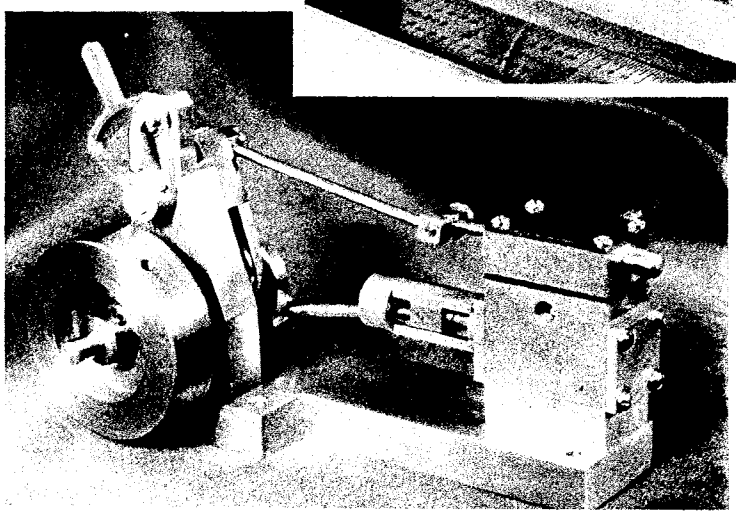
The **ECCENTRIC OFFSET** must be on the centerline through the Crank Pin and Shaft and to either side of the Shaft.

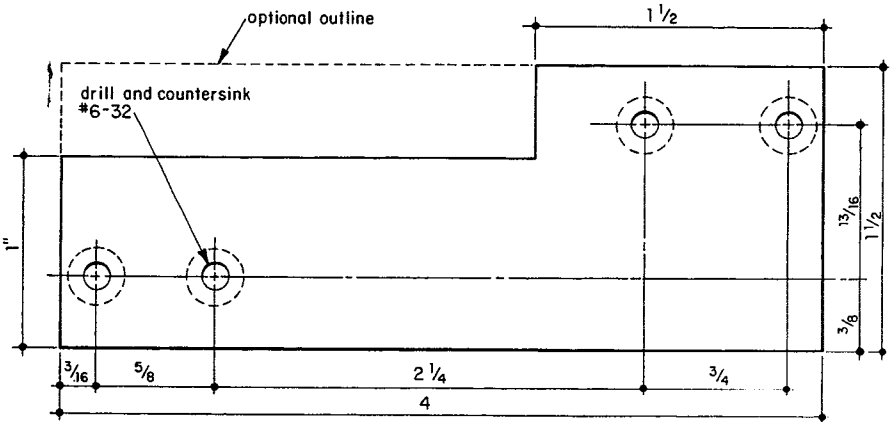
At final assembly, turn the Shaft until the Eccentric Rod is at one extreme and note (by looking through the steam connection hole) the position of the Valve nut. Turn to the other extreme. It should be equally opposite. Center the nut, if necessary, by removing the shoulder screw and rotating the valve rod.

So your Horizontal Mill Engine is now complete! It will make a good showing on as little as 5 to 10 psi air.

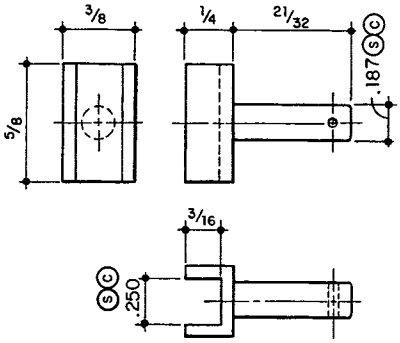




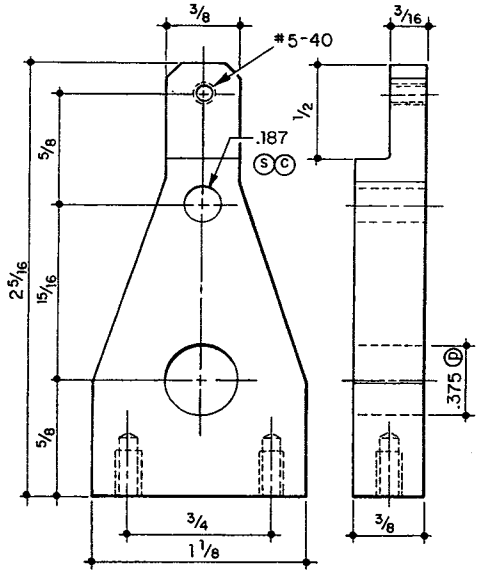




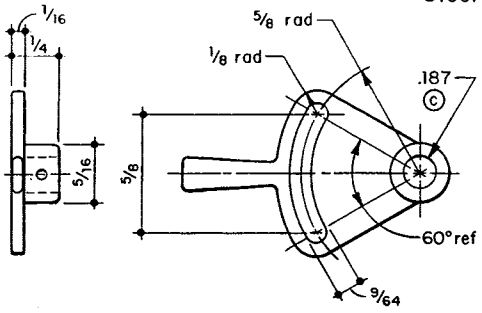
BASE—3/8" thick
Aluminum or Steel



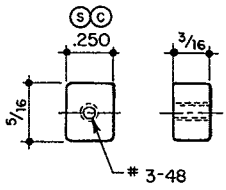
TILTING GUIDE
Steel



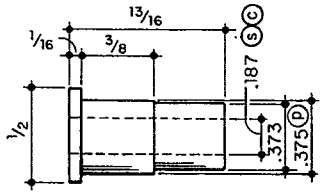
COLUMN
Aluminum or Steel



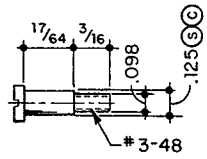
REVERSE LEVER
Aluminum or Steel



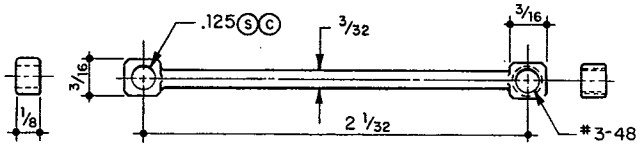
SLIDING BLOCK
Bronze



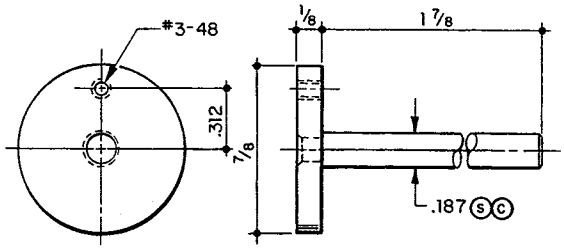
BEARING
Bronze



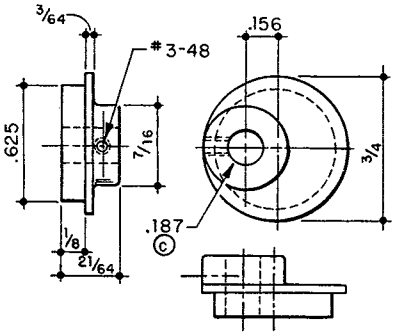
SLIDING BLOCK
PIN



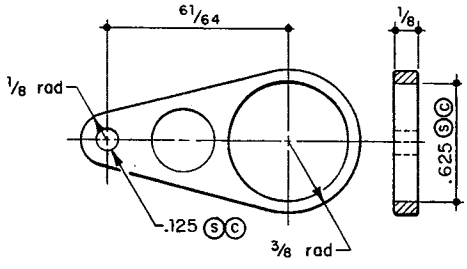
ECCENTRIC ROD
Brass



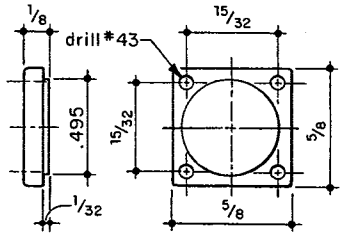
CRANK SHAFT
Steel



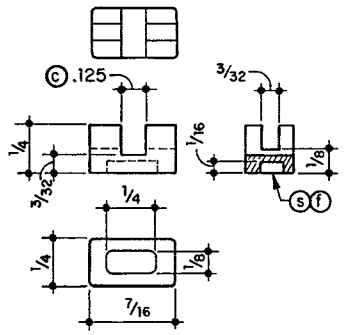
ECCENTRIC
Steel



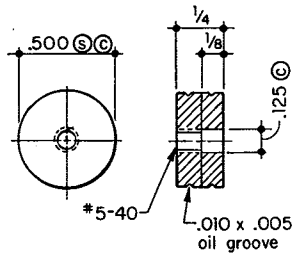
ECCENTRIC STRAP
Brass



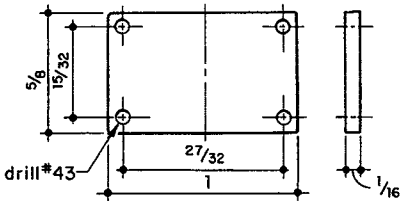
CYLINDER HEAD
Aluminum



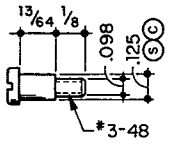
VALVE
Brass



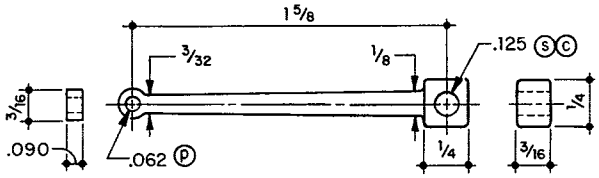
PISTON
Brass



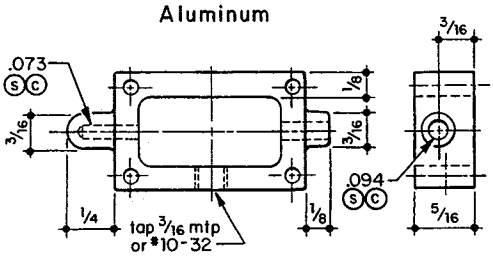
COVER
Aluminum



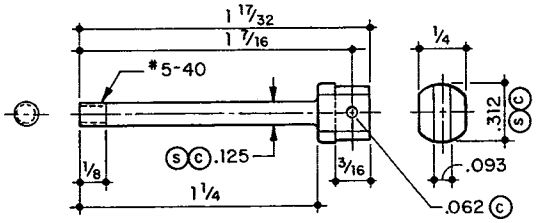
CRANK PIN
Steel - 2 required



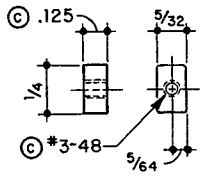
CONNECTING ROD
Brass



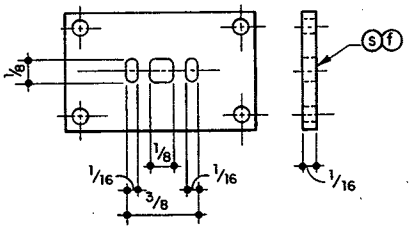
STEAM CHEST
Aluminum or Brass



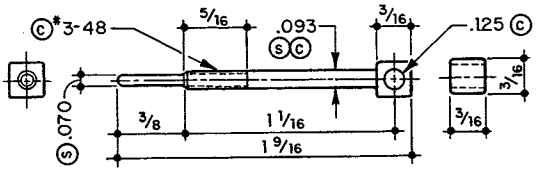
PISTON ROD
Brass



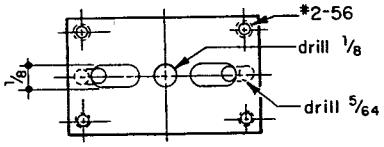
ADJUSTING NUT
Brass

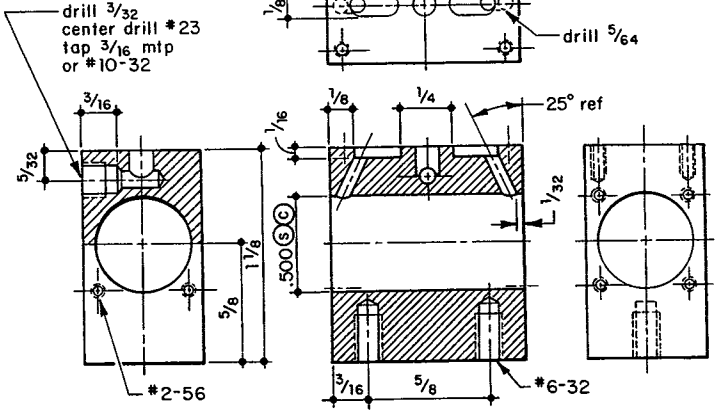


VALVE PLATE
Brass

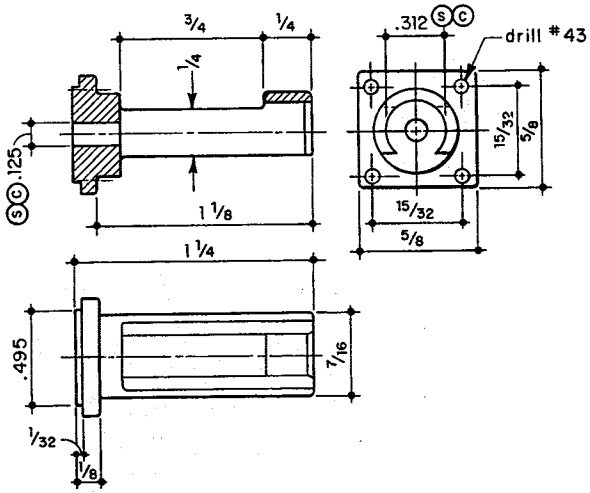


VALVE ROD
Brass

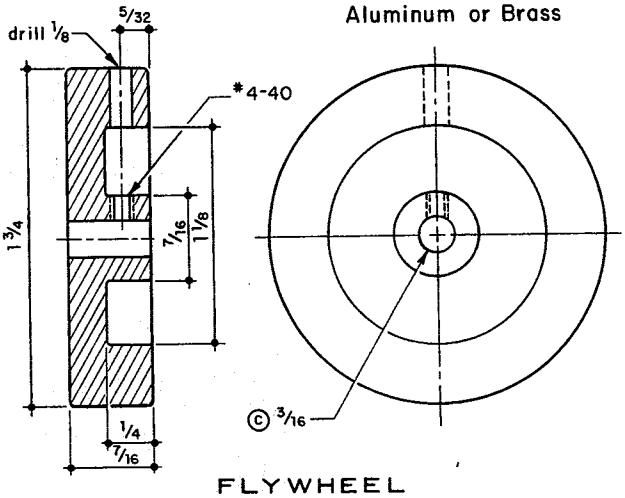




CYLINDER
Aluminum or Brass



HEAD AND GUIDE
Aluminum or Brass



FLYWHEEL
Any Metal

CHAPTER

44 Open Column Twin

This is a 3/4" x 3/4" single-action vertical two-cylinder engine using the Open Column construction and a regular Steam Chest and Slide Valve. It is a stocky, compact engine and fairly strong. The small diameter Flywheel, as used on marine engines, is combined with the Crankshaft, though this wouldn't be done in a larger commercial engine. The lack of an open Flywheel makes it just a bit more difficult to start. A pulley or coupling has to be used as a thumb wheel to give it a start. Rotate the Shaft until it is on a power stroke and it will start the instant the pressure hits it.

This is a fairly heavy engine. The Cylinder was made of a block of steel. A fine-grained semi-steel or Meehanite would have been preferred. Brass or bronze could be used, but it is expensive these days.

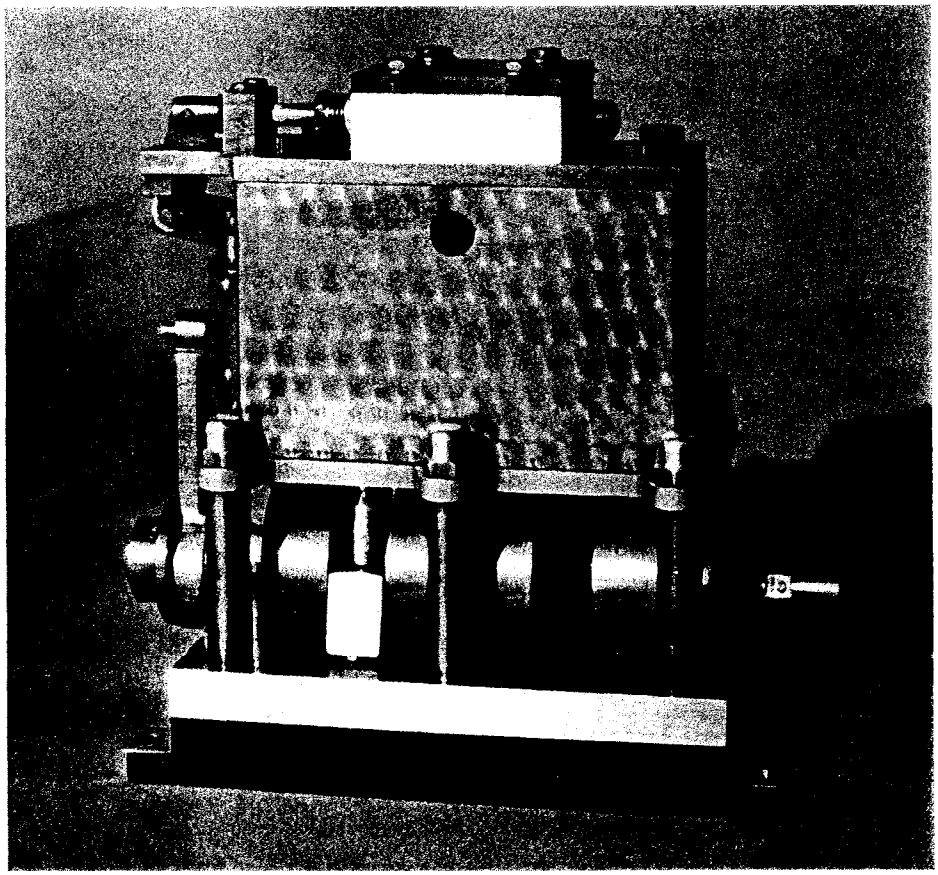
The Cylinder **TABLE** is a layout, filing and drilling job that must match the Crank frame and Cylinder drilling.

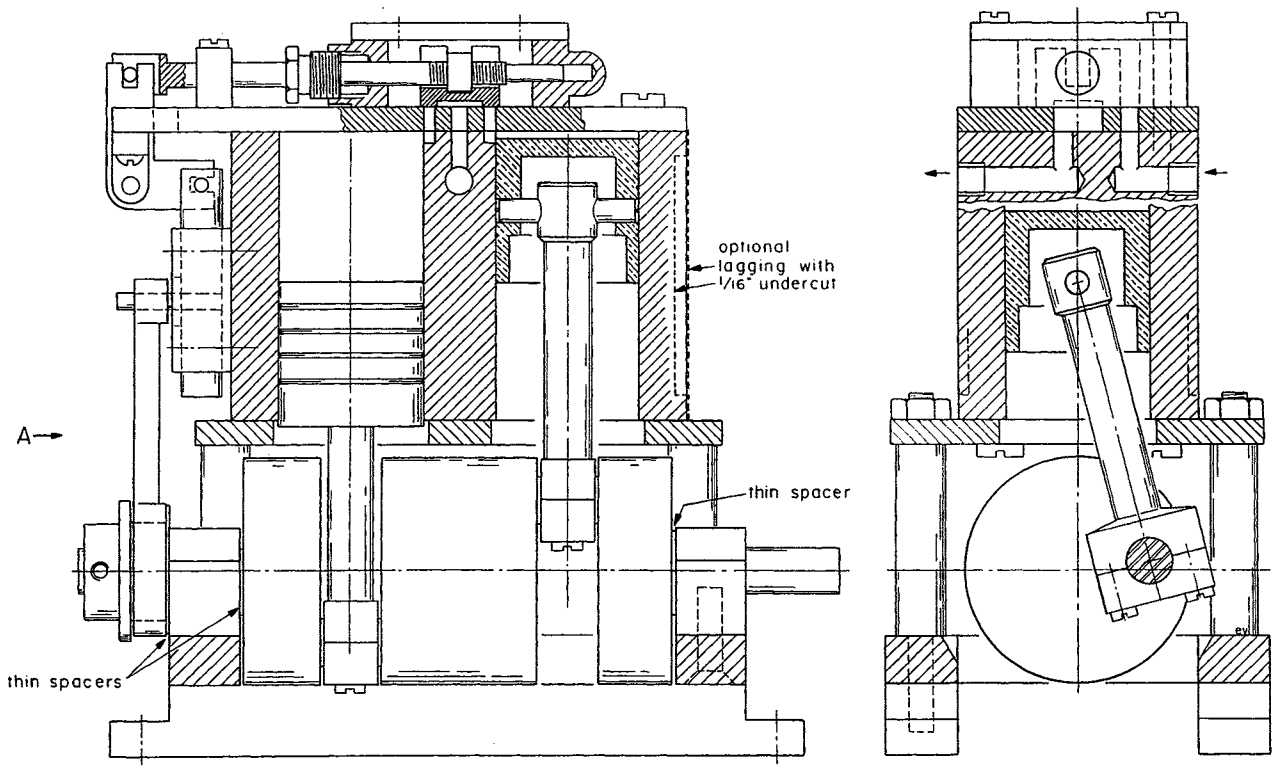
Steel disks and drill rod are used for the **CRANKSHAFT/FLYWHEEL**. Turn, and drill the center hole, for all three disks. Mount the disk in an indexing fixture and center so a 1/4" rod in the spindle chuck will enter the center hole. Read the crossfeed dial and move .375" off the center piece, rotate 180° for the opposite hole. Apply Loctite to the two Crank Pins and holes in the center piece ONLY. Assemble in place with the 4" center Shaft and the two outer Disks for alignment while the Loctite cures. When cured, apply Loctite to the two outer Disks and center Shaft, align and set aside to cure. When cured, add 1/16" spring pins and cut away the center shaft.

The **CYLINDER BLOCK** is formed from an accurate and square block 1/1-4" x 1-1/2" x 2-3/8". Apply layout dye to the top, bottom, one end and upper center of each side. Lay out the centers and prick punch for all the holes. The two 3/4" holes can be done in the 4-jaw, picking up each center with a center test indicator. Drill and tap all the holes. If lagging is desired, cut 1/16" deep paths on two sides and the end opposite the Eccentric as shown. Form the lagging from thin sheet metal and attach with four 2-56 screws.

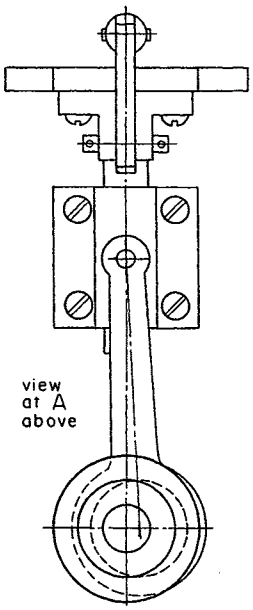
The **PISTONS** on the model shown are aluminum, but brass or bronze could be used. Mark each Piston so each stays with the bore it was fitted to.

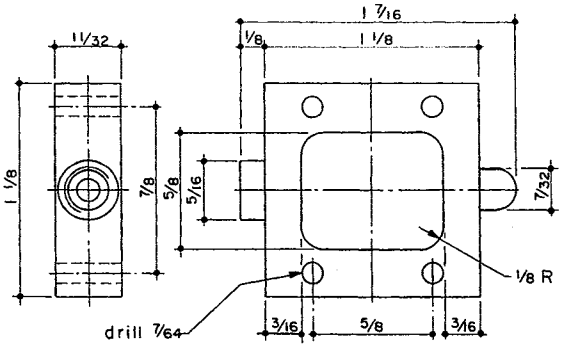
The **WRIST PIN** is drill rod, held in at assembly by a light prickpunch mark flowing a bit of Piston metal

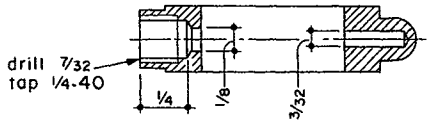




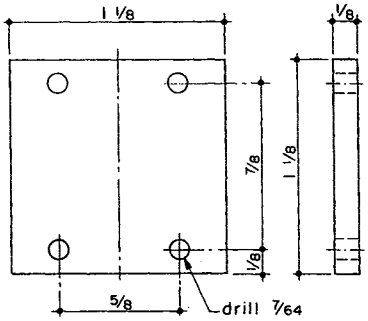
OPEN COLUMN TWIN



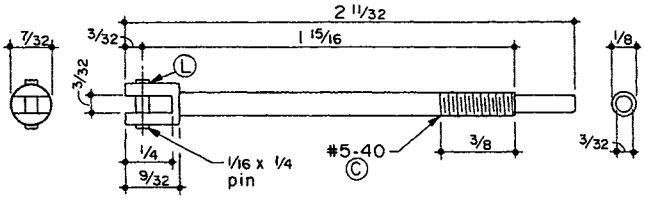




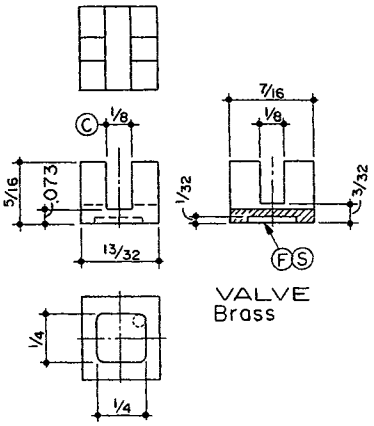
STEAM CHEST
Aluminum



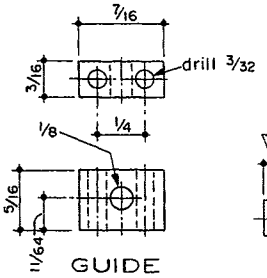
COVER
Aluminum



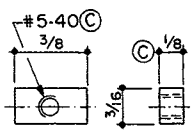
VALVE ROD
Brass



VALVE
Brass



GUIDE
Brass



NUT
Brass

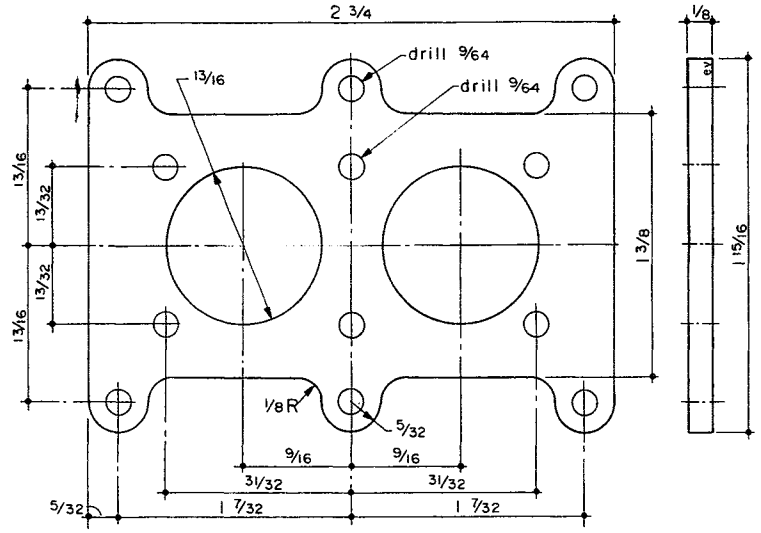
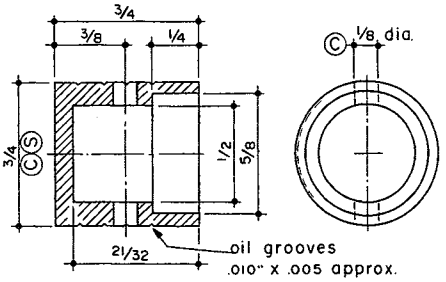
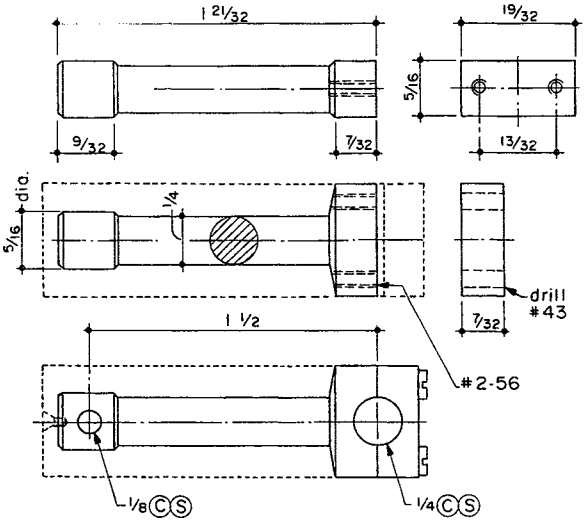


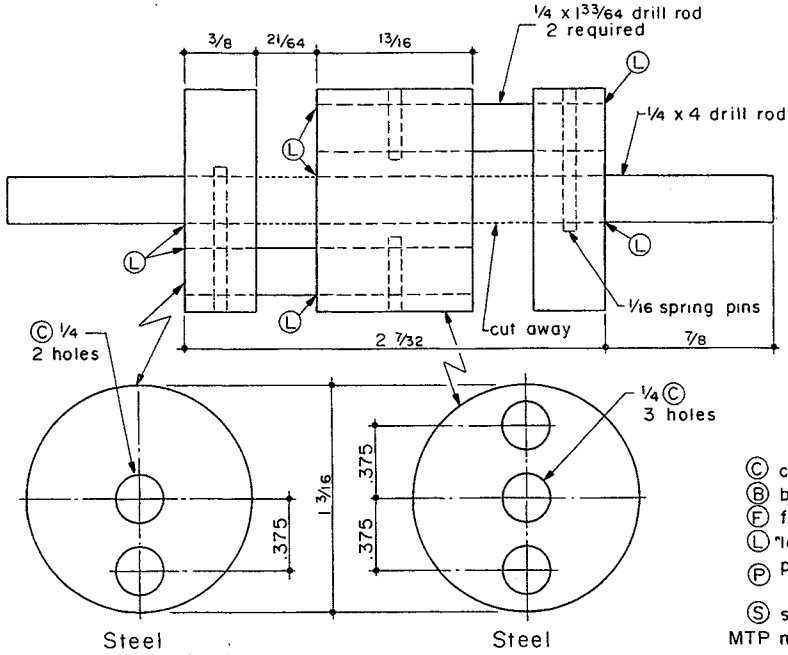
TABLE
Aluminum



PISTON
Brass
2 Required



CONNECTING ROD
Hard Aluminum
2 Required

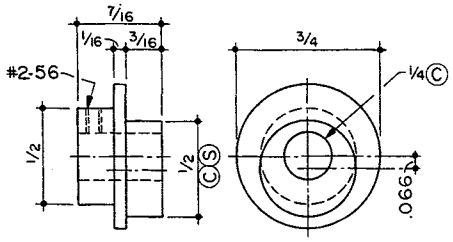


Steel
2 Required

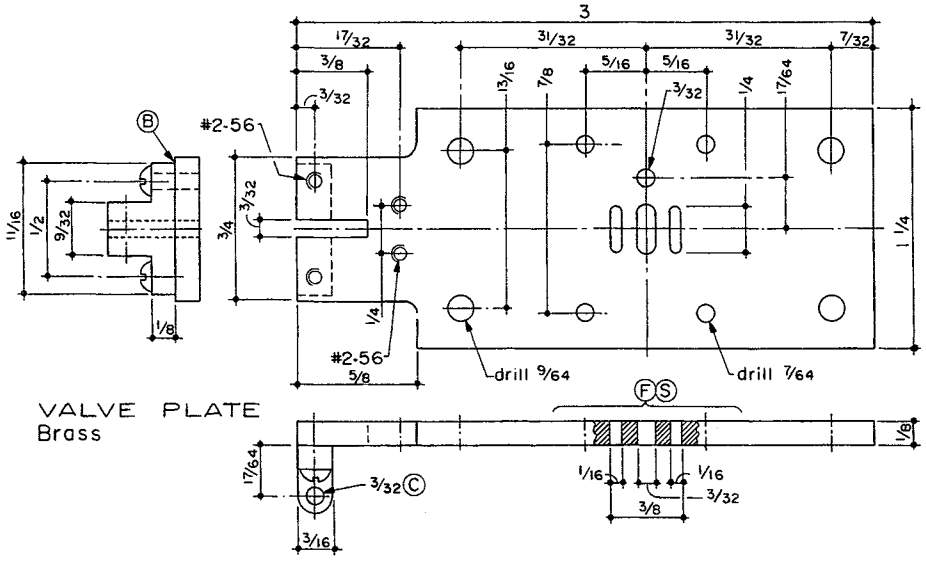
CRANKSHAFT

Steel

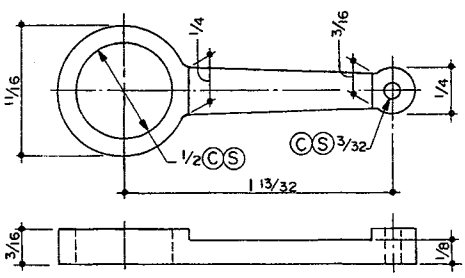
Ⓒ close fit
Ⓑ braze or solder
Ⓕ flat
Ⓛ "loctite"
Ⓟ press fit or loctite
Ⓢ smooth
MTP model taper pipe thread



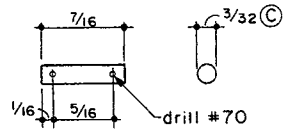
ECCENTRIC
Steel



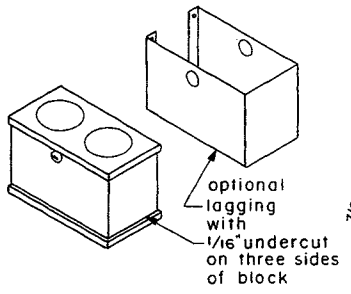
VALVE PLATE
Brass

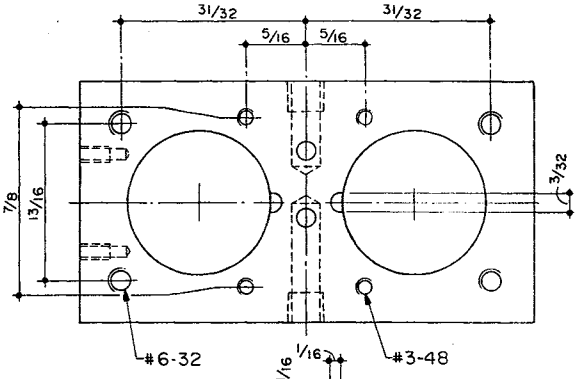


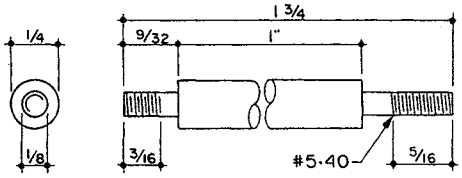
ECCENTRIC STRAP
Brass



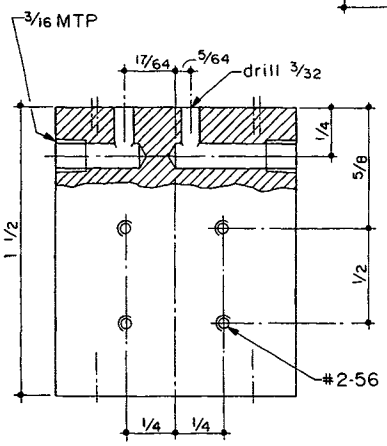
ROCKER PIN
Steel

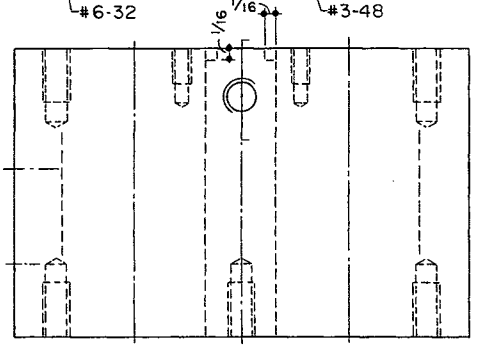


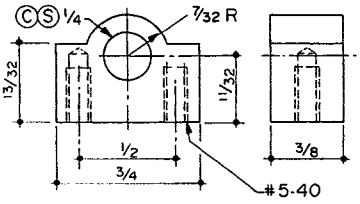




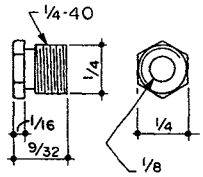
COLUMN
Steel
6 Required



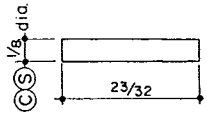




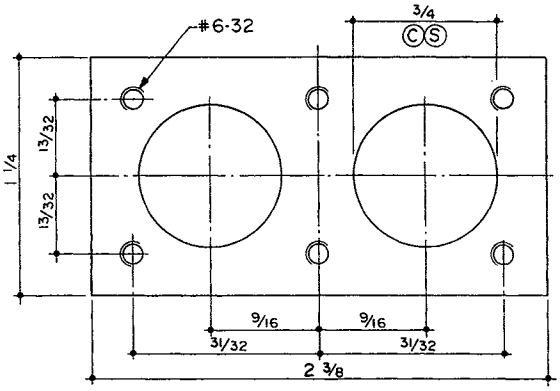
BEARING
Brass
2 Required



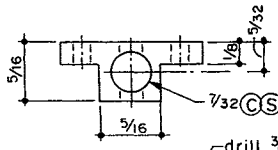
PACKNUT
Brass

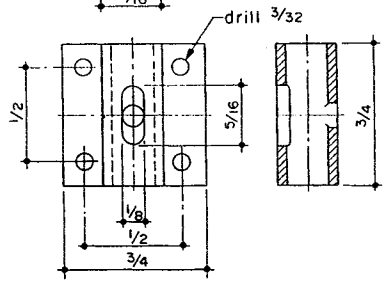


WRIST PIN
Steel
2 Required

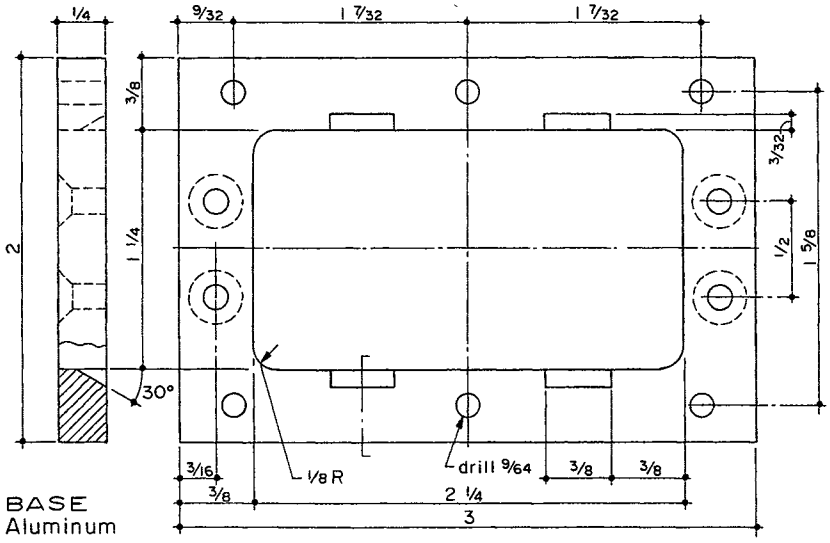


CYLINDER
BLOCK
Cast Iron,
Brass or
Hard Aluminum

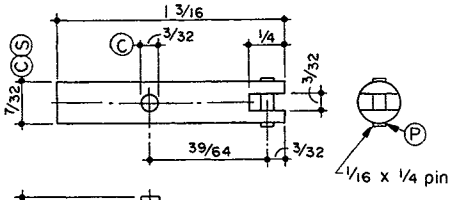


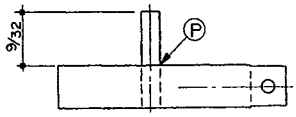


SLIDE
Brass

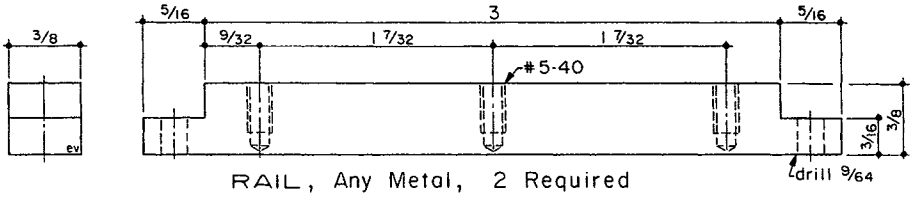


BASE
Aluminum

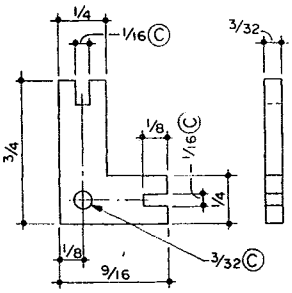




SLIDE
PIN
Steel



RAIL, Any Metal, 2 Required



ROCKER
Steel

over each end of the Pin. Dress any metal raised on the Piston O.D. with an oil stone.

The **CONNECTING RODS** start out as two accurate pieces of aluminum (used on the model shown) or brass 5/16" x 19/32" x 2" long. Lay out and tap-drill the two screw holes in one end of each piece. Using a thin slitting saw in the mill, cut a 7/32" piece off the end of each. Keep the related parts together. Tap the two holes in the "Rod" 2-56 and drill the "Cap" #43. Bolt the Cap in place and scribe a center line the full length of each assembly and around the end. Prick punch on this centerline at the Cap joint and 1-1/2" from that point for the 1/8" hole. Drill and ream these two holes in each. Prick punch the center of the Piston end of the Rod and center in the 4-jaw with only 1/8" projecting, using a center test indicator. Center drill with a tiny center drill (the one used here had a pilot drill diameter of .025"). Mark two adjacent jaws with chalk. Loosen these two jaws and move the piece out approximately 1-9/16" and hold against the tail stock center while tightening the two chalked jaws. Turn the 1/4" and 5/16" diameters. Next, on the end, make a parting cut at 1-21/32" until it almost touches the tail center. Remove and file off the small projection on the end.

The **ECCENTRIC** starts out as a piece of steel 3/4" diameter by approximately 1-1/2" centered in the 4-jaw chuck. Starting 1/4" from the end, turn the 1/2" hub for the set screw about 3/8" wide. Turn the O.D. smooth just under 3/4" to true it up. Bore and ream 1/4" for the Shaft. Mount a square-ended bar in the toolpost and bring it up against the finished O.D. and set the cross slide collar at zero. With two of the jaws horizontal, loosen the vertical jaws slightly. Back up the rear jaw about 3/32". Force the workpiece back about 5/64" using the front jaw. Turn the cross feed in .066". Ease the workpiece back against the bar using the rear jaw. Snug up all the jaws. Now, when the high spot just kisses the bar and the chuck is then rotated 180°, a .130" diameter rod should just pass between. Turn the 1/2" diameter eccentric and part off at 7/16". Add a setscrew located on the centerline through the bore and offset. This helps when timing the Valve.

The **ECCENTRIC STRAP** is laid out on a piece of 3/16" flat brass. Prick punch the two hole centers and make the 3/32" hole. Saw and file to the outline. True up in the 4-jaw, centering with a center test indicator for the 1/2" hole. Do not tighten the jaws so much that the hole will be distorted when removed from the chuck. Carefully bore to a close fit on the Eccentric.

The **SLIDE PIN** is drill rod. Mill the 3/32" slot as near parallel with the 3/32" pin as you can make it. The 3/32" pin must be square with the 7/32" pin.

The **ROCKER** is steel and, here, accuracy is also important. This engine has a fault like the linkage in a locomotive valve. The accumulated tolerance at all the joints can total up to quite a lot of clearance. There are eight joints. If each has 1/2 of a thousandths clearance, the total is .004". If each wears another half, the total is .008". That means from .004" to .008" of the Eccentric rise is used up taking out the slack in the line. So try to make all the joints close fitting.

The **SLIDE** is a brass block milled or shaped and bored for a close fit on the Slide Pin. Just simple machining.

The **VALVE PLATE** and **ROCKER PIVOT** are combined here. This is made of brass, and drilling has to match the Cylinder block. Make up the Pivot block in one piece. Coat the surface of the block with solder. Coat the Valve Plate at this spot with soldering flux. Assemble, tightening down the screws. Apply heat with a torch. When the solder melts and flows all around the joint, quickly tighten the screws. Mill the slot for the Rocker. Flatness and smoothness are important at the center Valve area.

The **STEAM CHEST** is aluminum on the model shown. Start with an accurate block of aluminum 11/32" x 1-1/8" x 1-7/16". Lay out the outline and all the hole centers, including the centers of the 1/8" radius inside. Chuck in the 4-jaw, centering on the 1/4-40 hole. Drill 3/32" to about 1/32" from breaking through. Enlarge this to 1/8" about half way through. Drill 7/32" depth 1/4" and tap 1/4-40. Reverse and turn the blind end. Drill the four 7/64" holes and four 7/32" holes at the 1/8" radius centers. If necessary, enlarge the 7/32" holes to 15/64" or 1/4", if the hole doesn't quite reach the layout lines. Saw and file the center opening.

The **VALVE** is a simple block with two milled slots and a recess in the bottom. When assembled, this block should seat exactly on the Plate when steam pressure is on it. It should float and not be held against the Plate by the Valve Rod. It should be able to rise a few thousandths off the Plate.

The **VALVE ROD** is made by chucking a 1/4" diameter x 3" brass rod in the 3-jaw with about 2-5/8" projecting, supported by the tailstock center. Use a tiny center drill. Start back a bit so the center can finally be cut away and turn to size and thread 5-40. Make a parting cut 9/32" from the shoulder. Mount in the cross slide mill and make the 3/32" slot. Fit a 1/16" pin squarely across the fork.

The model shown has a clear plastic cover so the Valve position and action can be seen. If live steam is to be used, it should be metal. At 30 pounds of air, it is hard to stop this engine with the fingers pinching the Shaft. Molykote lube was used at assembly to fill the surface pores and provide longer lasting lubrication.

At assembly, add a couple of turns of 1/16" strands of unraveled, braided, graphited asbestos packing to the Steam Chest Gland. Do not turn it up tight; just snug it up with the fingers.

With the Cranks at horizontal, the Valve should fully expose one slot. One half turn of the Crank should fully expose the other Valve slot. Set the Eccentric so it is at 90° to the centerline through the Cranks. Take half turns of the Valve Rod, adjusting the Valve so it exposes the Valve slots equally at both ends of the Valve travel.

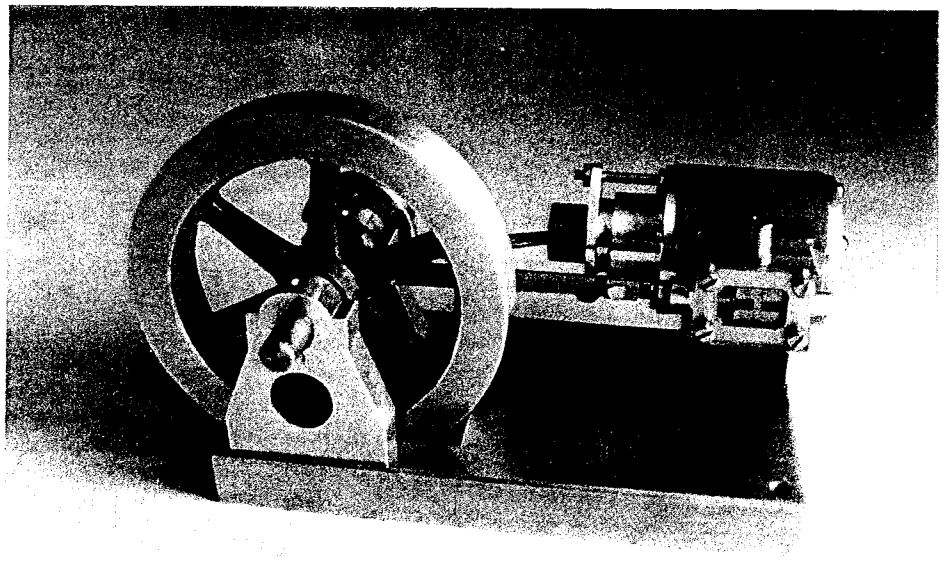
An option on the model shown was hex nuts above the Valve Plate and acorn nuts on the Columns. The metal lagging option was used and the metal stock given the damascening finish before it was formed.

This is an interesting engine and it ran fine on as little as five pounds of air pressure.

SAFETY FIRST — AND ALWAYS!

CHAPTER

45 Single Cylinder Compound



Richard Castagnola of Santa Barbara, California, sent in the suggestion for this engine. It is a compound using only one cylinder. The valve design feeds the exhaust from the high pressure side to the low pressure side. While steam is fed into the high pressure side, the low pressure side exhausts. The ratio of the areas of the low pressure to the high pressure is approximately 1.8 to 1. It seems a compound design on a small model is no advantage over a common double-acting engine but this shows an interesting principle and is a bit of an educational project. It is fun to build and it ran nicely on about 10 psi air. Care must be taken at the Piston, Head and Stuffing Box for good concentricity and a close, free fit.

Start the **CYLINDER** with an accurate 1-3/8" x 1-3/8" x 1-1/8" block. The one shown is a tough bronze. Compare the Cylinder drawing with the Assembly drawing and note how the 1/16" port pattern of holes is offset from the Cylinder center. Also, rather than run deep1/16" end milling, drilled holes are used at sections **CC** and **DD**. Lay out all of the outlines and hole centers (**Step 1**) and, while it is still a square block, make all bolt holes and port holes. In **Step 2**, the block is centered on the bore centerline in the 4-jaw using a center test indicator and bored 3/4". While on the same chucking, finish the 1-1/4" flange. For **Step 3**, reverse it in the chuck and turn the other flange. Make a milling setup and do **Steps 4, 5, 6** and **7**. Rounding, as in **Step 8**, is optional. After boring, mill the 3/32" openings at the bore end of the slanting steam passages.

Now that the Cylinder is finished, we can take a moment and mention the related **LAGGING**. A heavy paper pattern is made, mostly by cut and try. The outline is then transferred to the metal and the piece cut and filed to shape. Roll it over some round stock to a diameter smaller than the Head diameter and spring into place.

The **INBOARD HEAD** requires a bit of extra care. Chuck the stock and turn the 3/4" O.D. as well as the 1/2" and 5/8" bores, then part off at about 19/32" long. Chuck, centering on the 3/4" diameter; turn to length and form the dowel. Scribe a 1-1/6" bolt circle and pace off six centers for a #43 drill.

The **PISTON** can be completed, except for the Wrist Pin hole, in one chucking. As mentioned, work for a fine finish and close, free fit in the Cylinder and Head. At assembly, use a prick punch to flow a bit of Piston metal over the ends of the Wrist Pin to retain it. Remove any burrs with an oil stone.

The **GLAND** is made close-fitting to help support the Piston. The long neck on the Piston acts as a crosshead, guided by the deep Head and this Gland.

The **STEAM CHEST** starts as an accurate 1/4" x 5/8" x 1-1/4" block. All centers and outlines are laid out and the #43 holes made. Drill 4 holes and mill out the center 11/32" x 17/32" opening. Chuck in the 4-jaw, picking up the Stuffing Box center with a center test indicator. Drill #41 through, just making a starting dimple for the 1/16" hole. Drill #21 and tap 3/16-40. Make the 1/16" hole; turn the 1/4" diameter. Reverse and make the blind hub.

The **VALVE PLATE** calls for very careful layout. Note how the pattern of holes is offset like the Cylinder. Remove all burrs and grind flat with fine emery on a surface plate.

The **VALVE ROD** requires tailstock support while turning to the small diameters. When the turning is completed, the end can be cut off and the 2-56 thread added using a tailstock die holder. Use the cross slide mill to make the 1/16" slot and cut to 5/32" thickness.

The thread in the **NUT** should be a close fit on the Valve Rod. Avoid sloppiness at the Valve and Nut. The Valve should just float on its seat. The spacing of the ports and the Valve travel can tolerate only a very small amount of backlash at the Valve.

The **VALVE** is straight machining on a tiny part and will require patience. Make sure the rubbing face is flat and smooth.

The **BEARINGS** can be bushed with Oilite if desired. They can be mounted on the Base and line-reamed for a nice, free-running Shaft. Mark them so they can be

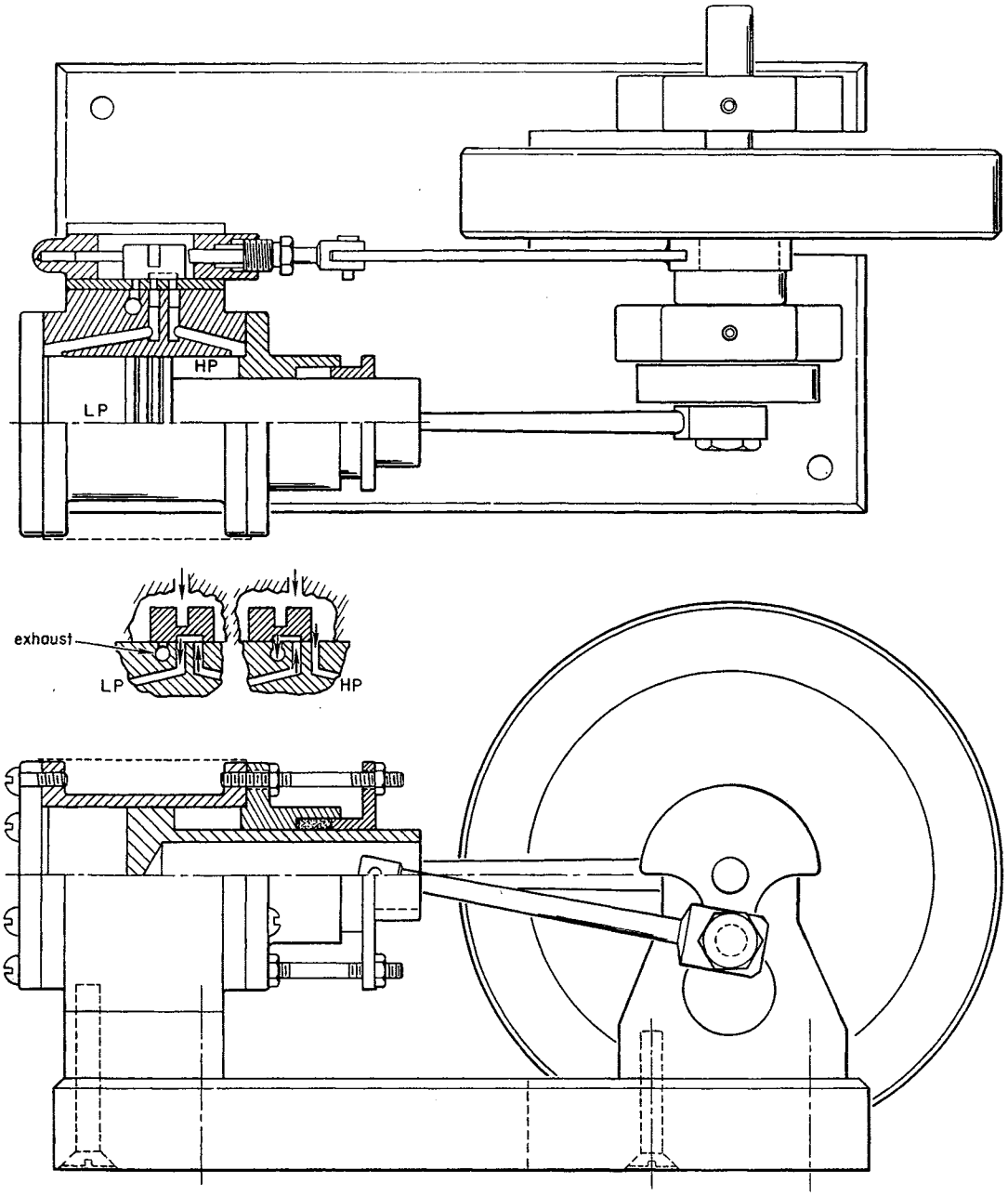
returned to where they were mounted when machined.

The **CONNECTING ROD** is made from 3/16" x 3/8" stock that is chucked and turned, using the tailstock support. First lay out and make the 1/16" and 3/16" holes while the stock is square. The 11/64" diameter tapered to 7/64" is not serious. It is roughly what you get at 1° setting. Make it so it looks good to you.

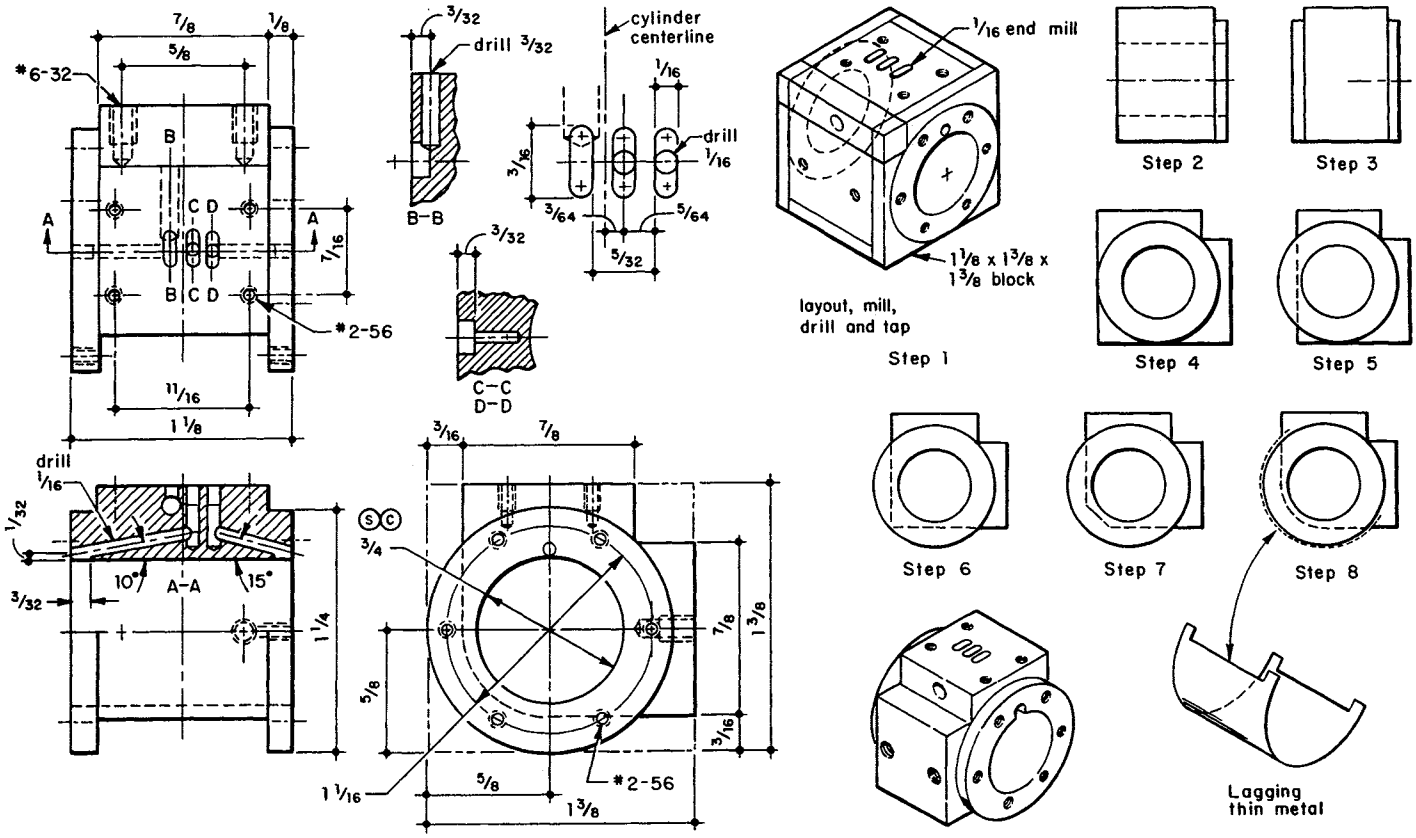
For the **ECCENTRIC**, center a short piece of 5/8" stock in the 4-jaw and take a fine cut to brighten up the O.D.; bore 1/4". Offset .050" and turn the 7/16" diameter. One way to make the offset is to turn the chuck so two jaws are horizontal. Mount a square-ended bar in the tool post and bring it up against the 5/8" diameter. Set the collar at zero, loosen the vertical jaws slightly and back up the rear jaw about 1/16". Force the work piece back using the front jaw. Feed the cross slide in .050" and bring the stock back against the bar using the rear jaw. Now snug up all the jaws. Ease the bar against the high spot and then rotate the chuck 180°. A .100" diameter rod should just pass between them.

The **ECCENTRIC STRAP** is a turned end, filed to shape and soldered to the 1/16" blade.

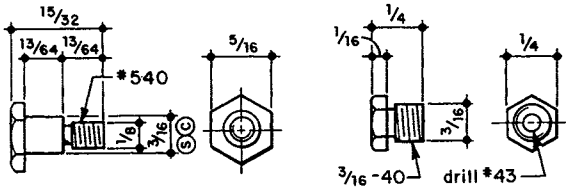
Set the centerline through the Eccentric offset and the Shaft at 90° to the centerline through the Crankpin and the Shaft. Adjust the Valve Rod so the high pressure port is just fully exposed at one end of the Valve travel. Apply compressed air and note the action. Try turning the Valve Rod 1/2 turn and note how the engine runs. You can easily find the spot where the engine runs best.



SINGLE CYLINDER COMPOUND ENGINE



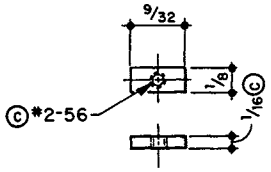
CYLINDER
Hard Aluminum, Brass or Cast Iron



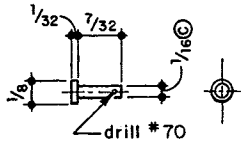
CRANK SCREW
Steel

PACKNUT
Brass or Aluminum

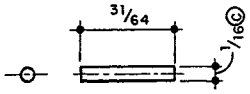
(c) close	(b) solder
(s) smooth	(p) press fit or loctite
(f) flat	



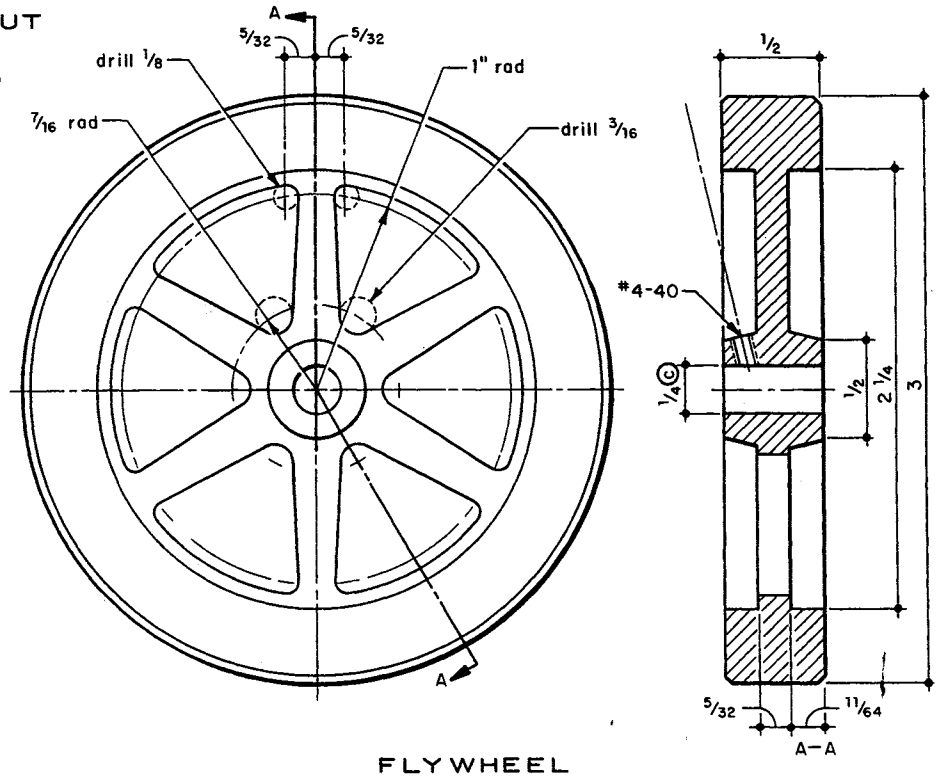
NUT
Brass



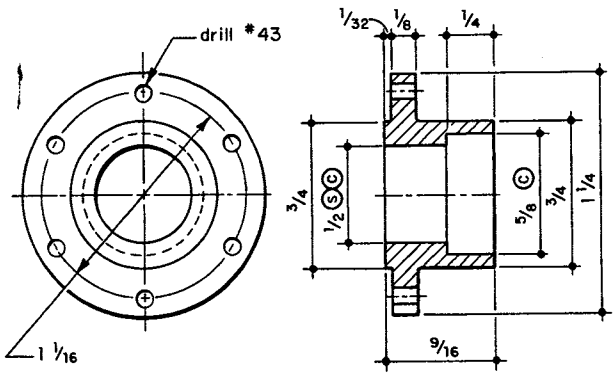
PIN
Brass



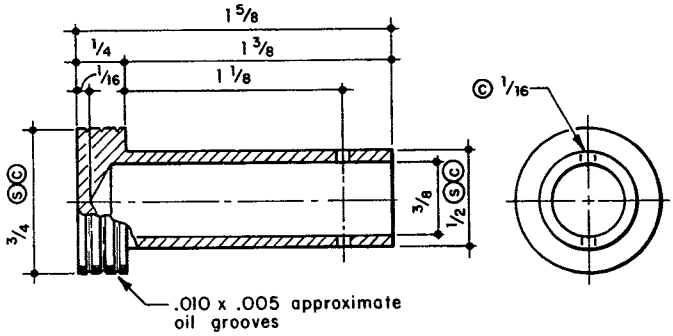
WRIST PIN
Steel



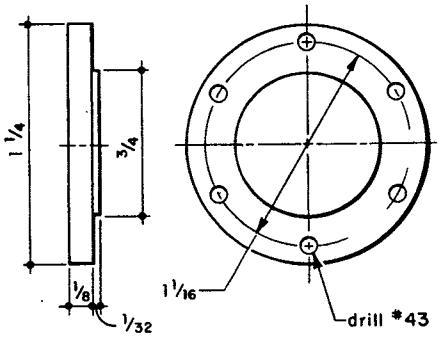
FLYWHEEL
Any Metal



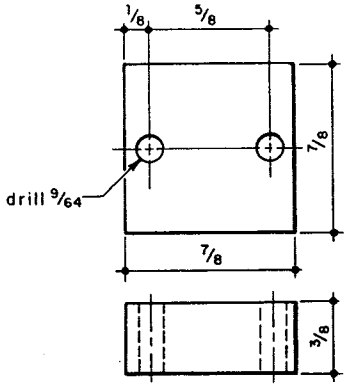
INBOARD HEAD
Aluminum or Brass



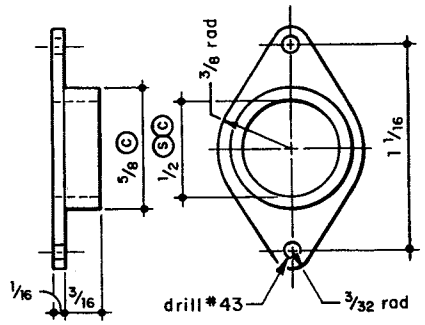
PISTON
Brass



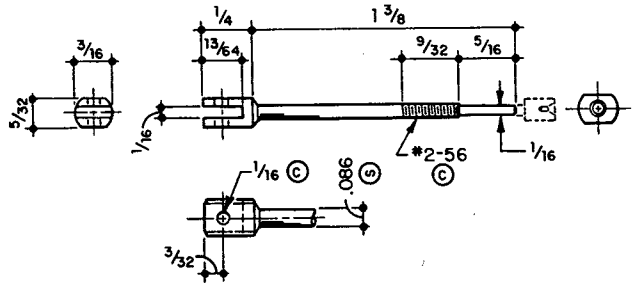
OUTBOARD HEAD
Aluminum or Brass



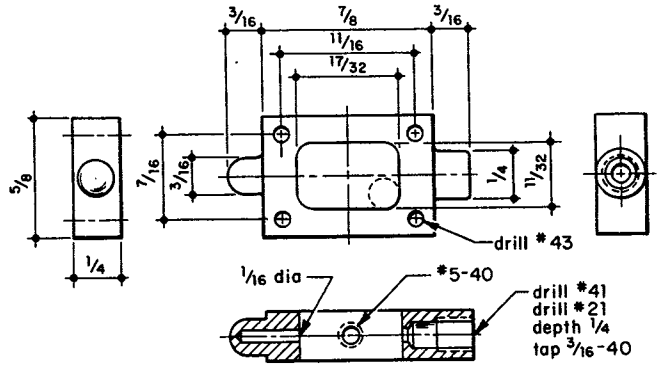
FOOT
Any Metal



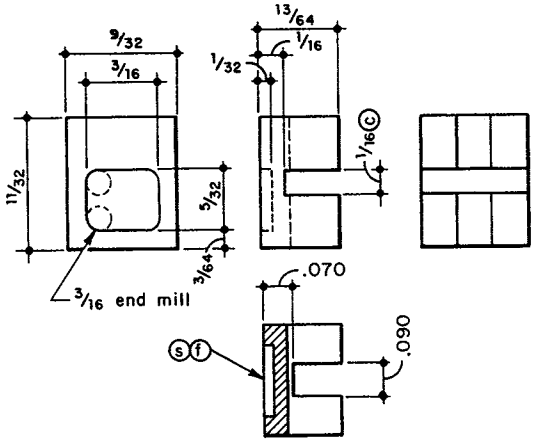
GLAND
Aluminum or
Brass



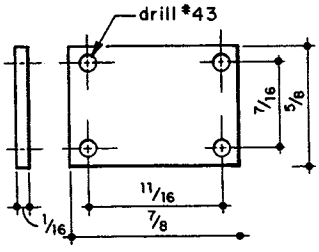
VALVE ROD
Brass



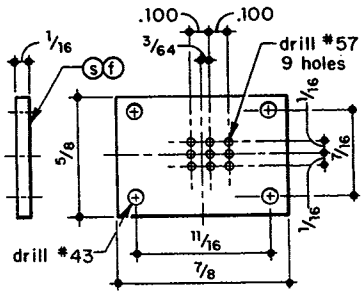
STEAM CHEST
Aluminum or Brass



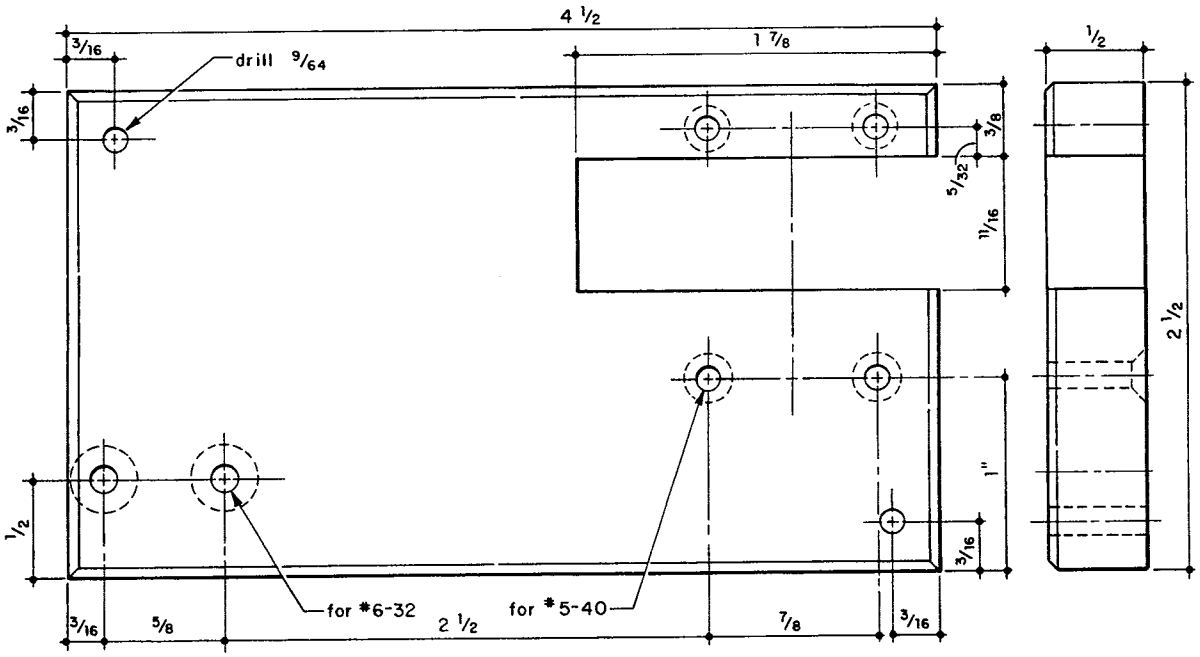
VALVE
Brass



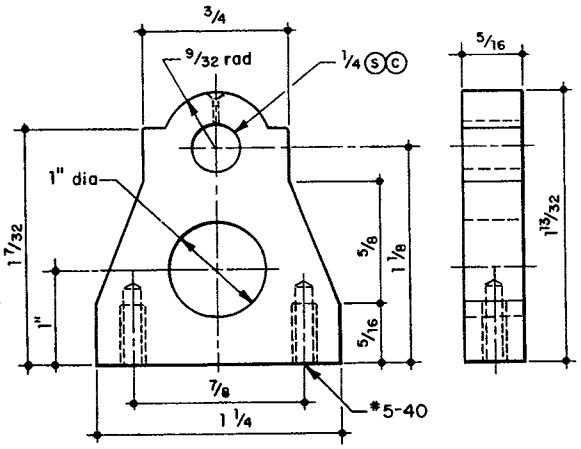
COVER
Aluminum or
Brass



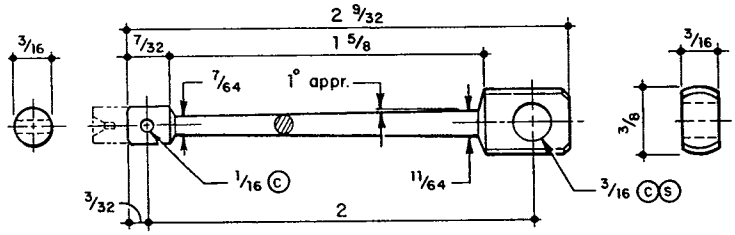
VALVE PLATE
Brass



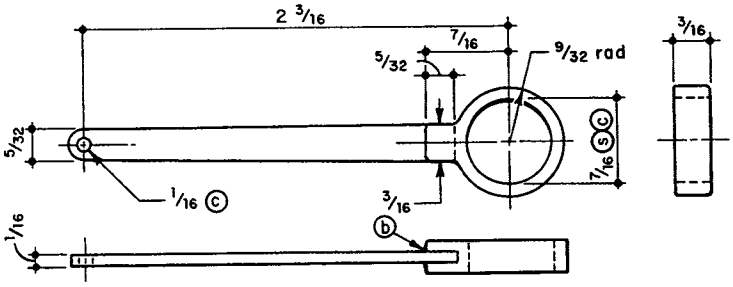
BASE
Any Metal



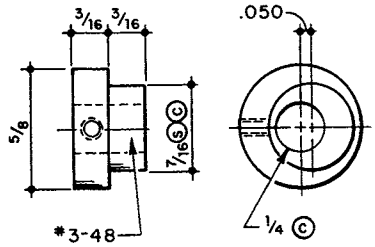
BEARING
Hard Aluminum or
Brass — 2 required



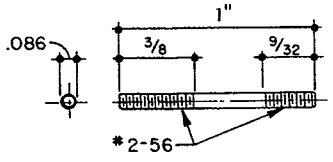
CONNECTING ROD
Hard Aluminum or Brass



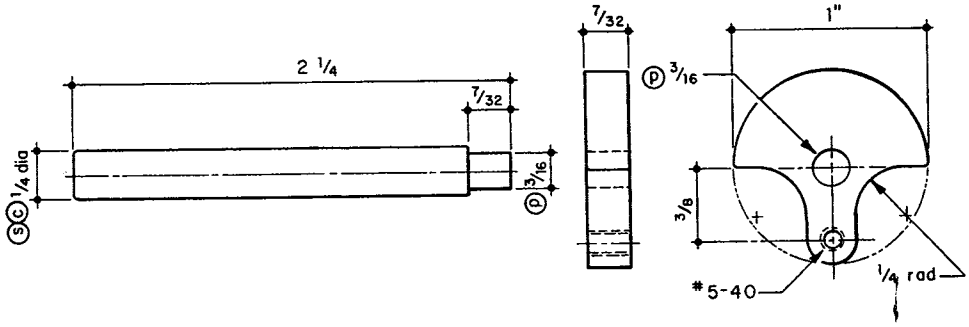
ECCENTRIC ROD
Brass



ECCENTRIC
Steel

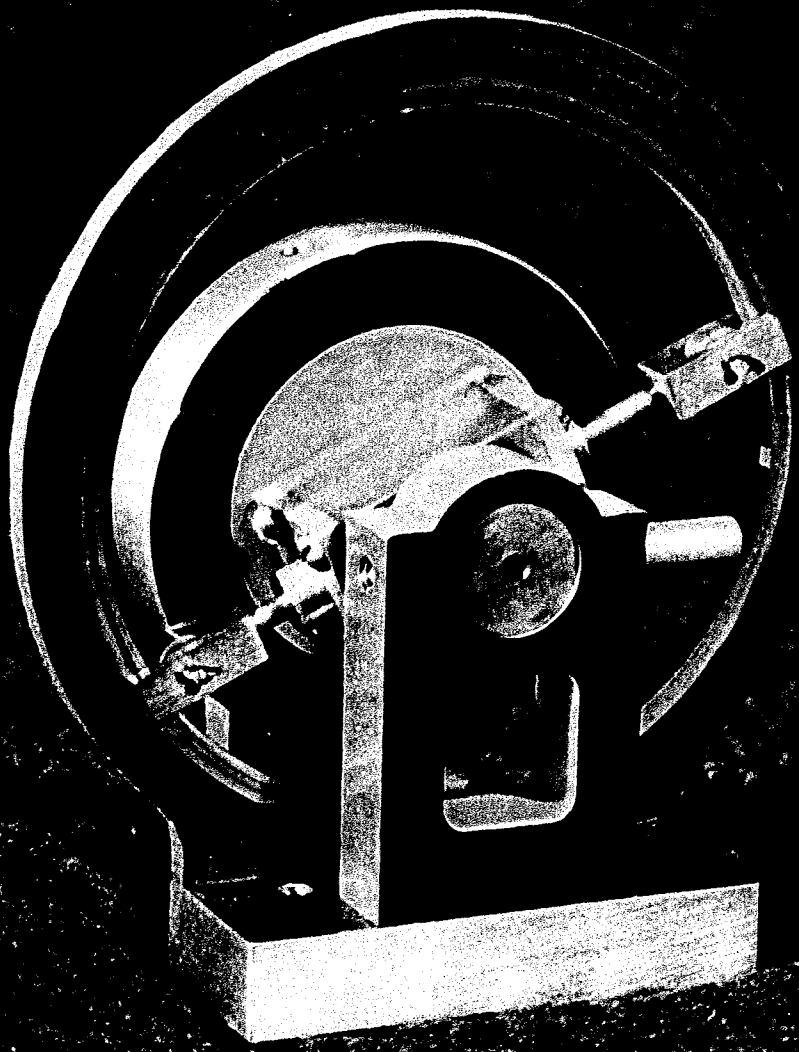


STUD
Brass — 2 required



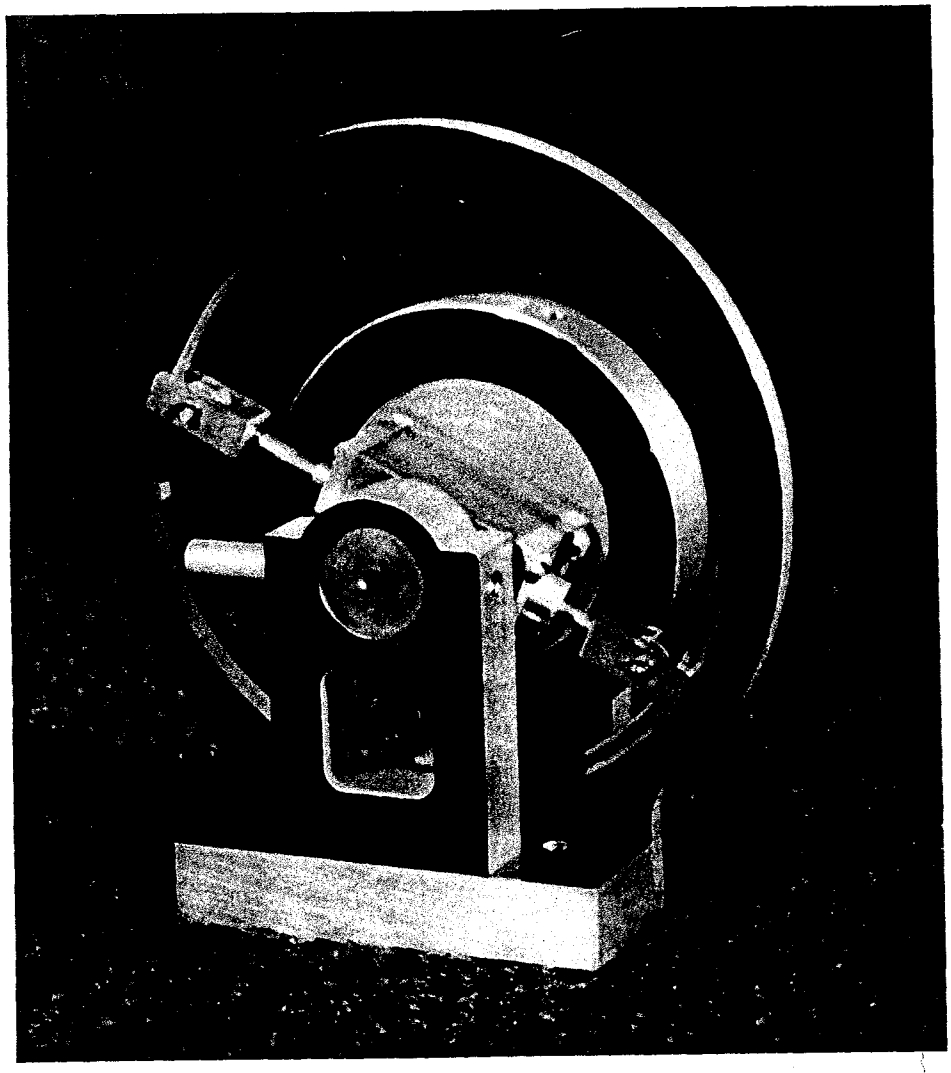
CRANKSHAFT
Steel

Comber Rotary Engine



CHAPTER

46 Comber Rotary Engine



Chet Sperry, a MODELTECer from Kalamazoo, Michigan, loaned Bill Fitt a book published in 1880 entitled *Appleton's Cyclopædia of Applied Mechanics*, and in it is a sketch and short description of the *Comber Rotary Engine*.

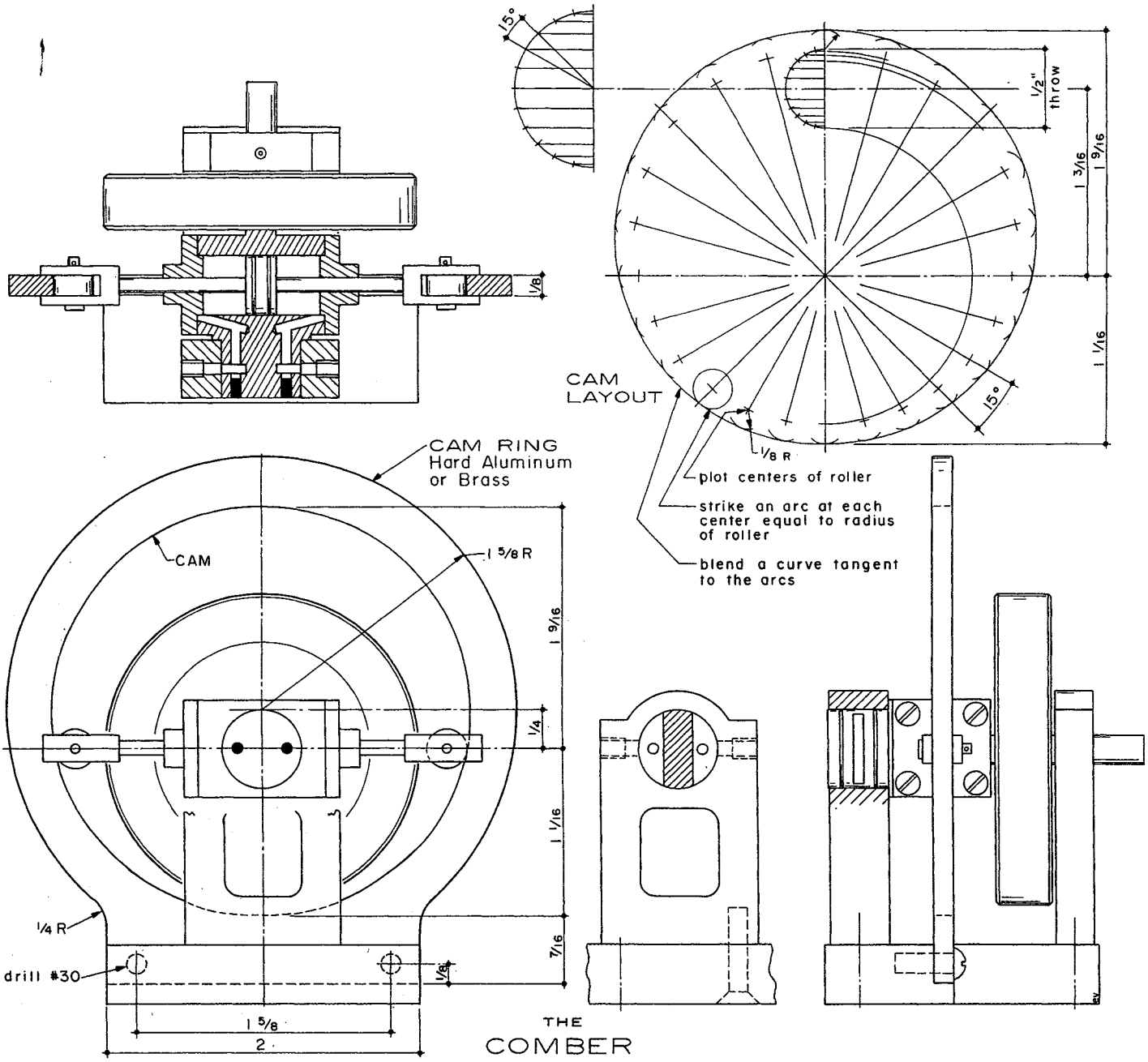
This is an unusual design and an attempt is made here to detail a miniature along those lines. Most of the proportions and design had to be worked from scratch and simplified considerably. The Cam and general accuracy will be a challenge.

The main feature is a Cam in which the Cylinder rotates with the Shaft. A double-ended Piston Rod with Rollers at each end follows the inside Cam. Valving at one Bearing admits "steam" just as one Roller starts pushing downhill on the Cam, causing the Cylinder and Shaft to rotate. At one half turn, the other Roller is exposed to steam pressure, and it starts down the Cam so it can be considered double acting. Of course, while one is working the other is exhausting. A true circular bore instead of the Cam did not show any promise on some trial layouts.

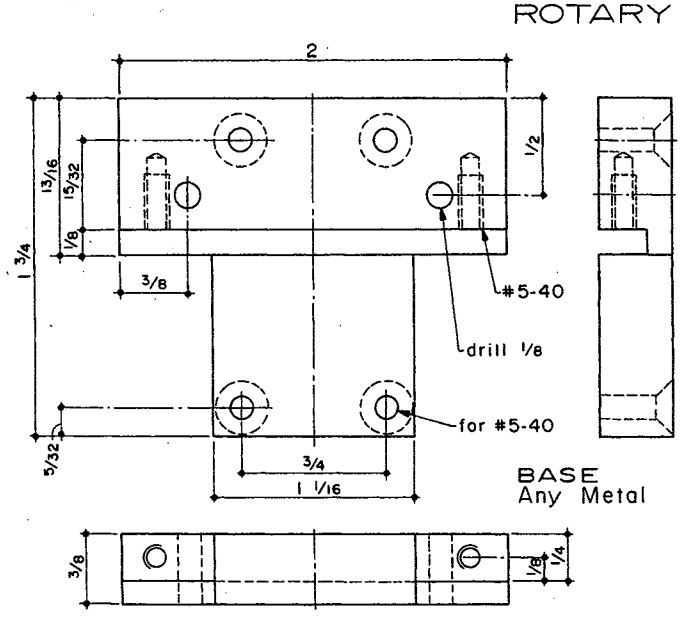
In general, this engine requires a bit more patience and care in layout and machining. Perhaps some will say it is too small, but we try to have projects within the range of small machine tools. Use your ingenuity and make it 1-1/2 or 2 times larger if you wish. This could be quite an experimental project by using some of your own ideas. The mechanism is a good classroom subject.

Since the **CAM RING** is the most difficult, we will start with it. Drawing space and the detailed Cam layout led to dimensioning on the assembly drawing (perhaps not good drafting practice, but it helps associate the Cam with the engine principle). It was required that at any time or position in the rotation of the engine that both Rollers touch the inside of the Cam. Now that does not mean extremely close fit. A wide gap between the distance across the Roller and the distance across the Cam could cause poorer performance and perhaps a pounding noise. Try for a gap in the neighborhood of .005 to .010".

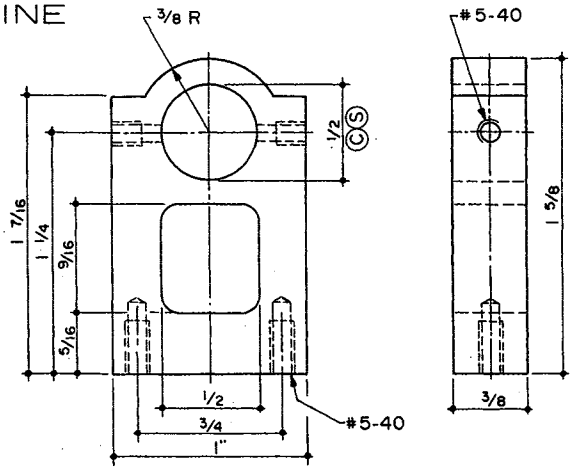
Start out with a flat square piece of stock 1/8" x 3-1/4" x 3-3/8". By using a square piece, a protractor or square can be used on any edge. After coating with layout dye, make a centerline 1-1/2" up from the bottom and another at right angles midway on the 3-1/4" width. Scribe a short centerline 1/4" above the horizontal centerline and prick punch. Using this center, scribe the 1-5/8" radius, and lay out the 2" wide lower mounting projection. What is needed is to plot the path of the Roller center. A double-size layout was made on paper. 24 spaces were laid out around the Shaft center and, 1-3/16" from this center, a centerline was made representing the mid-position of the Cam throw. A half circle off this center was divided into 12 equal spaces (24 divided by 2). Horizontal lines were drawn intersecting the vertical centerline, producing narrow spaces increasing in size to the center and then reducing down at the other end. An enlarged view of this method is shown. These intersecting points were the compass settings for radii intersecting the 24 radial lines. Each intersection was the center of the Roller as shown on the layout. Arcs equal to the radius of the Roller were scribed and the Cam



THE COMBER ROTARY ENGINE

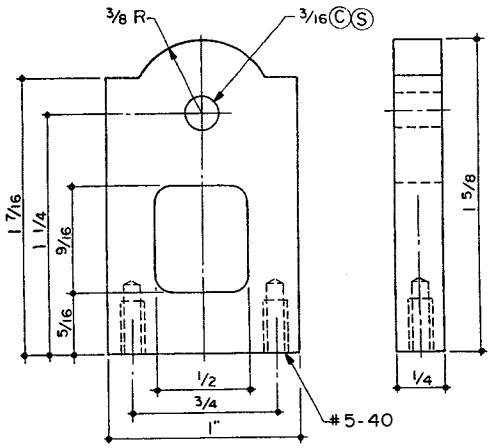


BASE
Any Metal

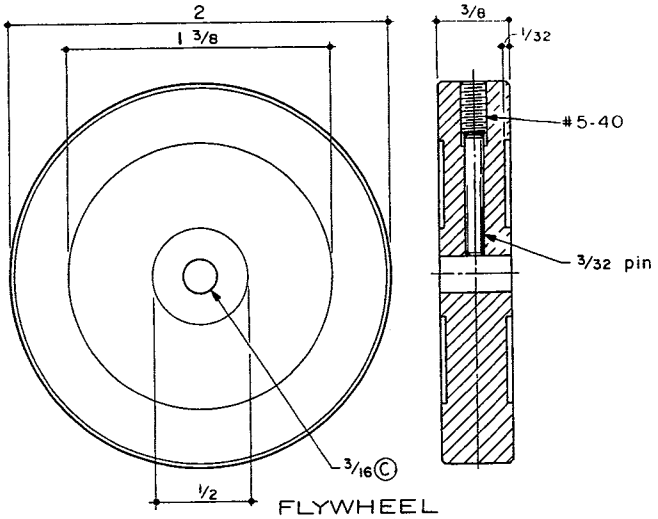


Ⓒ close fit
Ⓢ smooth
Ⓑ braze or solder

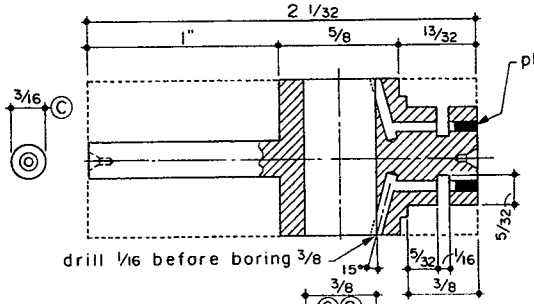
BEARING
Hard Aluminum or Brass

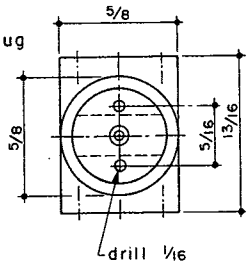


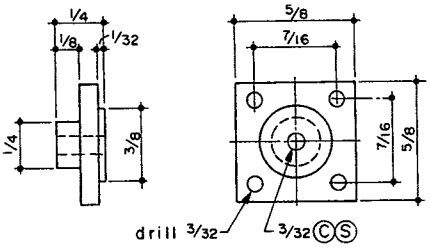
BEARING
Hard Aluminum or
Brass



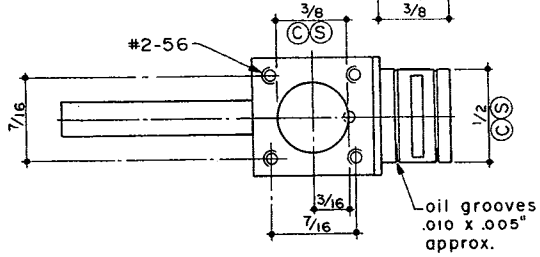
FLYWHEEL
Any Metal



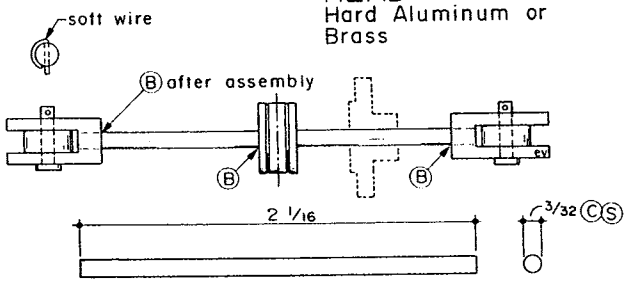




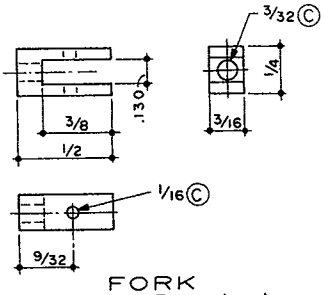
HEAD
Hard Aluminum or
Brass



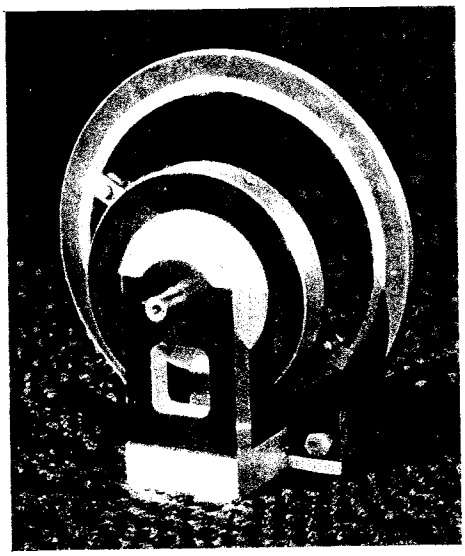
CYLINDER-SHAFT
Brass

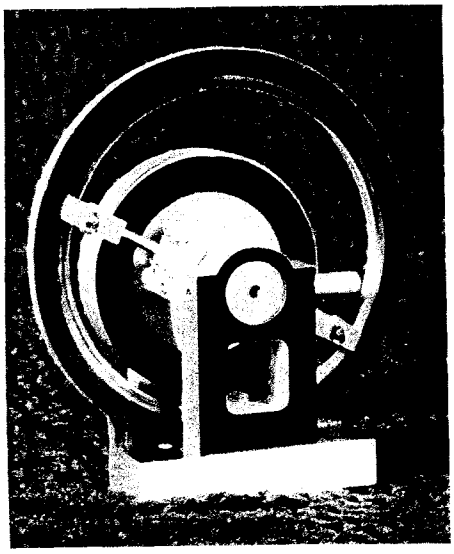


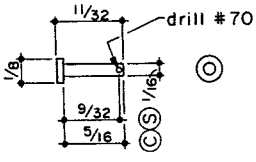
PISTON ROD
Brass



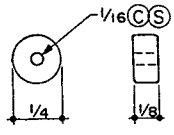
FORK
Brass, 2 Required



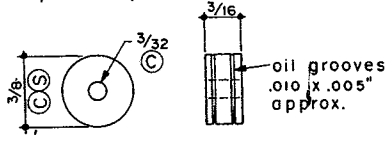




PIN
Brass, 2 Req.



ROLLER
Steel
2 Req.



PISTON
Brass

line made tangent to the arcs. This drawing is reduced down to actual size in the drawings presented here. If you choose to lay out the Cam as shown in these drawings, you may make a smooth Cam with only 12 total spaces, using the principle shown here. In any case, the number of spaces on the half circle must be the same as on one half of the Cam. This would be an even number such as 12, 14, 16, etc. The simplest choice is to use the Cam layout on the following page by tracing as accurate as you can on tracing paper. Be sure to draw in the centerlines so you can paste it onto the 1/8" metal matching the centerlines you scribed. Drill, saw and *very carefully* file the Cam to the lines on the tracing paper. File so you don't feel any ripples on the Cam surface.

When the time comes to fit the double-ended Piston Rod, do a little trial fitting and keep the slack to a minimum. If all came out right, it is 2-5/8" across the outside of the Rollers. By setting dividers at this dimension, it should fit across any one of the radial lines and be in contact with the Cam at both ends, with slight allowance for the off-center contact during midstroke.

Now is a good time to mention the importance of squareness and accuracy. If the bore for the Piston is not square with the Shaft, the Roller Forks will rub hard on the Cam ring. By making the Forks lap over onto the Cam ring, a guide is provided to keep the Rollers in position.

The fit of the Valve end of the Cylinder-Shaft should be a close fit in the Bearing to keep leakage to a minimum. This aggravates the binding if the parts are not in good square and parallel condition.

This is a novel engine to run on air pressure, and fun to show off for short runs. It is a good conversation piece. You may have to practice a bit of the old "fussin, fiddlin, filing and fittin" on this assembly.

The original article in the 1880 book mentions built-in adjustments that were impossible to make on such a small engine. The article mentions the Bearings as being mounted in brackets with adjustments in all directions.

The **BASE** is a simple machining job requiring care to insure squareness and fit among the related parts. After making the 1/8" groove, check for flatness since cuts like this relieve stress and the piece may warp. Spot the 5-40 tapped holes from the Cam ring.

The same care must be taken on the **BEARINGS,** the thick one especially, to make a free running engine. The 1/2" bore should be as close and as near air-tight as you can and still rotate free.

The **CYLINDER-SHAFT** combination is a bit complicated. If you can see a simple way, perhaps it can be made in two pieces sweated together. Start out with a piece of brass 5/8" x 13/16" x 2-1/32" and lay out all centers and lines. Lay out and make the lathe center holes. Remember accuracy so the Cylinder doesn't wobble. Drill the 1/16" steam passages. Mount squarely in the 4-jaw and make a fine 3/8" bore for the Piston. Next, mount between centers and do the outside turning. Mill the 1/16" grooves and use the Heads as jigs and spot for the 2-56 bolt holes. The corners can be sawed out to reduce turning time on the 3/16" end.

Not much need be said about the remaining parts. No stuffing boxes are used for simplicity and compactness.

At assembly, leave one Fork free so trials can be made and high spots in the Cam found and dressed down with careful scraping with a three-cornered scraper, until the Rollers run close and free for a full rotation. Place a piece of .005" shim stock between one Roller and the Cam and lightly wedge the Roller against the Cam. Use a tiny pellet of solder and a fine propane flame to solder in place. The construction of this engine is a compromise since it is so small. The solder on one Fork will have to be softened in order to disassemble.

After a break-in run, this engine ran on about 15 pounds of air. It did take a bit of time to free it and it turned out that it should not be fixed too close end-wise on the Shaft. Let it float and find itself where it has the least rubbing action at the Forks. In other words let the Forks center the Cylinder.

An interesting side light in making this engine was the use of some salvage brass plating bars. Turning off the crusty outside surface left a beautiful gold-colored bar that was about 1-1/8" in diameter, large enough to mill and shape into a rectangular piece. It worked up nice but the metal was made for beauty and not toughness. It was easily bent and dented, so a wobble came into the Flywheel. With patience, it was freed up and the engine ran but it will have to be replaced someday. It shows a hazard in using salvage material. Standard half-hard brass is a lot tougher.

SAFETY FIRST

WEAR PROPER CLOTHING — DOUBLE-CHECK SET-UP

USE PROPER LIGHT — KEEP FLOOR CLEAN

DON'T USE DULL TOOLS — USE YOUR GOGGLES

USE PROPER COUNTERBALANCE

USE PROPER SPEED

PURSUE YOUR HOBBY ACTIVITY SAFELY

CHAPTER

47 Model Boat Engine

Howard Green of Kerrville, Texas, sent a copy of an article about making a low-profile steam engine for a model boat. It was considerably more complicated than the engine described here. Only the general horizontal compact part of the design is used. Here is a double-acting wobbler with 7/16" bore and 5/8" stroke.

This writer does not claim any great knowledge of boat design and has tried to make a low center of gravity, compact and not too heavy engine which seems to be called for in powering a small boat. This engine, however, takes up more "floor space" than a vertical engine. Experts on small power boat models may find ways of improving on this.

To achieve the low profile, it was necessary to use miter Gears to get the output Shaft in a usable position. These Gears are purchased and not too expensive. This is a small engine, probably good for only about a 2'-0" boat. Lubrication is difficult in the Crankshaft and Gear areas. The surest method is to lift the engine out of the boat and free the Cylinder and Flywheel from the Frame and give a good coating of Moly lube before each run. If the boat is to be put through a lot of hard running, this engine may not be durable enough. In any case, it is fun to make and show off.

The **FOOT** is mostly common machining practice. The important point is matching the Frame at the 1" and 11/32" hole spacing for a free-running Crankshaft. Hold the length of the **SPACERS** alike within a few thousandths. This Foot can be made to match any ribs, cross members or timber as long as the three 2-56 holes and 1/8" Shaft holes are held as shown.

The **FRAME** provides a lot of the features needed for a tiny engine such as steam porting, Cylinder pivot, Crankshaft Bearing and Output Shaft Bearing.

On an accurate 3/8" x 7/8" x 3-1/2" piece of stock, lay out all the outlines and hole centers except the steam ports. Note two **X** 5/32" dimensions match the 5/32" dimensions on the Gear drawing. Holding these dimensions will provide the proper meshing of the Gears.

Next, drill and tap the three 2-56 holes, then drill and ream the two vertical 1/8" Shaft holes and counterdrill for the Spring.

Mount in the 4-jaw and center on, drill and ream 1/8" for the Output Shaft. All of these operations are done while the piece is rectangular. Turn the 1/4" hub.

Make the **DRILL JIG**. Mount the Jig over a close-fitting pin in the Cylinder pivot hole and hold against another close-fitting pin in the Crankshaft hole as shown while drilling the two 1/16" port holes. Turn the Jig over and do the same for the other two holes.

Transfer the centers of these port holes around onto the sides and make the 1/16" cross holes.. Pick up these centers and transfer to the end. Drill 1/16" and tap 5-40 for the Steam Connections. Cut to the outline and make the 5/8" opening for the Gear and mill or shape the Gear end of the Base down to the 5/16" dimension, concentrating on the **X** 5/32" dimensions. Clean out all the chips and plug the 1/16" cross holes as shown. Perhaps you will have a different sequence for these operations.

For the **CYLINDER**, make an accurate 5/8" x 23/32" x 1-1/8" block and lay out all the centers. Chuck in the 4-jaw and make the 7/16" bore. Use the Heads as jigs for spotting the bolt holes. Again, mount in the 4-jaw and make a fine skin cut to true-up the Valve face. Make the .010" undercut and squarely drill and tap for the **PIVOT**. Assemble the Cylinder, inboard head and Piston assembly as shown and drill the 1/16" ports using the Drill Jig.

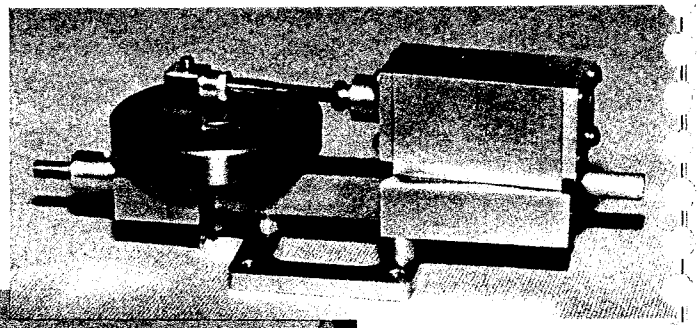
The **MITER GEARS** are purchased and have to be bushed for a close fit on the 1/8" hafting. One is fitted with a set screw for the Output Shaft. The other is fitted into the Flywheel and set with Loctite. The Crankshaft is then set into the Gear with Loctite. Both of these Shafts have flats for the set screws so there will be no problem disassembling.

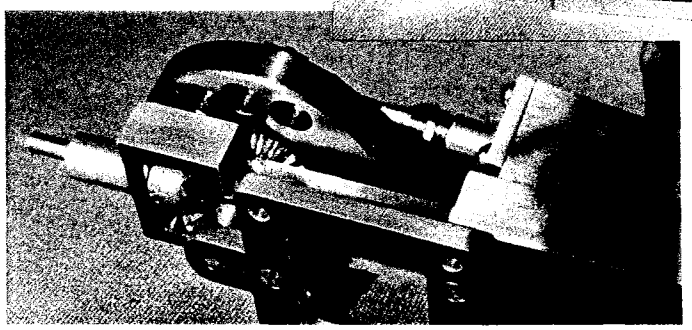
At moderate speeds with the engine well anchored, vibration was not too bad. There is a spot where you will have to cut and try in reducing vibration.

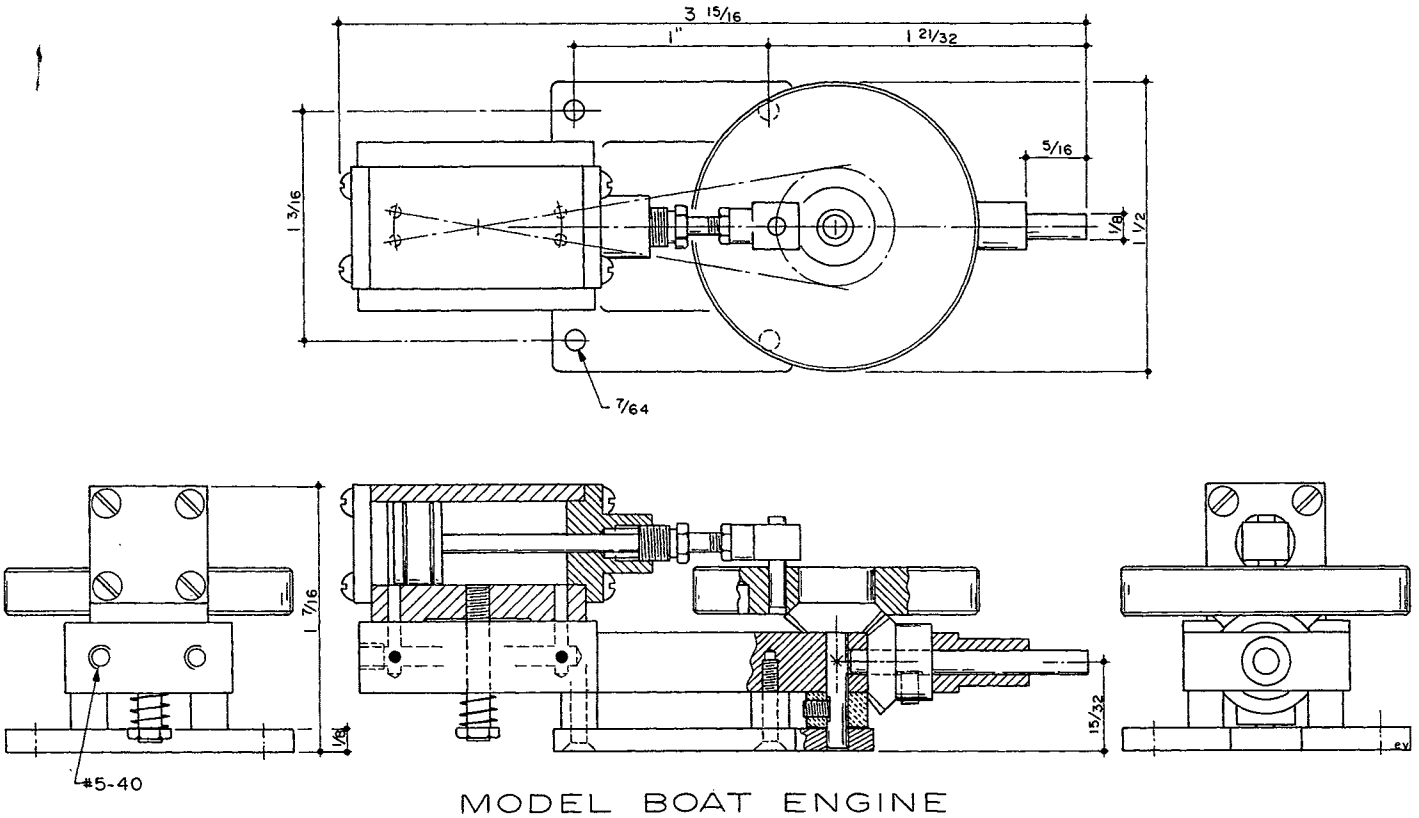
The dimensions of the **SPRING** used on the model are shown. Try some from your collection.

Removing the nut at the Spring frees the Cylinder and it can be easily lifted off. Loosening the **COLLAR** set screw, the Flywheel assembly can be lifted off for cleaning and lubrication. If it does not rotate in the right direction, use the other port as intake. Use your favorite packing.

This engine ran good on 5 to 10 psi air.

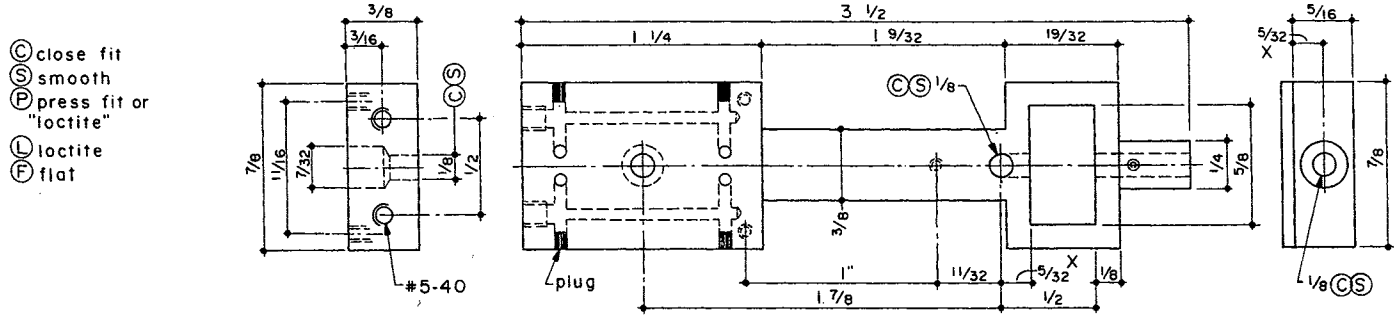


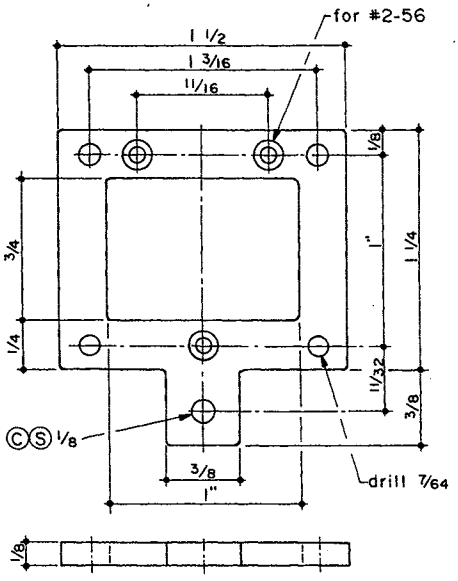




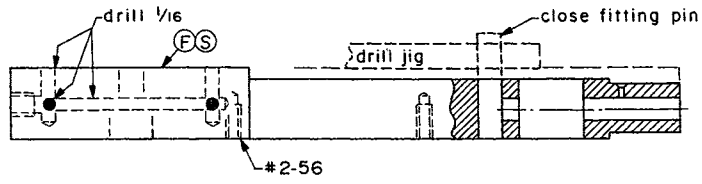
MODEL BOAT ENGINE

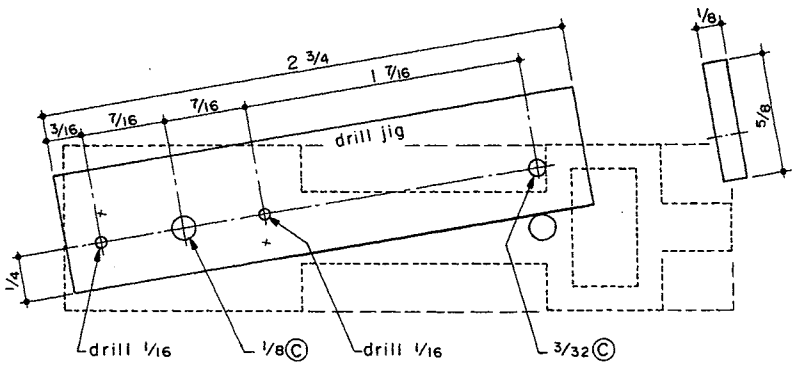
Ⓒ close fit
Ⓢ smooth
Ⓟ press fit or "loctite"
Ⓛ loctite
Ⓕ flat



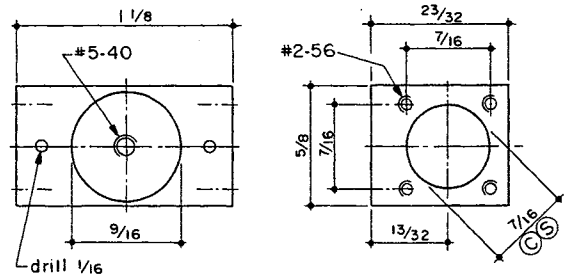


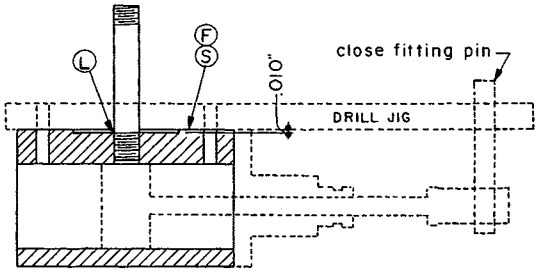
FOOT
Aluminum



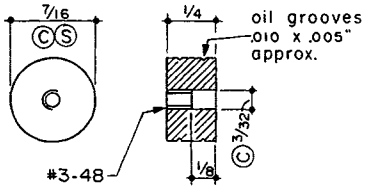


FRAME
Hard Aluminum

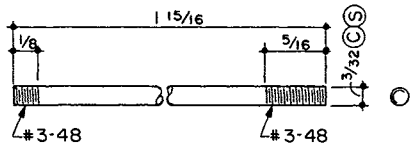




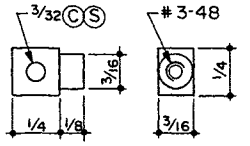
CYLINDER
Hard Aluminum or Brass



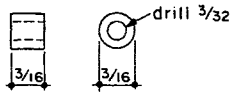
PISTON
Brass



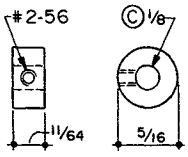
PISTON ROD
Brass



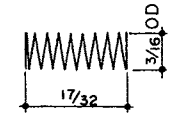
BEARING
Brass



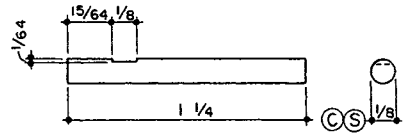
SPACER
Aluminum



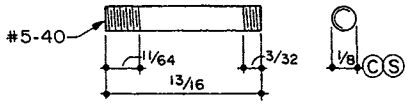
COLLAR
Brass



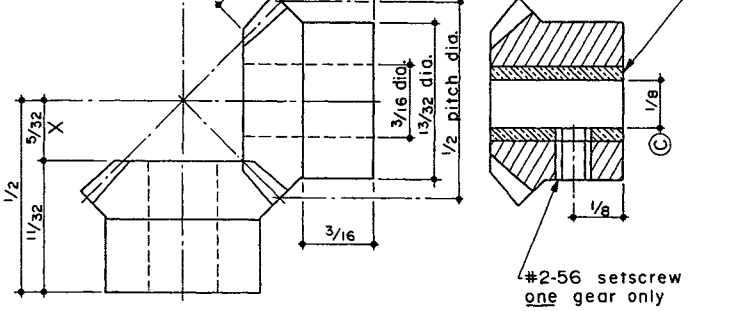
SPRING
Steel
.028" wire



SHAFT
Steel

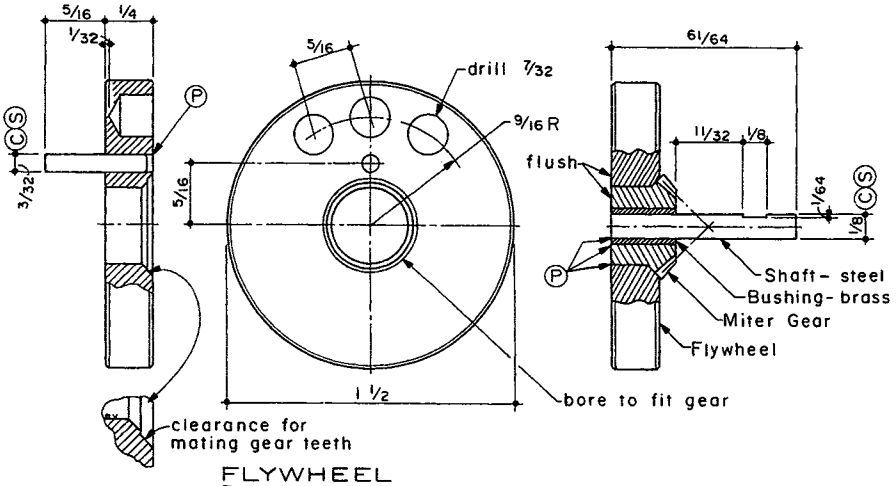


PIVOT
Steel

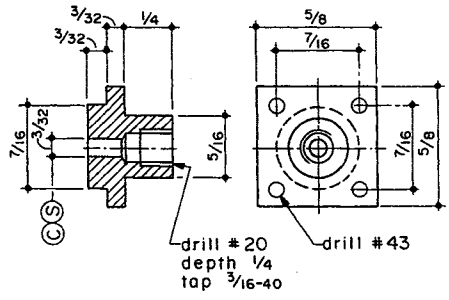


GEARING

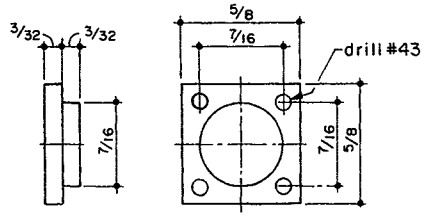
PURCHASE:
one set of miter gears-
brass
20° pressure angle
32 pitch
ratio 1:1
16 teeth
Boston Gear: catalog no. G462Y
item code 12114



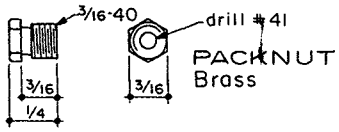
FLYWHEEL
Brass



HEAD
Aluminum or Brass



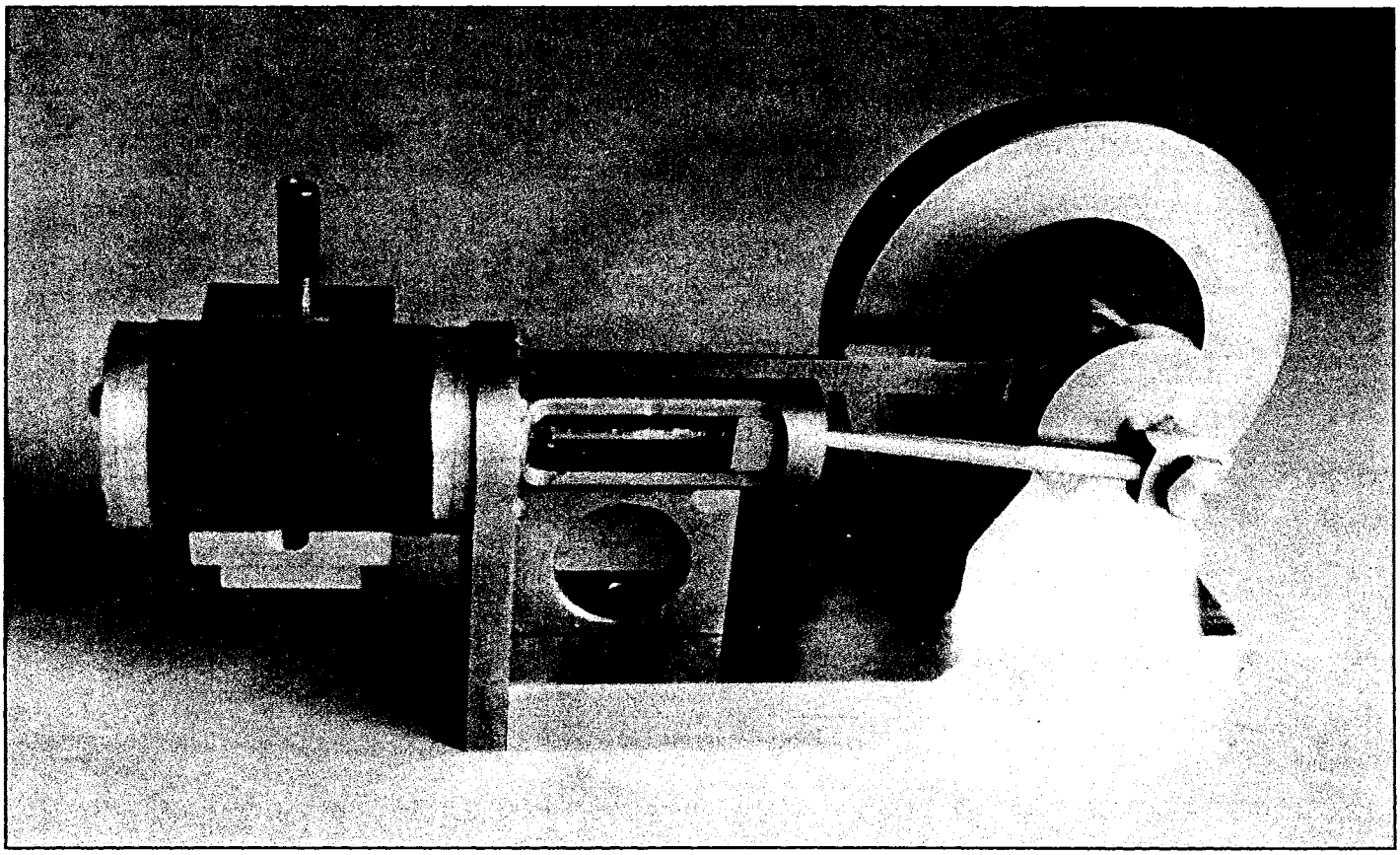
HEAD
Aluminum or Brass



PACKNUT
Brass

CHAPTER

48 Una-Flow Engine



This model is an attempt to help beginners build a stationary engine using the Una-Flow principle. For all appearances, it looks like many of the past models. It is double-acting and the exhaust can be piped away and controlled. One thing gathered from past articles is that the Piston length is 9/10ths as long as the stroke. The steam does not reverse in the ports. The flow is continuous in one direction and the new steam entering is not cooled by passages that could be cooled by exhaust steam and moisture. There is a bit of back-pressure at the end of each stroke which acts as a cushion, and contributes to the action. Much has been written about this type of engine. Perhaps you can improve upon this design.

For a change, this one uses a Piston Valve which is quite simple, perhaps over-simplified. The Base is odd shaped, but can be plain rectangular. The Block under the Crosshead Guide is used to take away some of the thin skeleton appearance. It can be omitted though and, if a screw is run up through the Base into this Block, it will add a bit of support to the Cylinder Plate.

The **BASE** doesn't need any mention except to suggest that the last operation should be cutting away to the odd shape.

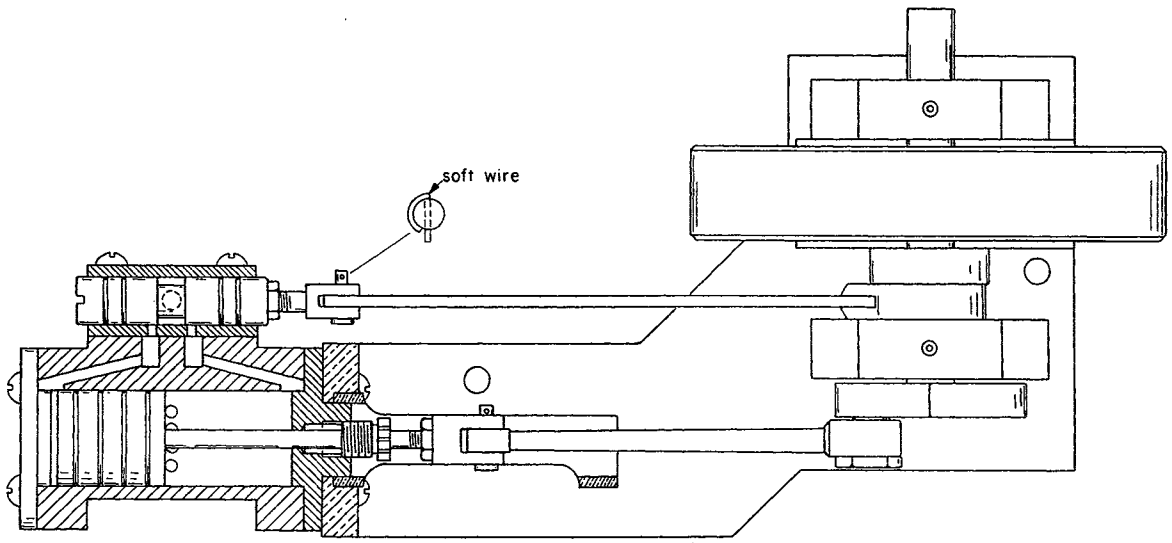
The **CYLINDER PLATE** and **CROSSHEAD GUIDE** should both be brass for sake of easy soldering. While the Plate is still rectangular, lay out all centers, drill and countersink for #4 screws and drill #43. Chuck in the 4-jaw. Indicate true and centered for the 1/2" counterbore, making the seat for the Guide parallel to the face. The Guide is made by centering a piece of stock in the lathe and boring 3/8" for a fine-running fit for the Crosshead. The flats can be milled in the cross slide milling attachment. Round the top of the Plate to 1/2" radius and solder Plate and Guide together.

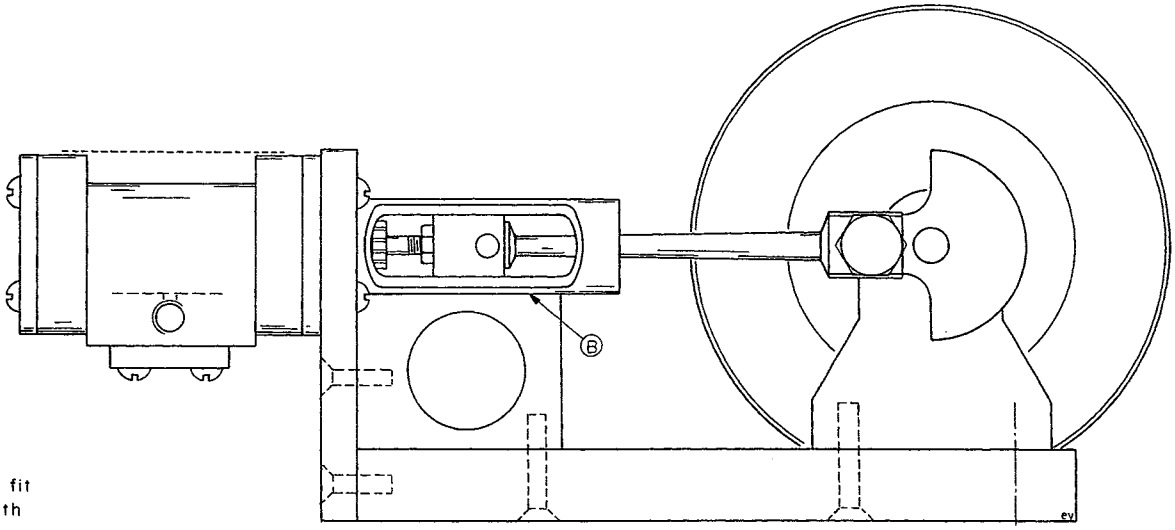
Make the **BLOCK** under the Guide as plain or fancy as you wish. Attach to the Plate and solder to the Guide at the outboard end. Running a screw up through the Base into the Block makes a more rigid support.

The **BEARINGS** are simple and require little mention. An option, if made of aluminum, is to bore out and press in bronze bushings for the Shaft. Mounting on the Base and line-reaming is the surest way for a free-running Shaft. Mark them so they can be returned to the position at which they were machined.

The **FLYWHEEL** should be heavy so most of the metal is left in the blank. A pin is used instead of deep tapping for the set screw.

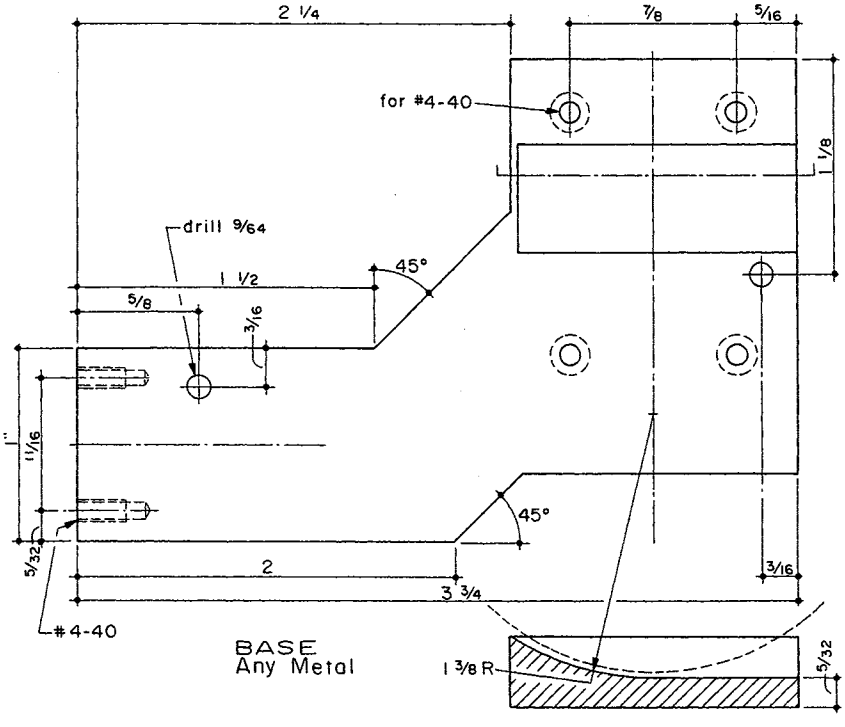
Center some 5/8" stock in the 4-jaw

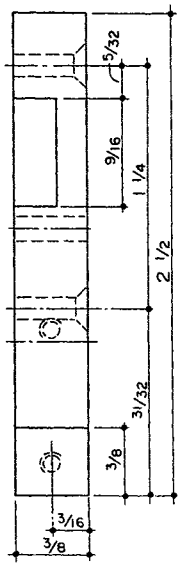


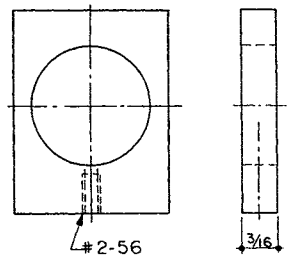


Ⓒ close fit
Ⓢ smooth
Ⓑ braze or solder
Ⓟ Press fit or "Loctite"
MTP model taper pipe

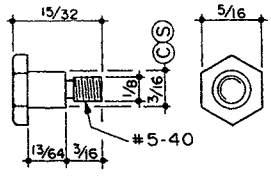
UNA-FLOW ENGINE
WITH PISTON VALVE



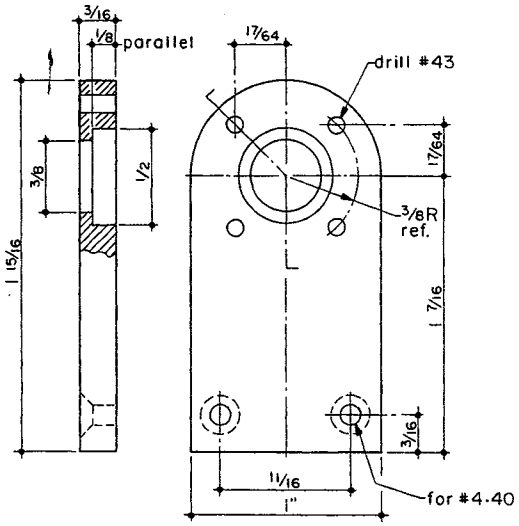




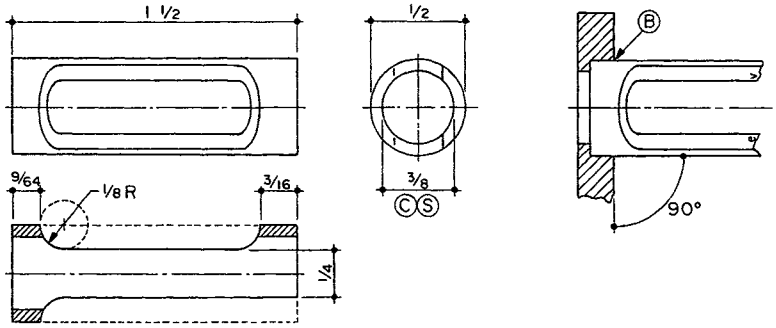
BLOCK
Brass
(shape and fit to suit)



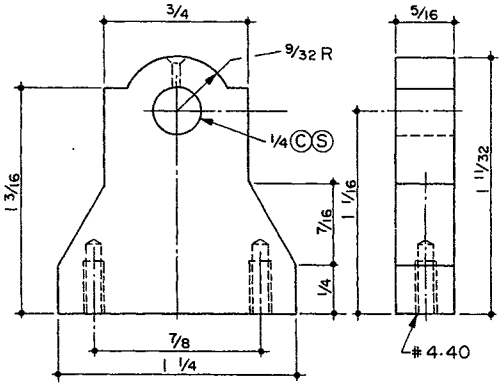
CRANK SCREW
Steel



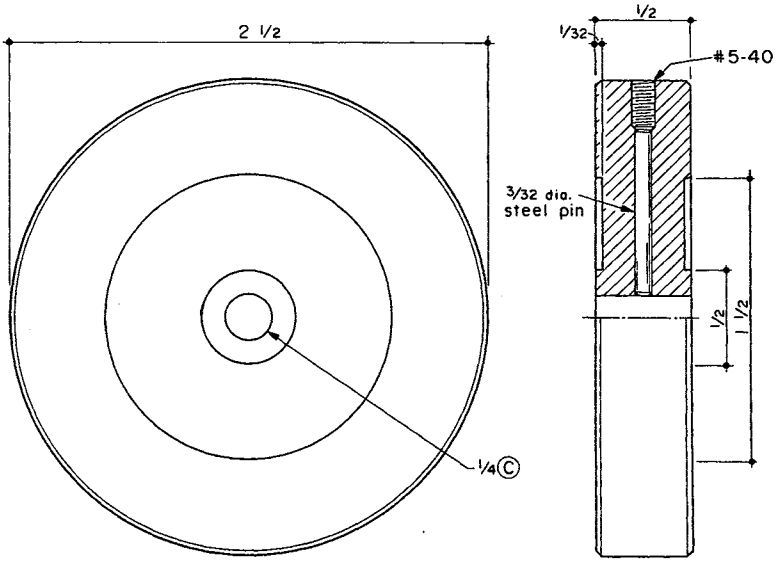
CYLINDER PLATE
Brass



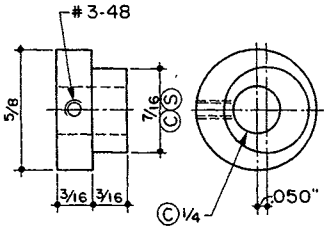
CROSSHEAD GUIDE
Brass



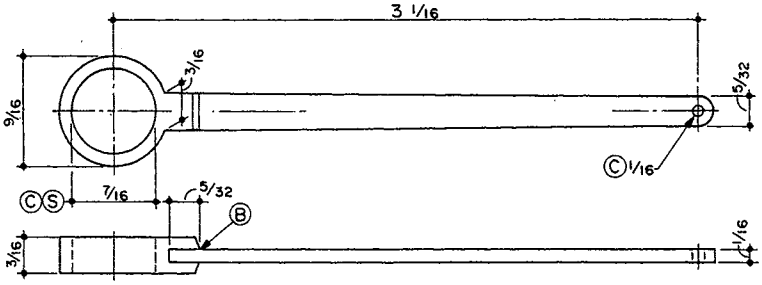
BEARING
Hard Aluminum
2 Required



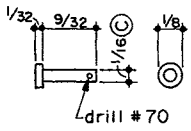
FLYWHEEL
Any Metal



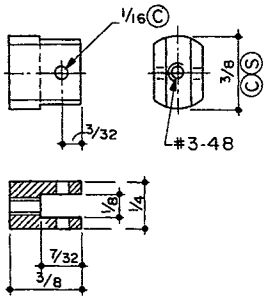
ECCENTRIC
Steel



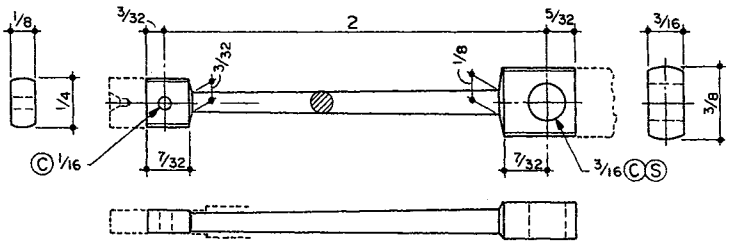
ECCENTRIC STRAP
Brass



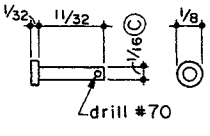
PIN
Brass



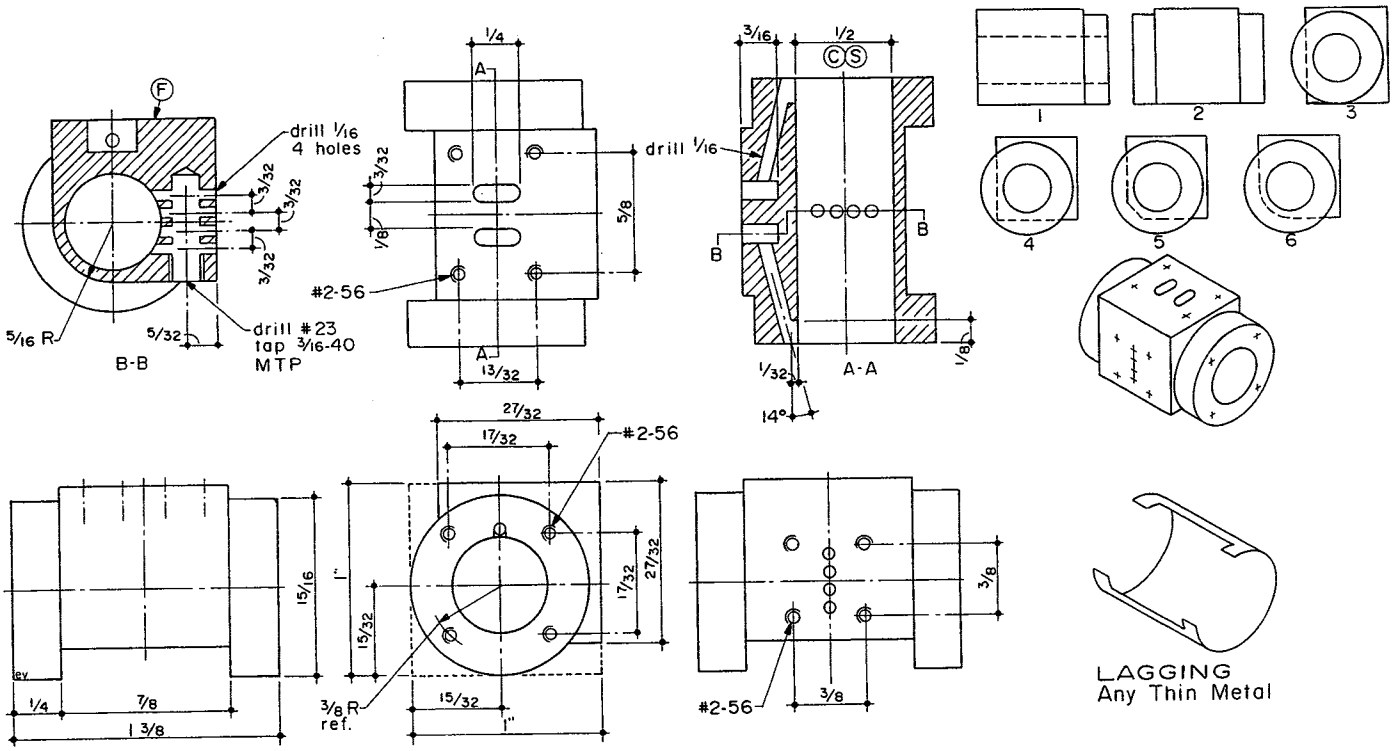
CROSSHEAD
Brass



CONNECTING ROD
Brass

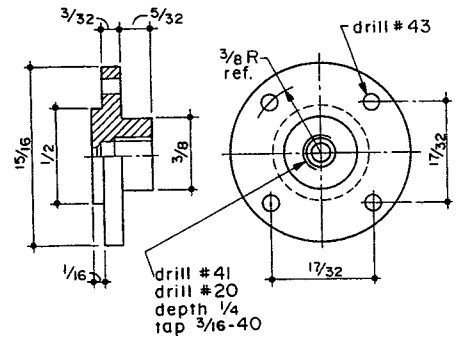


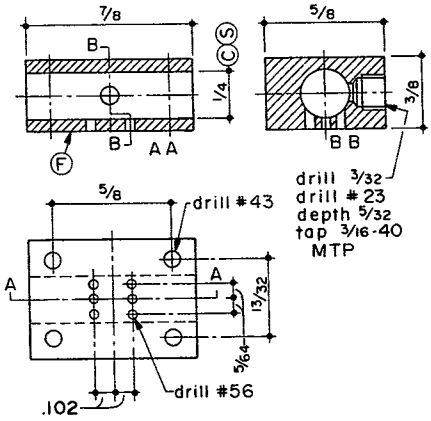
PIN
Brass

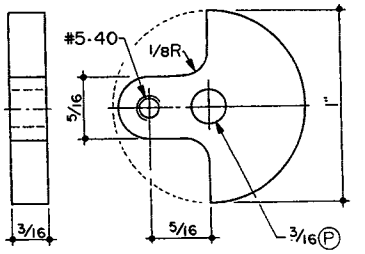


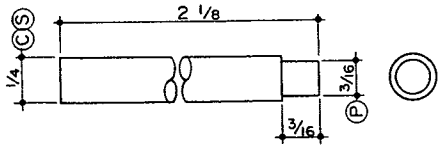
CYLINDER
Hard Aluminum or Brass

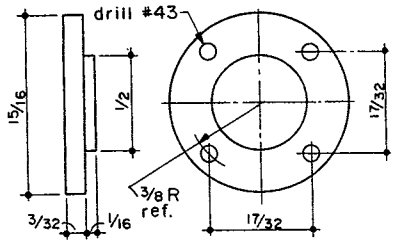
LAGGING
Any Thin Metal

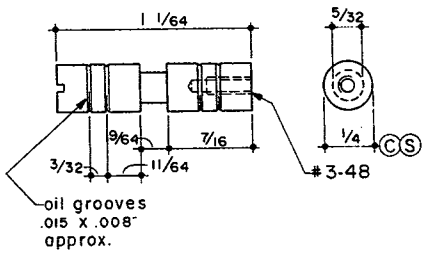


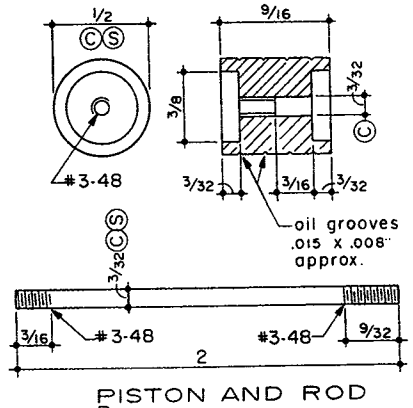


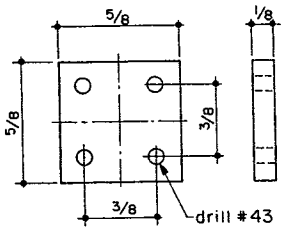


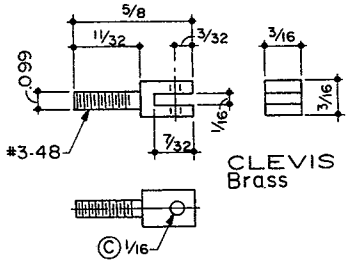


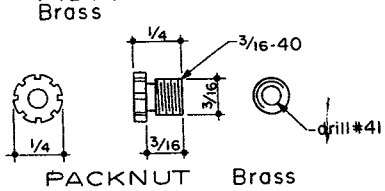












for the **ECCENTRIC**. Take a fine skin cut to brighten the O.D. and bore the 1/4" Shaft hole. Offset .050" and then turn the 7/16" diameter. One suggestion is to mount a square-ended bar in the tool post and bring it up against the stock. Zero the cross slide collar. Turn the chuck so two jaws are horizontal. Ease off the vertical jaws slightly and back up the rear jaw about 1/16" Push the stock back to the rear using the front jaw. Advance the cross slide .050" and ease the stock back against the bar, using the rear jaw. Snug up all jaws. Now, when the high spot just kisses the bar and the chuck is rotated 180°, a .100" diameter rod should just pass between the bar and the stock. You are now ready to turn the 7/16" diameter. Spot the set screw on the centerline through the offset. It helps when timing the engine.

The **ECCENTRIC STRAP** is made of 3/16" stock, laid out, bored, sawed, filed to shape and then soldered to the 1/16" stock. Measure 2-27/32" from the edge of the hole to locate the 1/16" hole at 3-1/16" center to center.

For the **CROSSHEAD**, center some bar stock in the lathe and turn to 3/8" for a close, free fit in the Guide. Tap 3-48 at least 3/8" deep. Transfer the stock to the cross slide mill and cut to 1/4" thick. Mill the 1/8" slot and cut off at 3/8" long. Lay out and drill for the 1/16" pin. Run a tap through to clean up the 3-48 hole.

The **CONNECTING ROD** starts with some 3/16" x 3/8" stock. Lay out the 3/16" and 1/16" hole centers and drill and ream. Mill to the 1/8" thickness for about 1/2" from the end. Allow stock for chucking and tailstock support. Turn the shank with the compound set at about 3 or 4 degrees. Start at the small end and watch when the cut runs out. Adjust the compound very slightly if the cut does not run out near the 1/8" diameter at the large end. It is not serious if the dimensions do not meet the print as long as it looks good to you.

Lay out all centers and lines on an accurate 1" x 1" x 1-3/8" block for the **CYLINDER**. Note the 1/2" bore is 15/32" from the faces at one corner of the 1" square. Drill and tap 2-56 for the Heads, the Valve and the Exhaust Cover. Mill the two 3/32" x 1/4" slots for the steam passages. Drill the two 1/16" holes at 14°. Drill the four 1/16" holes for the Exhaust at least 3/8" deep. Drill #23 across these four holes for tapping later at 3/16-40 MTP. Center in the four-jaw for boring 1/2" and turning one 15/16" flange as in **Step 1**. Reverse and turn the second flange. Make a milling setup for **Steps 3**, **4** and **5**. Filing **Step 6** is optional. Tap 3/16-40 MTP and mill to the 1/8" dimension at the 14° passages.

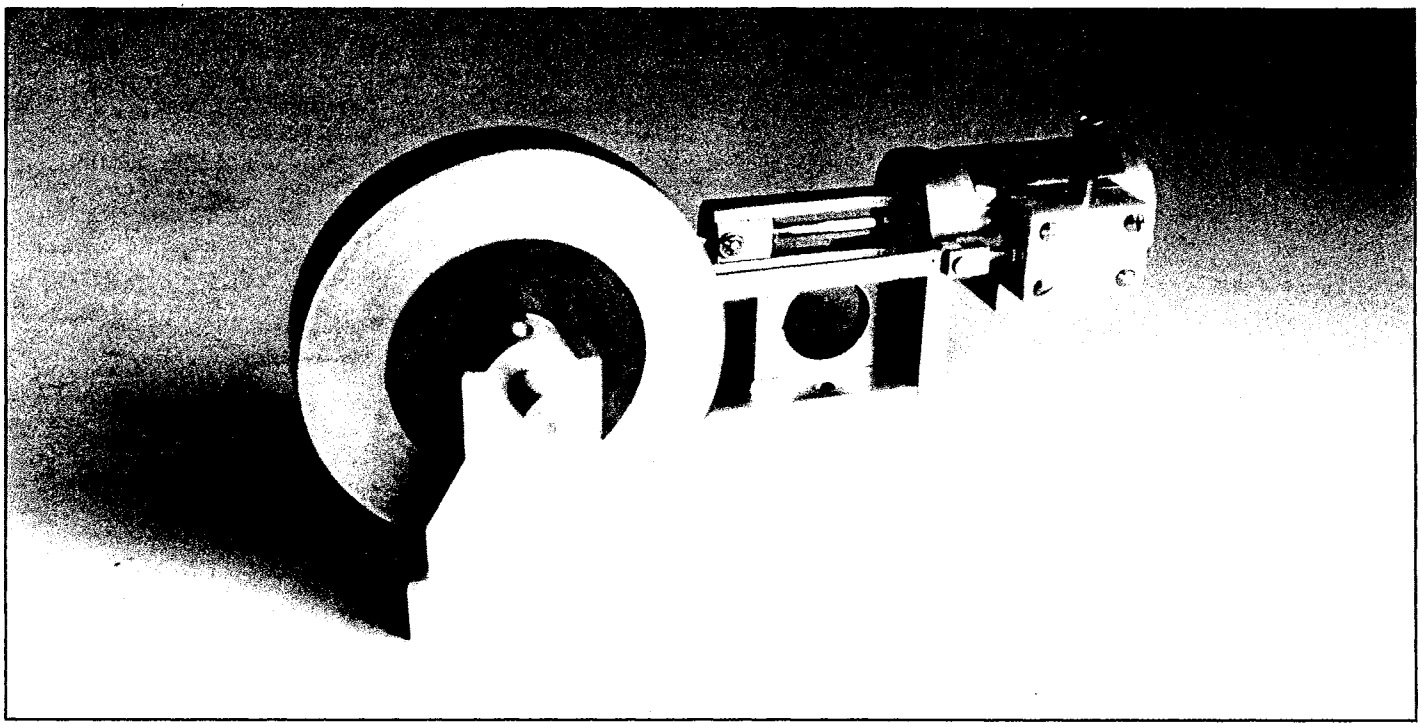
Make the **LAGGING** from thin sheet stock. Trace from a cut-and-fit paper pattern. Roll over about a 5/8" or 3/4" round bar so it will spring into place.

The **VALVE BODY** is quite simple but requires a very accurate and smooth passage for the Valve. Lay out all the holes on a 3/8" x 5/8" x 7/8" block. Center in the four-jaw and bore 1/4". Drill the six #56 holes, the 3/32" hole and the four #43 holes. Enlarge the 3/32" hole and tap 3/16-40 MTP. This is a shallow tapping job but it is preferred that the hole entering the 1/4" bore should be no larger than 3/32". An option is to counterdrill a shallow 3/16" diameter hole and solder a short piece of 3/16" tubing for use with common 3/16" aquarium tubing.

The **VALVE** and **CLEVIS** are fairly simple and about the only mention would be to make the O.D. the closest free fit you can. The slot helps in centering the Valve travel.

The **PISTON** is another close fit job. There is adjustment here for centering the Piston travel in the Cylinder. There is a 3/8" x 3/32" recess in each end in an effort to reduce somewhat the back pressure at the end of the stroke. Centering the Valve and Piston travel is critical to a smooth running engine. It may take several trials to achieve.

At final assembly, set the centerline through the Eccentric offset at 90° from the centerline through the Crank. The engine shown required a bit more speed than past slide valve engines and pressure around 25 psi. The exhaust sound is sharper. This is an interesting engine but not easy to explain at an exhibit. There is nothing on the outside that shows the principle of Una-Flow.



CHAPTER

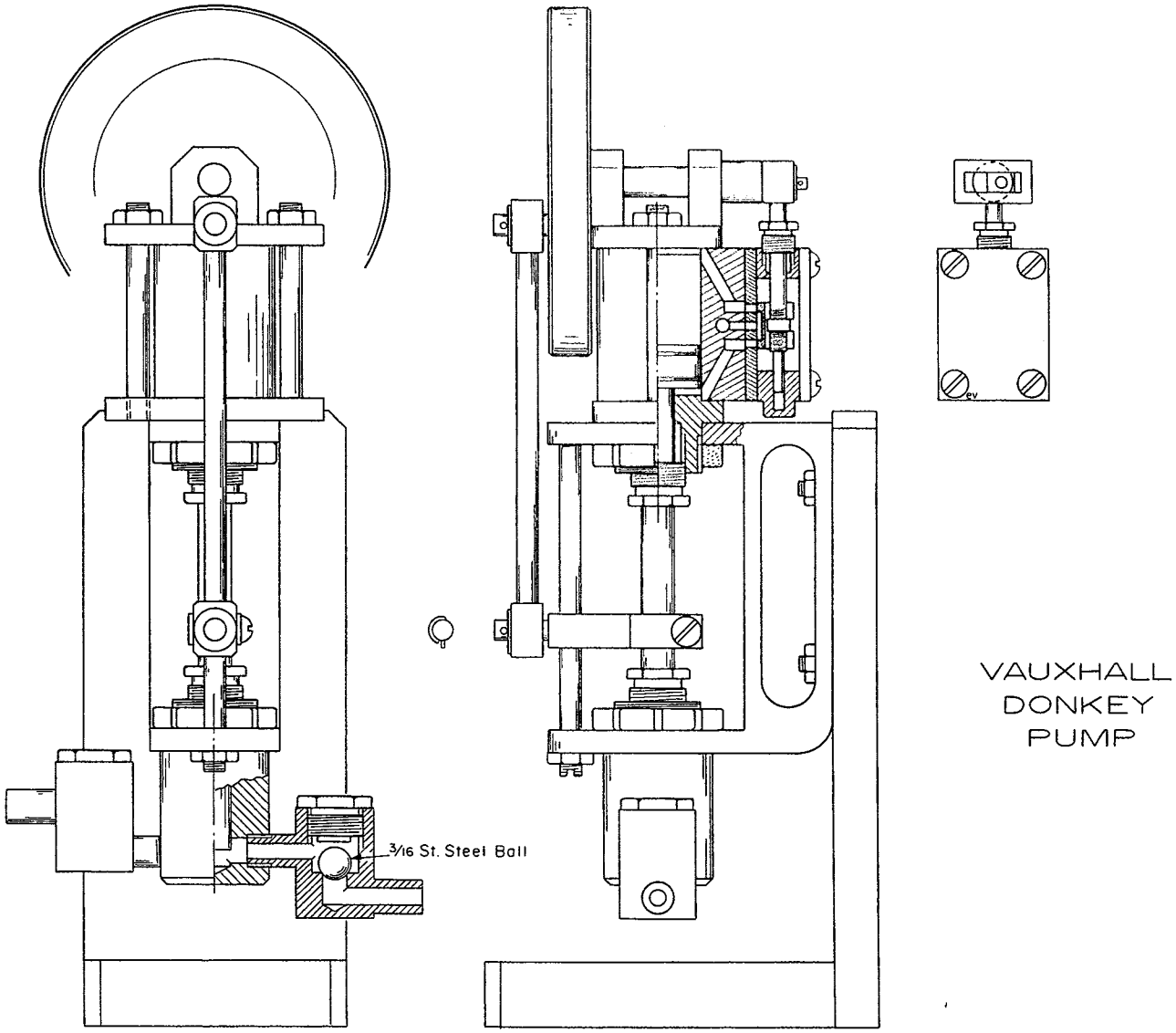
49 Vauxhall Donkey Pump

Graham Baker of Mareeba, Queensland, Australia, sent in the suggestion for this engine. The Vauxhall Steam Pump is a wall-mounted unit and used for boiler feed water and other water transfer applications. The force of the steam is directly applied to the pump plunger and easily rotates a flywheel to operate the steam valve. The general principle and appearance are fair on this miniature, machined from bar stock and using common screws. The original pump had a large casting containing the pump valves and was a bit more compact than this copy. Two simple ball valve bodies are used here, making an easier model to build. Here is a chance for you to use some of your own ideas, making the pump cylinder and valve chambers in one compact unit. This engine has a double-acting steam cylinder and single-acting pump.

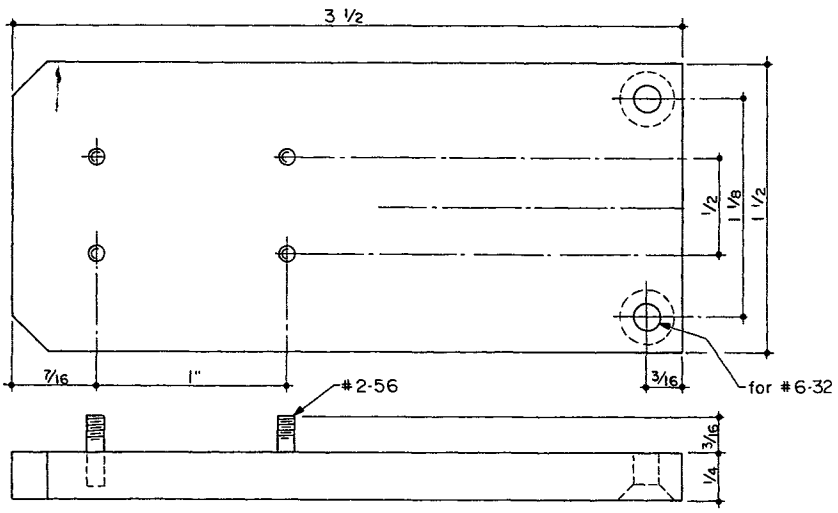
The drawings pretty well tell the story and only some points that came out in building this engine will be mentioned.

The **BASE, COLUMN** and **FLYWHEEL** are common machine shop practice. The Base and Column are up to the builder. Since this is a wall-mounted engine you can use your imagination and make it wider and look like a boiler room wall.

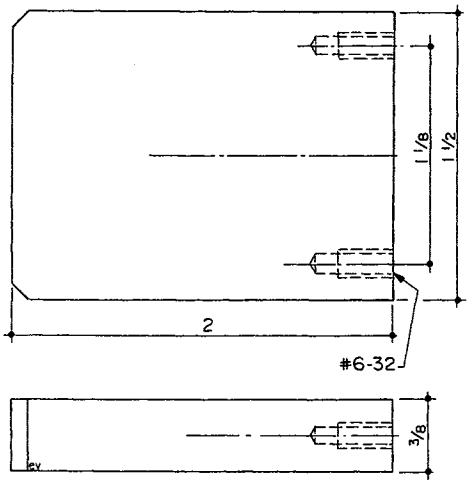
The **BRACKET** can be made out of the solid or built up like the one shown. On the original, this Bracket, the Steam Cylinder and Pump Body were one casting. Here the 1/8" thick projections were soldered with 430° solder to a 1/2" x 3/4" x 1-5/8" block



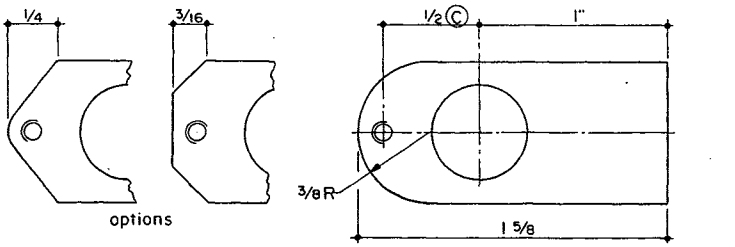
VAUXHALL DONKEY PUMP

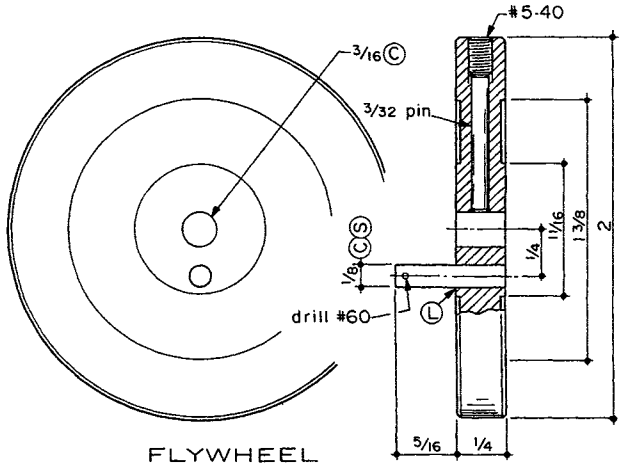


COLUMN
Any Metal

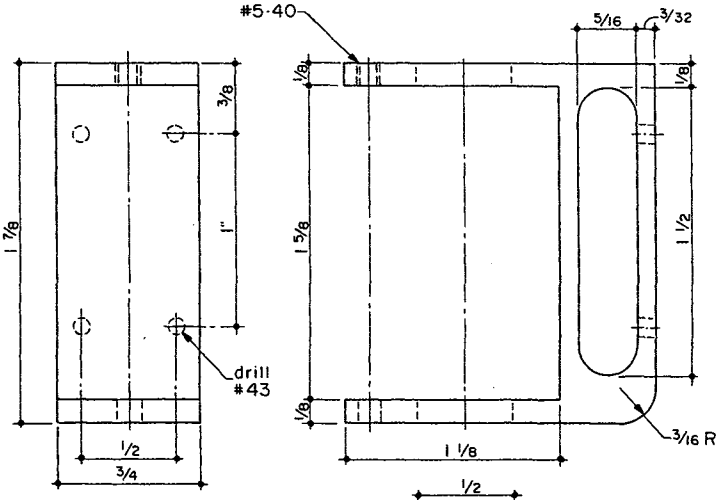


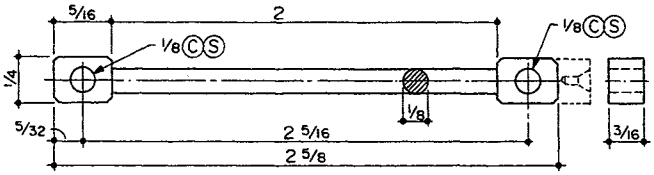
BASE
Any Metal



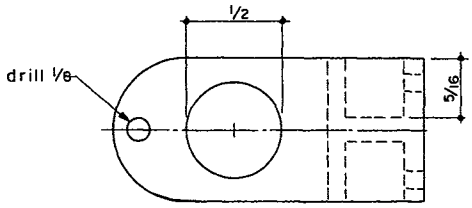


FLYWHEEL
Any Metal

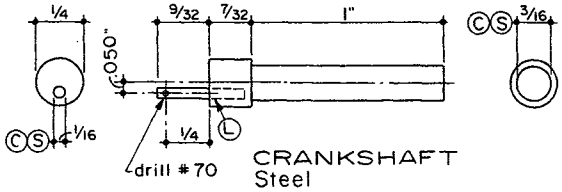




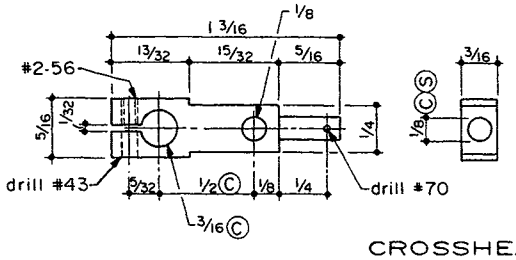
CONNECTING ROD
Hard Aluminum
or Brass



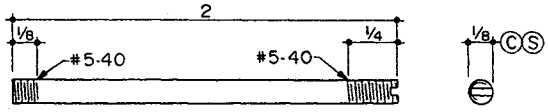
BRACKET
Any Metal



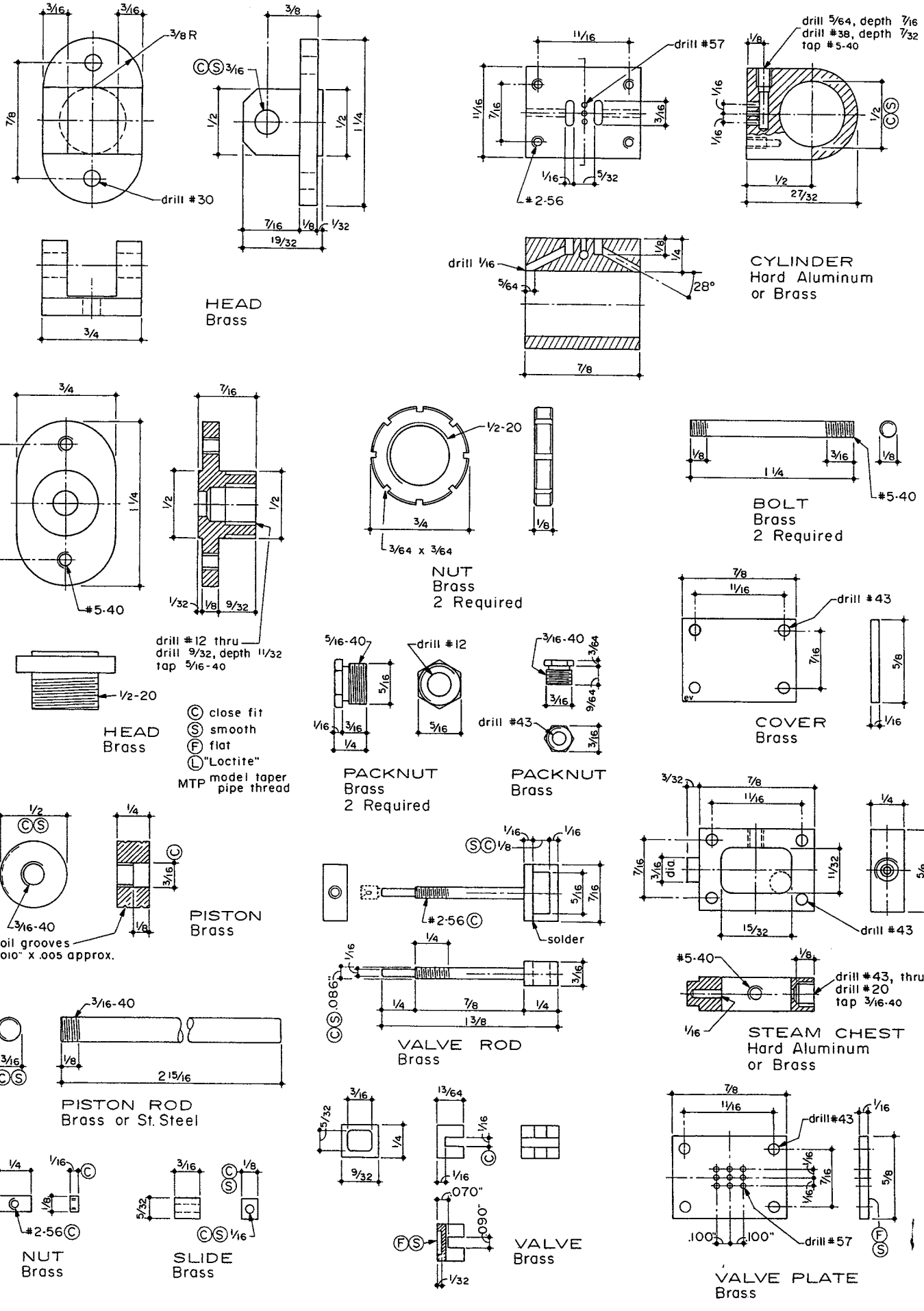
CRANKSHAFT
Steel



CROSSHEAD
Brass



CROSSHEAD GUIDE
Steel


HEAD
Brass
CYLINDER
Hard Aluminum
or Brass
NUT
Brass
2 Required
BOLT
Brass
2 Required
HEAD
Brass
Ⓒ close fit
Ⓢ smooth
Ⓕ flat
Ⓛ "Loctite"
MTP model taper pipe thread
PACKNUT
Brass
2 Required
PACKNUT
Brass
COVER
Brass
PISTON
Brass
oil grooves .010" x .005 approx.
VALVE ROD
Brass
STEAM CHEST
Hard Aluminum
or Brass
PISTON ROD
Brass or St. Steel
NUT
Brass
SLIDE
Brass
VALVE
Brass
VALVE PLATE
Brass

and then laid out, shaped and drilled to dimension. Squareness is important so that the Steam Cylinder lines up with the Pump Cylinder. The 1/2" distance between the Pump centerline and the Crosshead Guide centerline must be parallel to avoid binding. The few thousandths of an inch clearance in these holes will permit tunking around a bit until the Crosshead and Piston Rod slide free.

The **CRANKSHAFT** has a 1/16" pin offset .050", carrying the **SLIDE** which fits in the **YOKE** of the Valve Rod. The **VALVE ROD** was made by sweat soldering two machined parts to form the Yoke. Fit the Slide so it runs free and easy in the Yoke without sloppiness since the Valve travel is a very small amount. Perhaps you can machine the Yoke out of the solid and have a stronger Rod. Open the 2-56 die to make a close fit in the Valve Nut thread.

Since the force of the steam tends to spread apart the 1/8" thick Cylinder and Pump mountings, a nut was added to the lower end of the **CROSSHEAD GUIDE**. Snug up this nut just a bit until there is a sign of binding on the Piston Rod. A drop of "Lock 'N Seal" will keep the nut in place. Match the distance across the holes in the Crosshead to the related holes in the Bracket.

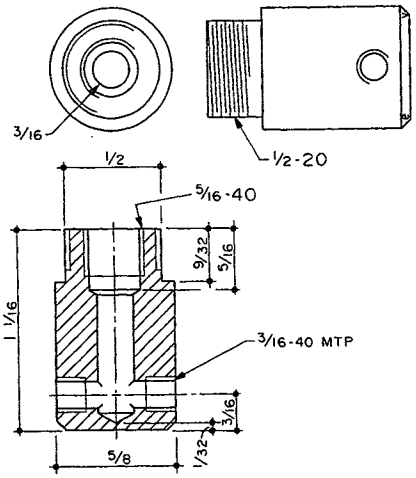
The Cylinder **HEADS** on this engine serve two purposes. The Lower Head has a 1/2-20 threaded projection which anchors the steam assembly to the Bracket. The round 1/2-20 **NUT** is used here and similarly on the Pump Body. This Nut could be hexagon shaped. The Upper Head has projections which provide the Crankshaft Bearings, and the two Heads and Steam Cylinder are held together by the 1-1/4" long **BOLTS**. At assembly, it will take a bit of time for a good line-up in relation to the Steam Chest and Bracket.

For the **CYLINDER**, start out with an 11/16" x 27/32" x 7/8" block. Lay out all lines and hole centers. While it is rectangular, drill all holes and mill the 1/16" slots. The 1/16" steam passages at 28° should be started with an end mill at the slant surface. Where these holes enter the milled slots is not serious but, after boring the 1/2" hole, make sure there is at least a 5/64" opening where it breaks into the bore. Make a 1/16" end mill cut if necessary. Chuck in the 4-jaw and center on the Cylinder bore. Bore to a fine, smooth finish for the 1/2" Piston. Use this Cylinder as a gauge when making the **PISTON** to a close fit.

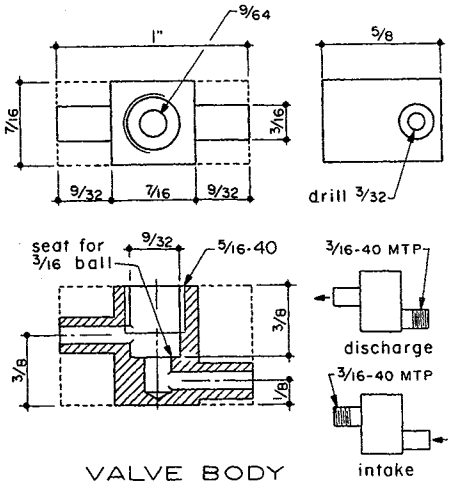
The **STEAM CHEST** is a bit cramped for space although it worked out O.K. Here you can see the value of the 40 series of thread at the **PACK NUT**. This makes it possible to get at least 1-1/2 to 2 threads engaged and leave room for a couple turns of packing. Snug up the Pack Nuts only finger tight for a start. When drilling for the Valve Rod, run the #43 drill in 5/8" deep and then drill 1/16" for guide 1/32" short of breaking through. Use a new drill so the hole will be as smooth and accurate as it can be. A 3/16" bottoming tap is a help here. Now, for a compressed air setup for occasional runs and showoff, the Stuffing Box end can be fitted with a simple close-fitting .086" hole. A good coating of light grease will make a fair seal. The remaining Steam Chest parts are plain machining. Make sure of flatness where the Valve slides on the Plate. Keep out all sloppiness at the Valve Nut since the Valve travel is very small as mentioned above.

The **PUMP BODY, VALVE BODIES** and **COVERS** are straight machine shop practice and pretty well explained. The only reminder would be to thread the Valve Bodies for intake and discharge mounting. Seat the Ball Valves by holding a short brass rod with a dimpled end on the ball and giving it a light blow with a small hammer. Make the corner clean and accurate to make it easier to produce a good seat. This type of Valve can find other uses in your collection of miniatures.

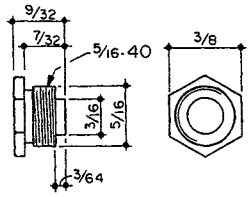
As the manufacturers claimed, it is a simple pump and assembly is no great problem. After it was lined up and turning easy with about 15 minutes of running time, well lubricated, it made a good showing at 5 to 10 psi air.



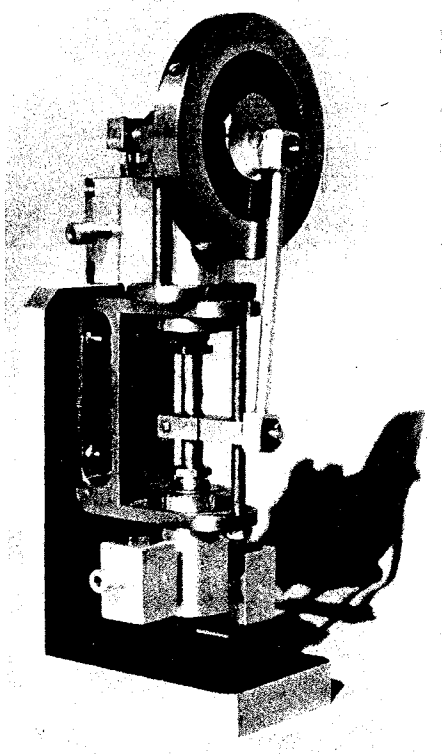
PUMP BODY
Hard Aluminum or Brass



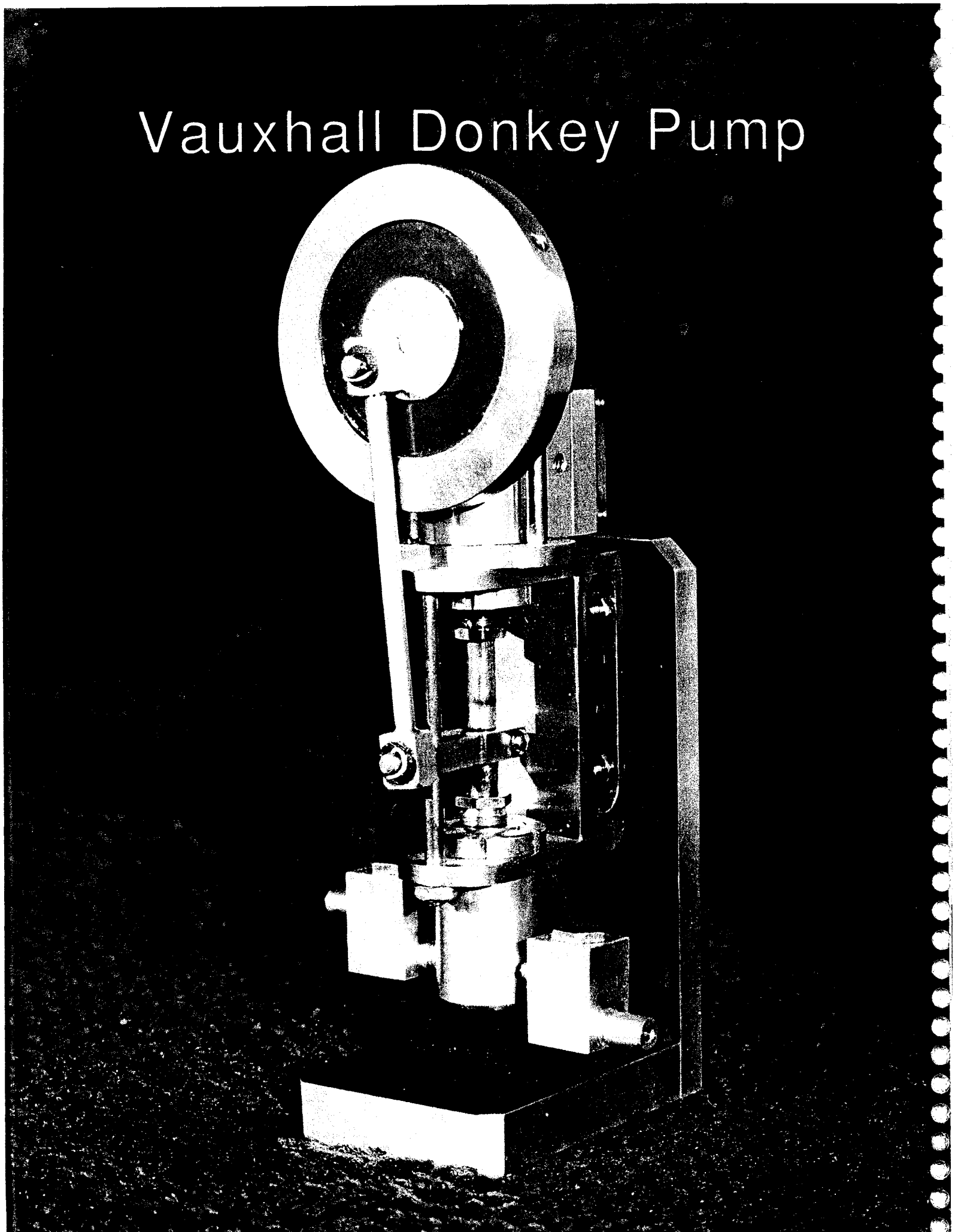
VALVE BODY
Aluminum or Brass
2 Required



VALVE COVER
Brass
2 Required



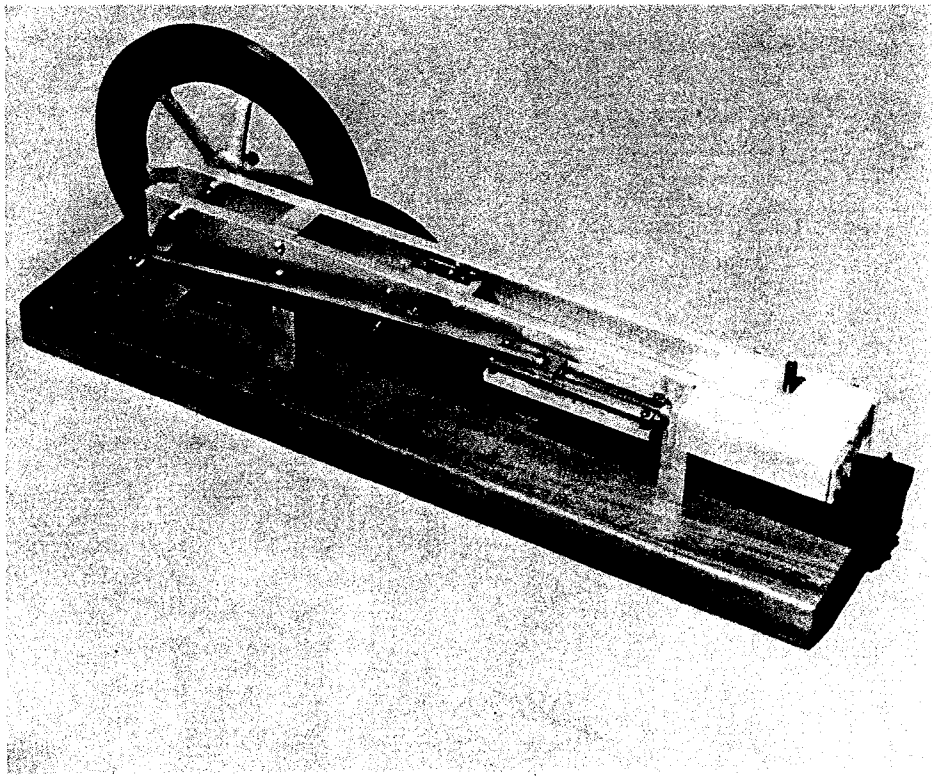
Vauxhall Donkey Pump



CHAPTER

50

Educational Model



An effort has been made on the past engine designs to show different ways of rotating a shaft with air or steam pressure. Among these engines such terms as wobbler, vertical, horizontal, slide valve, piston valve, oscillating valve, poppet valves, cams, eccentrics, single action, double action, reverse linkage, Scotch yoke and more are mentioned.

This engine is still another, showing the long stroke, slow speed principle of a riverboat engine. The framing is a very simple form to get across the idea, expecially the Cam which was used on these engines. The data for the Cam was supplied by Bob Maynard who detailed the *Omar* riverboat for us in **MODELTEC** Magazine.

The full stroke Cam is fascinating and a bit more complicated. It holds the Valve open for a longer time and provides steam pressure for most of the length of the Piston stroke, quickly reversing the Valve at each end of the stroke. The engine in Bob's *Omar* uses a drive for the Cam which is interesting to watch. It is taken off the Connecting Rod instead of the Crankshaft. It reduces the length of the Valve Rod and is mounted away from the splash of the paddlewheel. It is used on this model.

There is no attempt made to control the exhaust. There are no stuffing boxes. Close fits and a bit of oil make a fair seal. It is a showoff and conversation piece or a classroom demonstration model run on low pressure air. It should be run as slowly as possible.

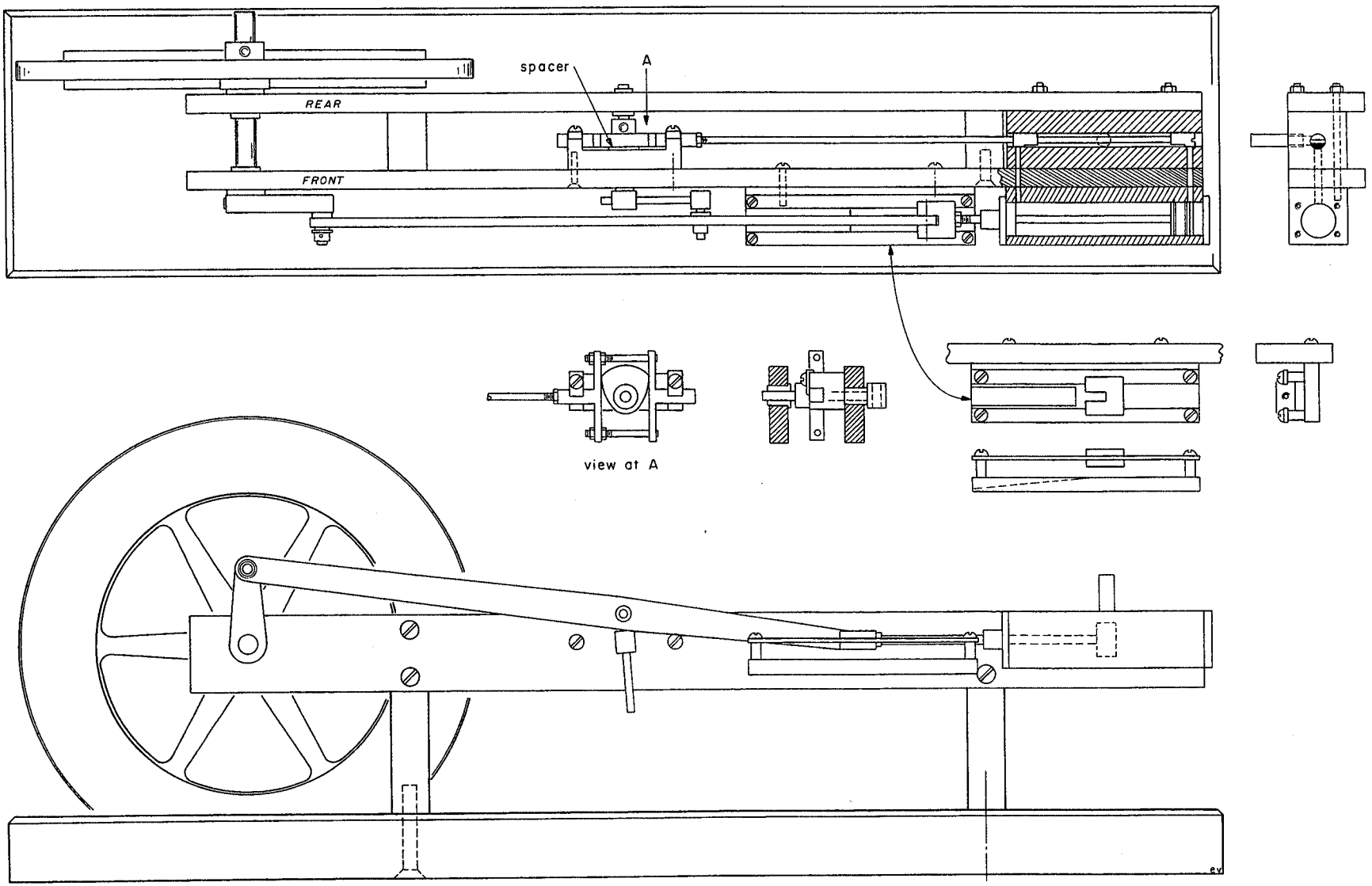
The **BASE** and **LEGS** are simple. Use any piece of wood that you like and give it a fine varnish finish.

The **RAILS** were made of the 1/4" x 11" aluminum found in many hardware stores. Lay out all the centers on the **FRONT RAIL** and clamp the Front and Rear Rails together. Drill through BOTH pieces for all the holes called out on the **REAR RAIL**. On the Front Rail, drill two holes for the steam passages and two for the Shelf, and two holes for the Cam Frame Guide. Some holes are shown countersunk. You can use round or hex screws if you wish.

Two identical blocks are made into the steam **CYLINDER** and the **VALVE BLOCK**. Lay out and bore the Cylinder 7/16". Use the Heads to SPOT the Head capscrew holes. The word "spot" used here means making only a dimple to guide the tap drill. Very carefully, lay out and tap ONE 3-48 hole in the Cylinder. A 3/32" stud is inserted through the Front Rail and into this hole, and clamped together well aligned and square. Use the Front Rail as a jig and spot the remaining stud holes and two steam ports. Remove the clamp and tap drill and tap 3-48. Complete drilling the steam passages.

Again using the Front Rail, do the same for the **VALVE BLOCK** after reaming the 3/16" Valve bore. This time the #41 drilling can go completely through the block. One close-fitting pin is inserted before aligning and clamping.

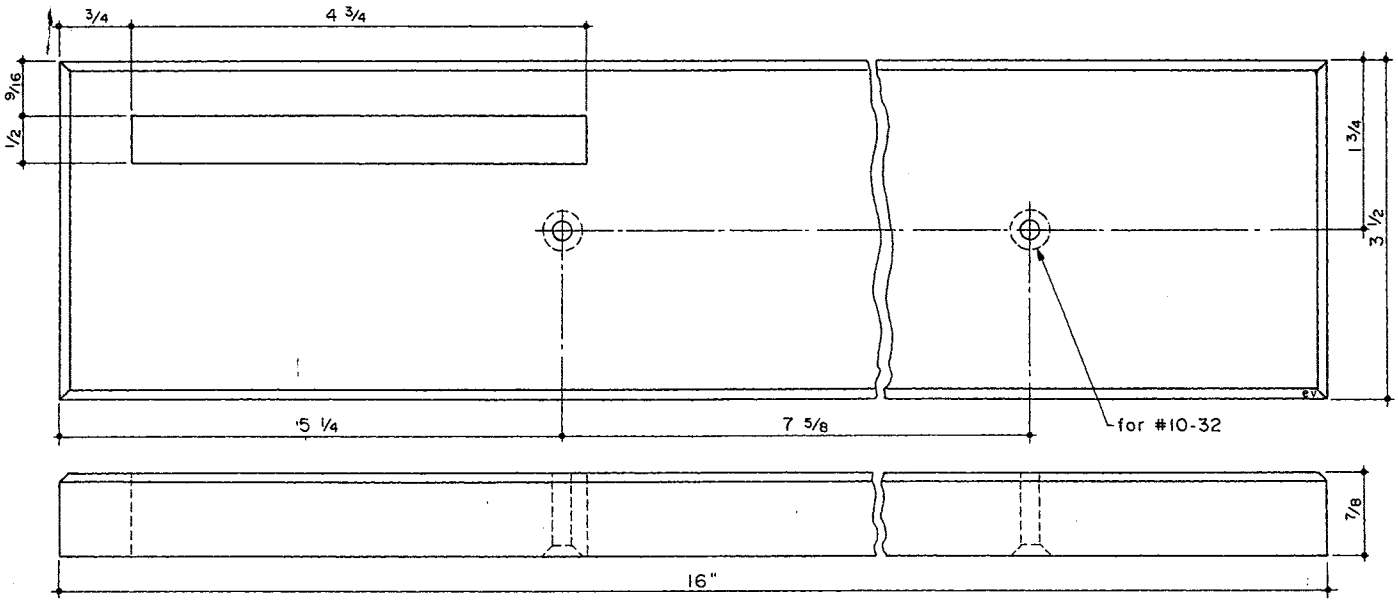
On both **HEADS**, lay out the centers and all bolt holes while both are



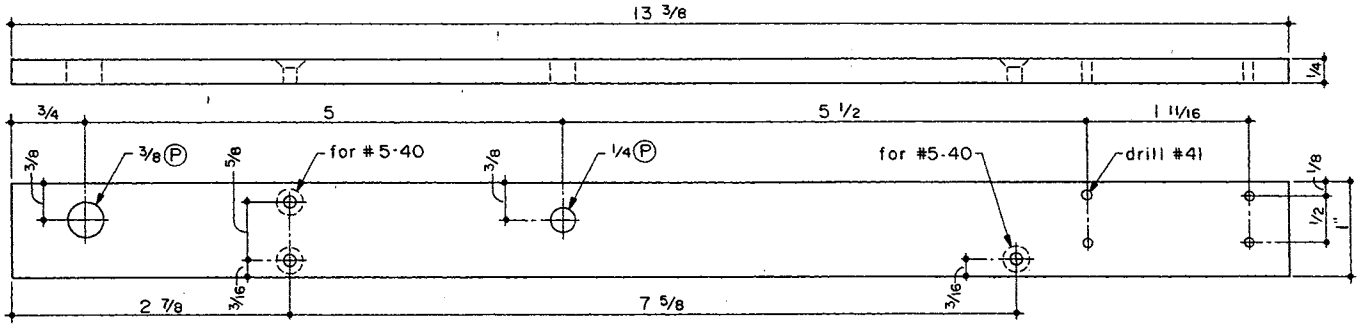
EDUCATIONAL MODEL

SIMILAR TO A

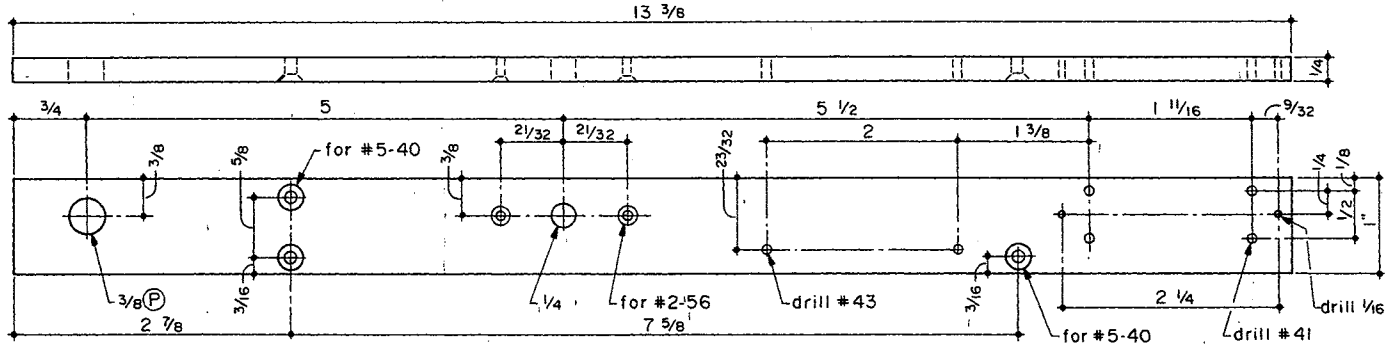
RIVER BOAT ENGINE WITH FULL STROKE CAM
DRIVEN OFF THE CONNECTING ROD



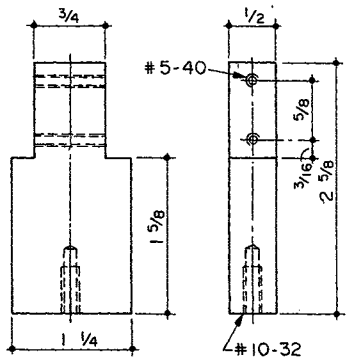
BASE
Wood



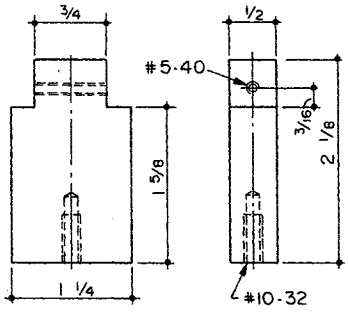
REAR RAIL
Aluminum



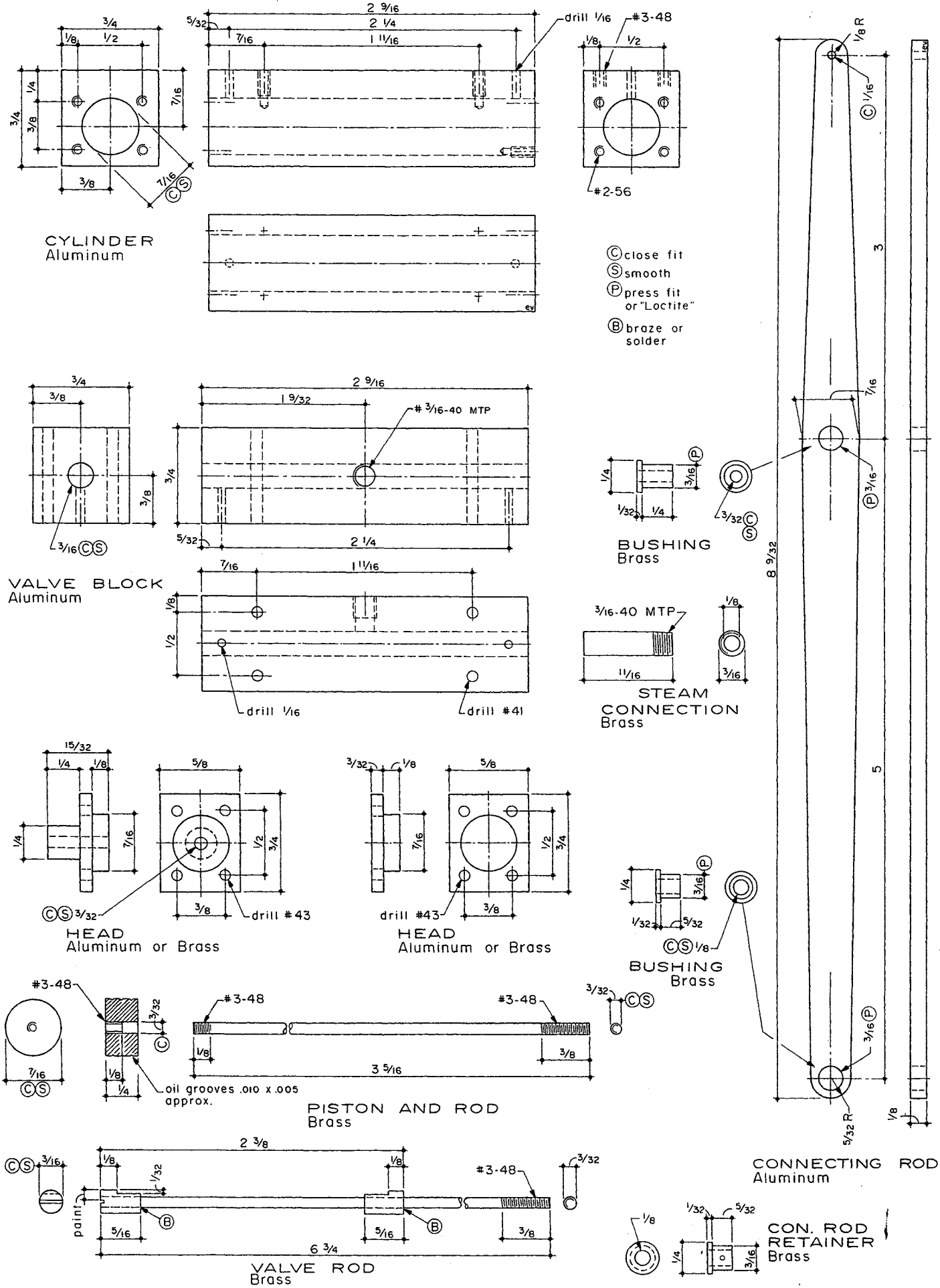
FRONT RAIL
Aluminum

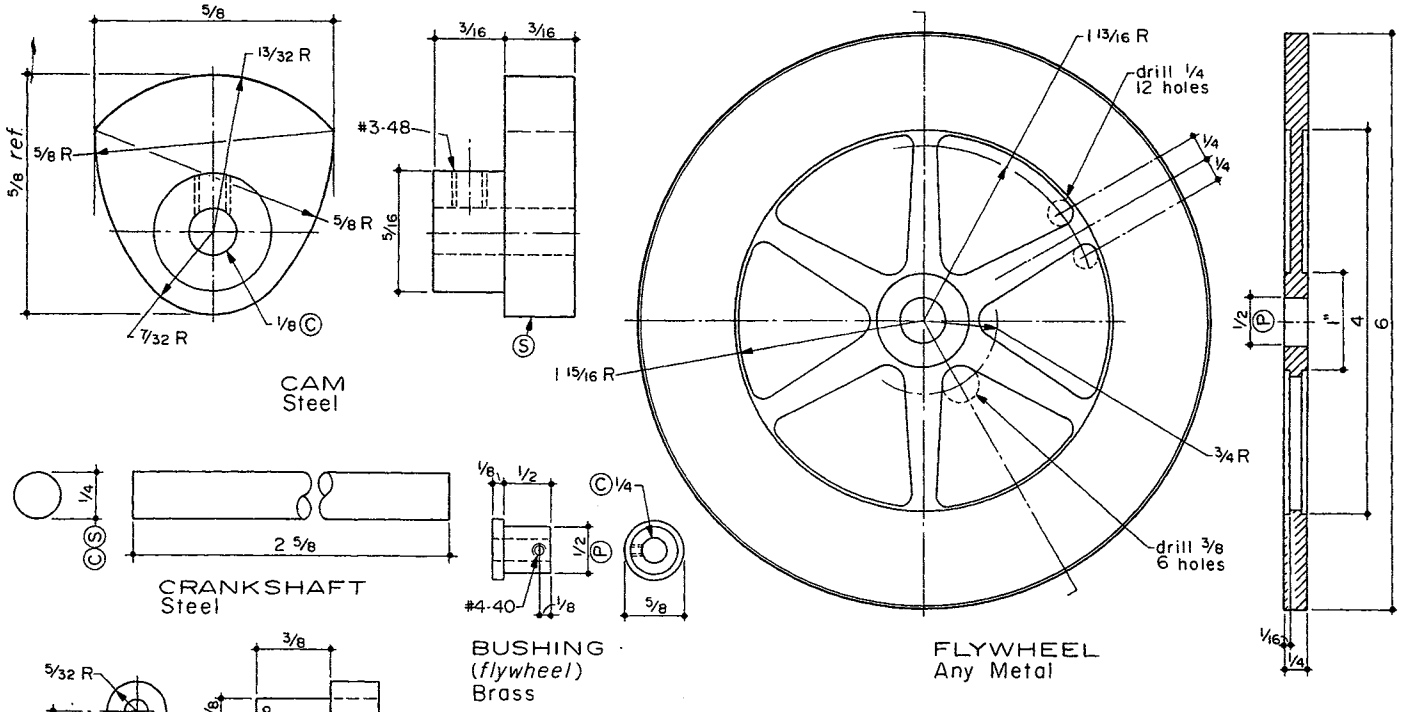


LEG
Aluminum



LEG
Aluminum


CYLINDER
Aluminum
drill 1/16
#3-48
#2-56
Ⓒ close fit
Ⓢ smooth
Ⓟ press fit or "Loctite"
Ⓑ braze or solder
VALVE BLOCK
Aluminum
3/16-40 MTP
drill 1/16
drill #41
BUSHING
Brass
STEAM CONNECTION
Brass
3/16-40 MTP
HEAD
Aluminum or Brass
drill #43
HEAD
Aluminum or Brass
BUSHING
Brass
#3-48
oil grooves .010 x .005 approx.
PISTON AND ROD
Brass
CONNECTING ROD
Aluminum
paint
VALVE ROD
Brass
CON. ROD RETAINER
Brass



rectangular blocks. Drill through the blocks for the bolt holes. On the Inboard Head, chuck the block, centering for the 1/4" hub using a center test indicator. Turn the hub projection and reverse in the 3-jaw chuck for turning the dowel and 3/32" bore.

The **PISTON** and **ROD** are simple machining. About the only mention here is good concentricity.

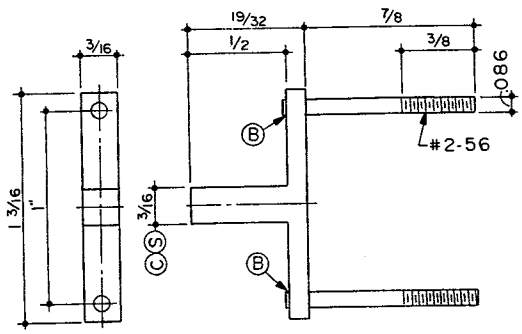
The **VALVE ROD** is a soldering job. Carefully solder the two 5/16" x 3/16" pieces to the Rod at 2-3/8" spacing. Set up in the cross slide mill and mill the flats, holding the 1/8" dimensions. On the same milling setup, change to a thin slitting cutter to make the screwdriver slot PARALLEL to the flats. This slot helps to align the flats squarely facing the ports. Painting the half on the side of the flats with layout dye will tell you which side has the flats. The Valve can be adjusted 1/48" per revolution; that is, one turn of the Rod moves the Valve .021". At final assembly and tuning, the Valve will be close to flush with the ends of the Valve Block at each end of the Valve travel.

The **CRANKSHAFT**, **CRANK** and **RETAINER** are simple machining. Spot the Retainer about .010" from the Connecting Rod Bushing and drill for a 1/32" cotter pin through the Crank Pin.

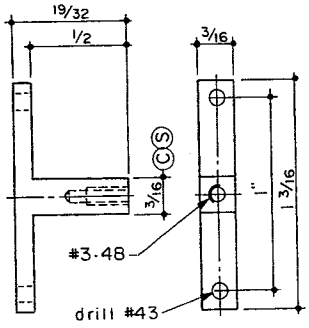
The **FLYWHEEL** on the model shown was made from some salvage 1/4" cast aluminum plates so the surface is rough. Rolled stock will make a better-looking wheel. The 18 holes are laid out and drilled on a rough 6-1/8" disk. Using a center test indicator, center the disk in the 4-jaw and turn the recess on one face. By careful chucking in the 3-jaw on the 1/16" x 4" recess, the second side and outside diameter are turned and center-bored 1/2". Lines are drawn connecting the holes and the spokes sawed and filed to shape.

The **CONNECTING ROD** on the model shown is 1/8" blue anodized aluminum with Bushings set with Loctite. The light weight of the aluminum is desireable for this Rod.

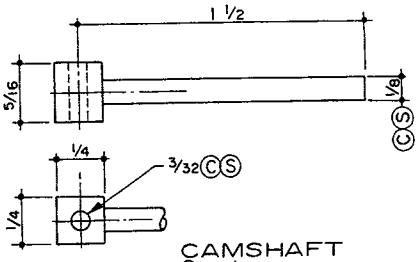
The **FULL STROKE CAM** is made of steel. First lay out the Cam on some 1/32" brass. From one straight edge of the brass, scribe at 90° two lines 5/8" apart. Scribe a centerline midway between these two lines. About 1/4" from the edge, scribe a centerline parallel to the edge. Prick punch at the crossing of the two lines. Scribe a 13/32" radius intersecting the two 5/8" lines. At the intersections, scribe two 5/8" radii. They should meet a 7/32" radius struck from the center. Scribe a 5/16" circle for the hub. Very carefully, bore the 5/16" hole and then cut and file down to the Cam outline. Set a slide caliper to 5/8" and try the Cam. It should rotate between the blades with only a few thousandths freedom. True up the end of a 1-1/2" piece of 3/4" diameter free-cutting steel and prick punch a center for the Cam about 1/4" from the O.D. Center in the 4-jaw, using a center test indicator, and turn the hub until it will just enter the brass template you just made. Next, bore the 1/8" Shaft hole. Turn a smooth 13/32" radius until it just matches the radius on the template. Using a parting tool, cut off at a bit over 3/8" overall and rechuck on the hub to finish to 3/16" thick. Coat the Cam blank with layout dye, insert the Cam in the template and scribe around the template. Make small overlapping mill cuts almost to the outline and then file to the line. A filing machine is almost a must for this. Polish the



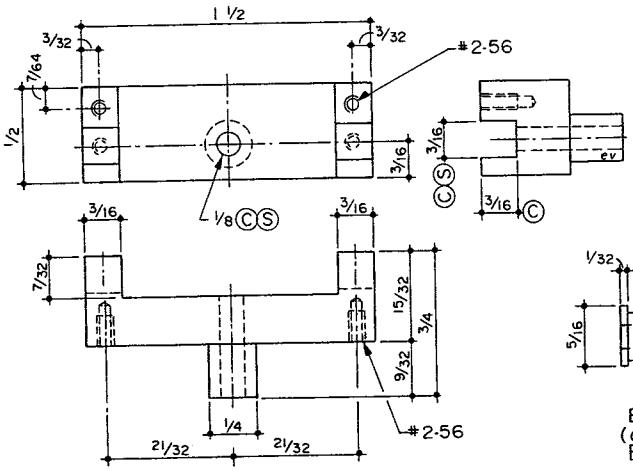
CAM FRAME A
Brass



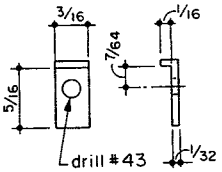
CAM FRAME B
Brass



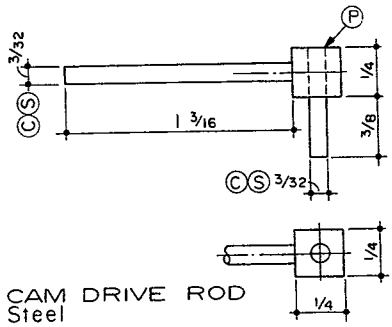
CAMSHAFT
Steel



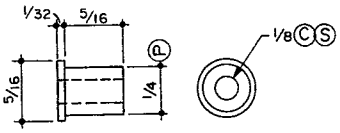
CAM FRAME GUIDE
Brass or Hard Aluminum



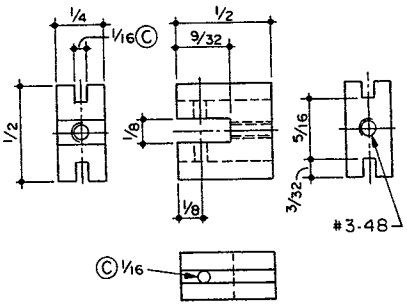
RETAINER
Brass
2 Required



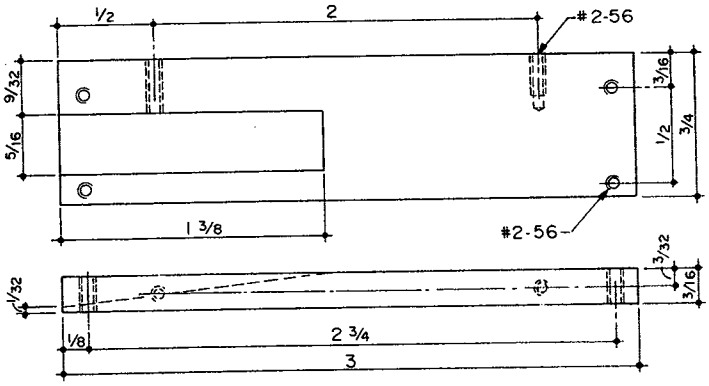
CAM DRIVE ROD
Steel



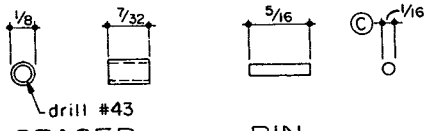
BEARING
(camshaft)
Brass



CROSSHEAD
Brass

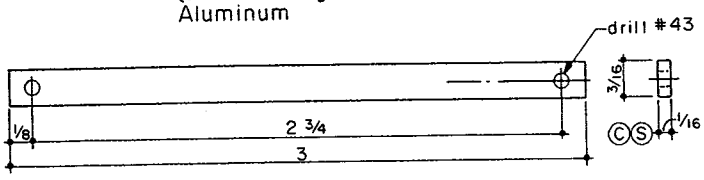


SHELF
(crosshead guide)
Aluminum

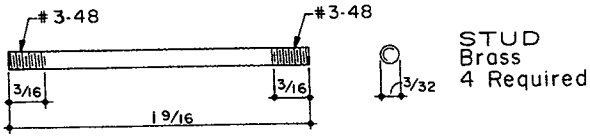


SPACER
Any Metal
4 Required

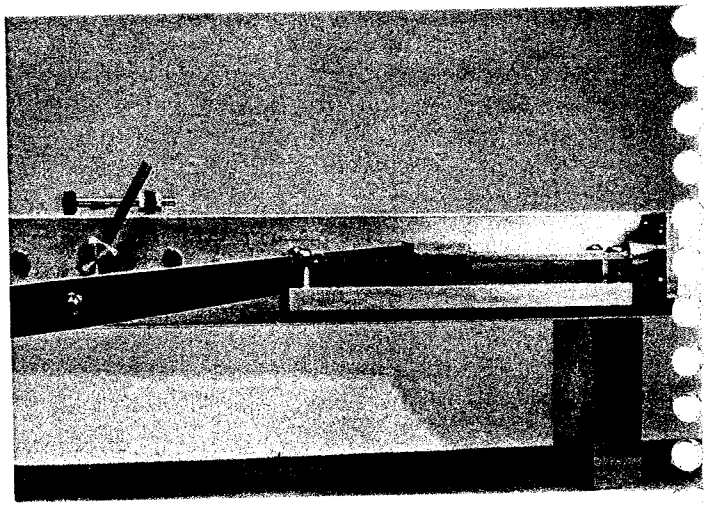
PIN
(crosshead)
Brass



CROSSHEAD GUIDE
Steel
2 Required



STUD
Brass
4 Required



Cam surface on a surface plate, using fine emery cloth. Again, try the Cam with the calipers set at 5/8".

The **CAM FRAME** is built up from 3/16" brass stock. The two main pieces are alike except that **A** has the two studs squarely soldered in, while **B** slides on the studs, and a hole is tapped for the Valve Rod. At assembly, the two pieces of the Frame are adjusted so the Cam just easily rotates between them with minimum slop. Take care when soldering that the 3/16" x 3/16" bars are in line and slide freely in the Frame Guide.

The **FRAME GUIDE** starts out as a 3/4" x 1/2" x 1-1/2" piece of brass. Lay out all outlines and centers on this bar except the two at 21/32" which are spotted from the Front Rail. Drill and tap the two holes for the retainers. Chuck in the 4-jaw and turn the 1/4" diameter projection. Squarely clamp the Guide into the Front Rail and spot, drill and tap the two 2-56 holes. Mount in the cross slide mill and mill the 7/32" x 1-1/8" area. On the same setup, you can mill the two 3/16" x 3/16" slots for the Cam Frame. These two slots must be parallel with the face and top edge of the Front Rail and must be a nice, close, free fit on the Cam Frame.

The **CAM SHAFT** and **CAM DRIVE ROD** are simple and about the only mention is squareness and a close, free fit. Make the rubbing surfaces smooth for long life. When the engine is running, these parts are really active.

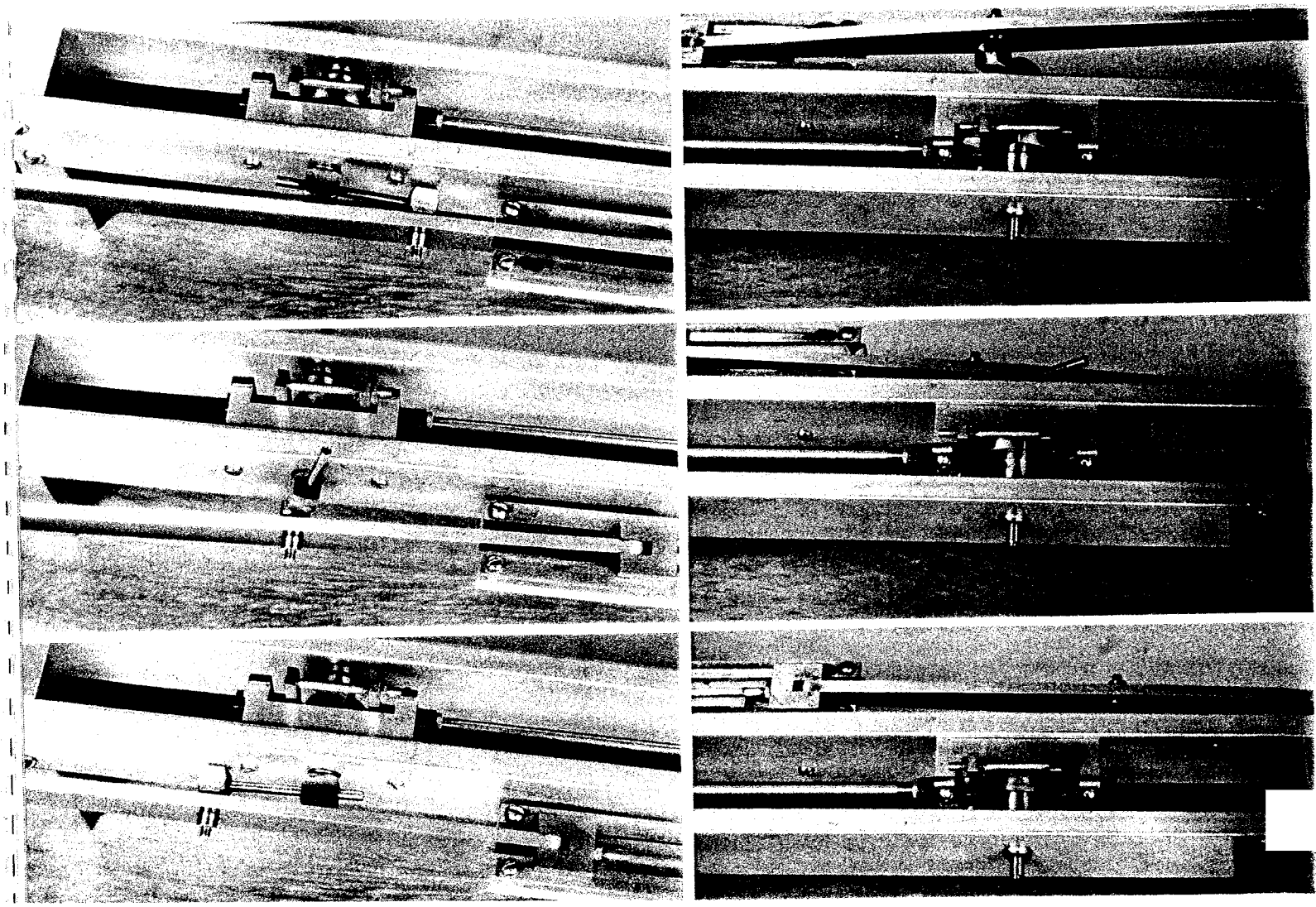
The **CROSSHEAD GUIDE SHELF** is laid out completely and the four holes on the face drilled and tapped. One mounting hole is carefully laid out and tapped. Mount the Shelf on the Front Rail with one screw; align, clamp and spot for the second mounting screw. Mill the 5/16" clearance for the Connecting Rod.

The **CROSSHEAD GUIDE** consists of two smooth steel bars mounted on the Shelf, using the **SPACERS** to bring it in line with the Cylinder bore. At assembly, the Crosshead should be just a nice free-running fit between these bars.

For the **CROSSHEAD**, square up the end of a 1/2" x 1/2" x 1-1/2" brass bar. Lay out all the lines and centers at the end of this bar on all faces. Make the 1/16" hole for the Connecting Rod Pin. Drill and tap 3-48 for the Piston Rod. Mount squarely in the cross slide mill with the end toward the head stock in such a way that you can make a 1/16" cut up one side and down the other, thus keeping them in the same plane. Note that the 1/16" hole and these 1/16" cuts must coincide. On the same setup, cut the block to the 1/4" thickness, using a slitting cutter. With another setup in the mill, make the 1/8" x 9/32" cut.

At assembly, mount each part so it runs free. Add light grease or a light coat of STP or equivalent to all Slides and Cam. Squirt oil into the steam connection to lube the Valve and Piston. A drop of oil on the Shafts at the Bearing will work in for light-duty running. If you wish, oil holes can be drilled. This engine will run on very low air pressure. Adjust the Valve until the engine runs smooth.

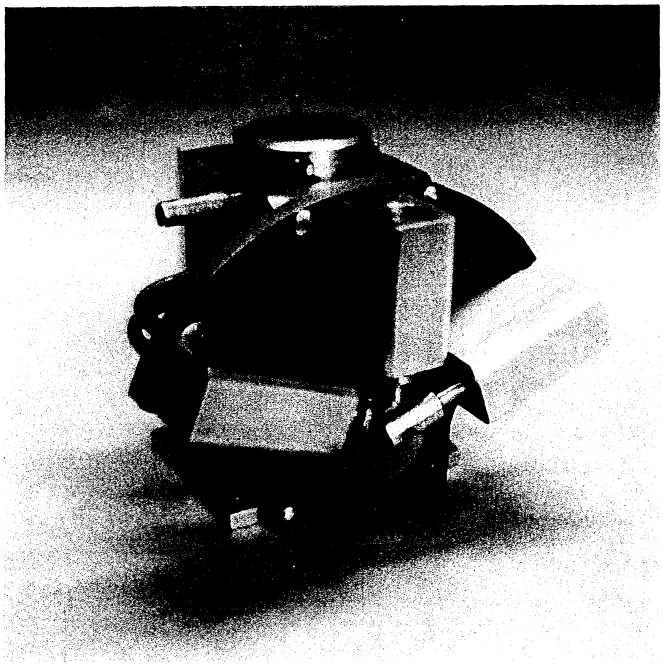
Photos below show the function of the Cam.

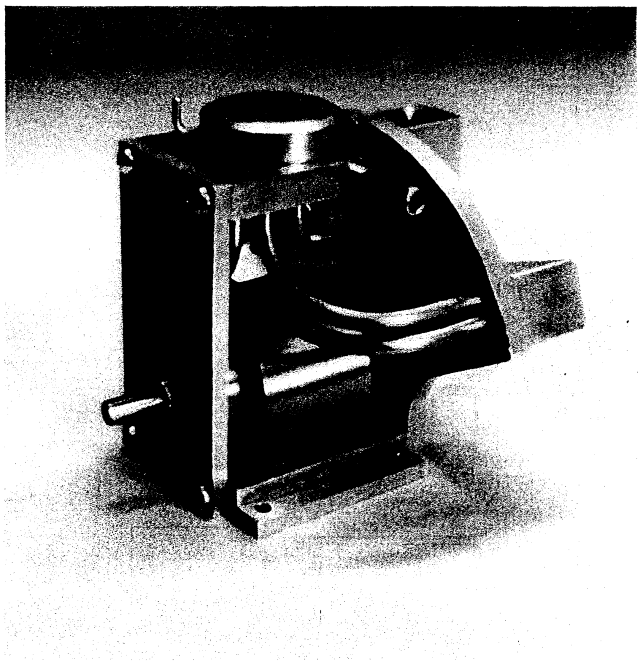


CHAPTER

51

V3R





Jason Smith in Hilliard, Ohio, sent in the sketches for this three-cylinder engine. It is a reversing, single-action wobbler, using a clever way to bring the three cylinders 60° apart instead of 120°. The center Cylinder applies pressure to the Piston and Crank in the same direction as a Cylinder at 120° would give. It is a good showoff conversation piece to run on compressed air.

The fitting of the Tubing will be a challenge. Since any dimension that might be shown would be hard to follow, it was decided that this was a cut-and-fit job. Perhaps pieces of 1/8" diameter solder is the best way to arrive at the length and bends for each Tube.

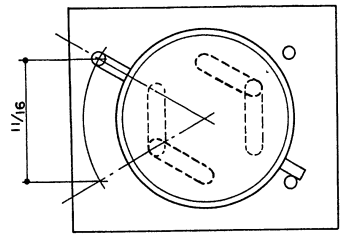
It is really a tiny, compact engine and some parts are quite small. We try to make projects for those with small machinery.

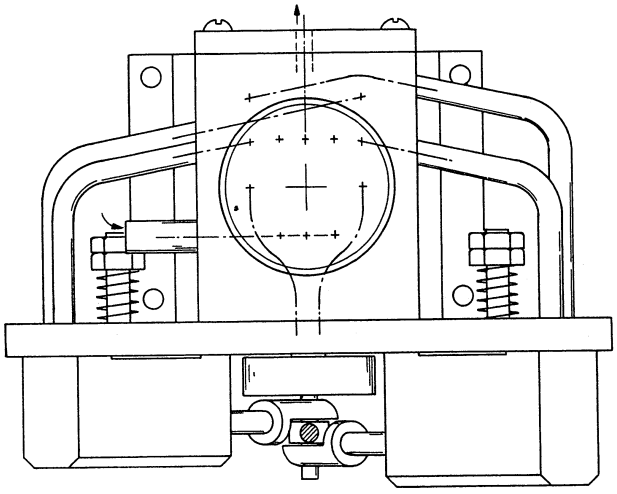
The **BASE** and the **BACK PLATE** are plain machine shop practice. The bore for the Bearing must match the bore in the Front Plate for good alignment with the Crankshaft.

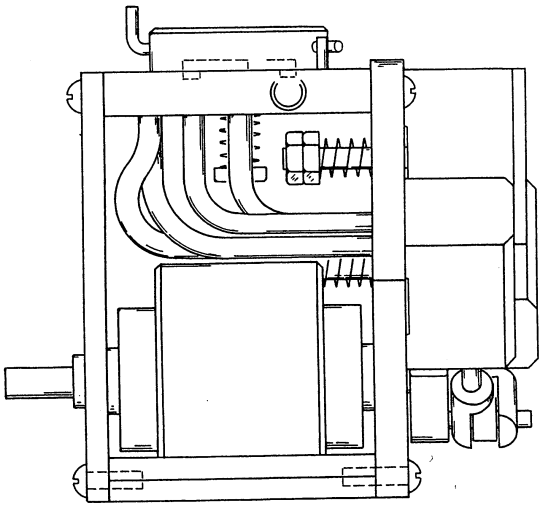
On the **FRONT PLATE**, lay out all the centers and outlines except the six 1/16" steam ports. Make all the remaining holes. This Plate must be smooth and flat at the Cylinder areas. Make the drill jig and jig pin. Drill the 1/16" steam ports as shown, using a close-fitting 1/8" pin in the pivot holes and holding the jig against the 1/8" diameter on the jig pin. Drill out these 1/16" port holes 1/8" diameter and 9/64" deep to take the 1/8" Tubing. This depth helps to hold the Tube in place while assembling with epoxy or soldering, in which case the Plate should be brass. Cut the Plate to fan shape. This is a spot where you can shape to suit your own ideas on appearance. Make and press-fit the Crankshaft Bearings into the Front and Back Plates. Note the shoulders are on the inside.

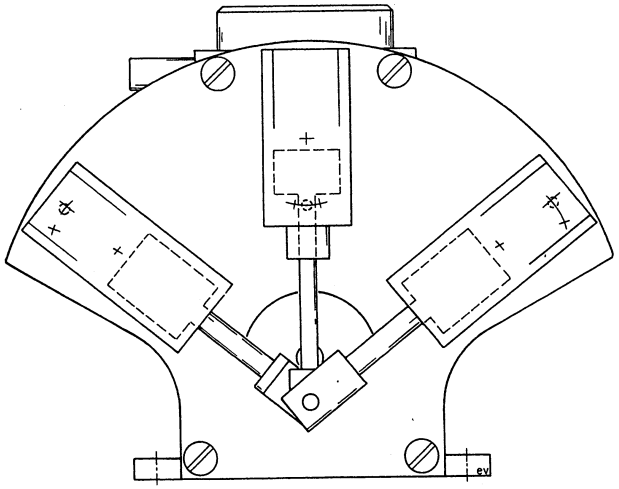
The **VALVE PLATE** requires careful layout and drilling. A 5/8" circle is scribed in the center and six spaces paced off using the 5/16" radius just used for the circle. Two of the 3/32" holes go down and meet the passage to the Tubing. The other four are drilled shallow, only about 1/32", indicating the ends of the 3/32" milled slots. After milling the slots, two holes are centered in the slots and drilled down to meet the intake and exhaust passages. It is important that this Plate be flat and smooth for a good metal-to-metal seal. Make sure there are no burrs or dirt at assembly. Determine the two extreme positions of the Valve movement and spot the two 1/16" pins.

Assemble the Base, Front, Rear and Valve Plates. Fitting the **TUBING** takes a bit of patience. Make and fit all the Tubes. To fit the shortest pieces, the screws through the Front Plate and into the Valve Plate will have to be loosened a bit. If you use the five-minute epoxy, you will have to be organized and work fast. You will be better off with the slower type. Apply the Epoxy very carefully so it will not get inside the Tubing. Apply to the shortest Tubes first and tighten the screws. For the rest of the Tubes, apply the cement and spring each Tube in place, one at a time. The ends of the Tubes at the Front Plate can be drilled out if the cement gets into the passage, BUT at the other end it is blind and you will have to take it apart and start over if

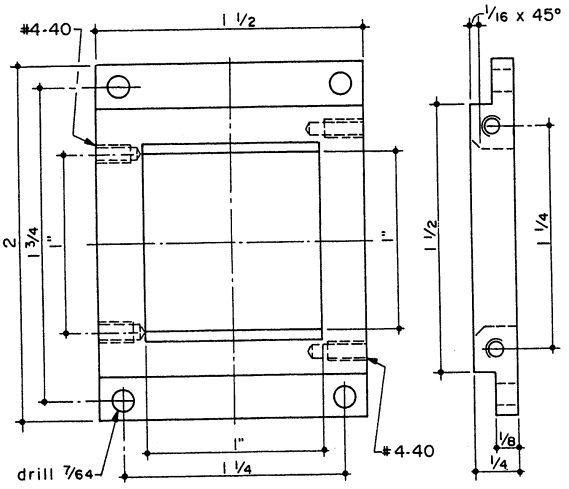




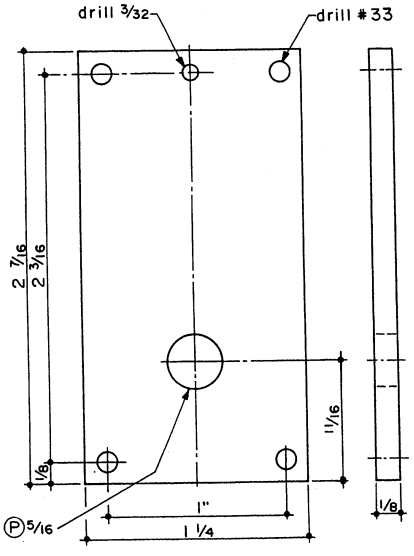




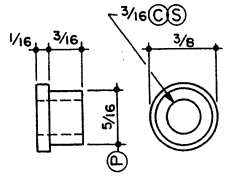
V3R



BASE
Any Metal

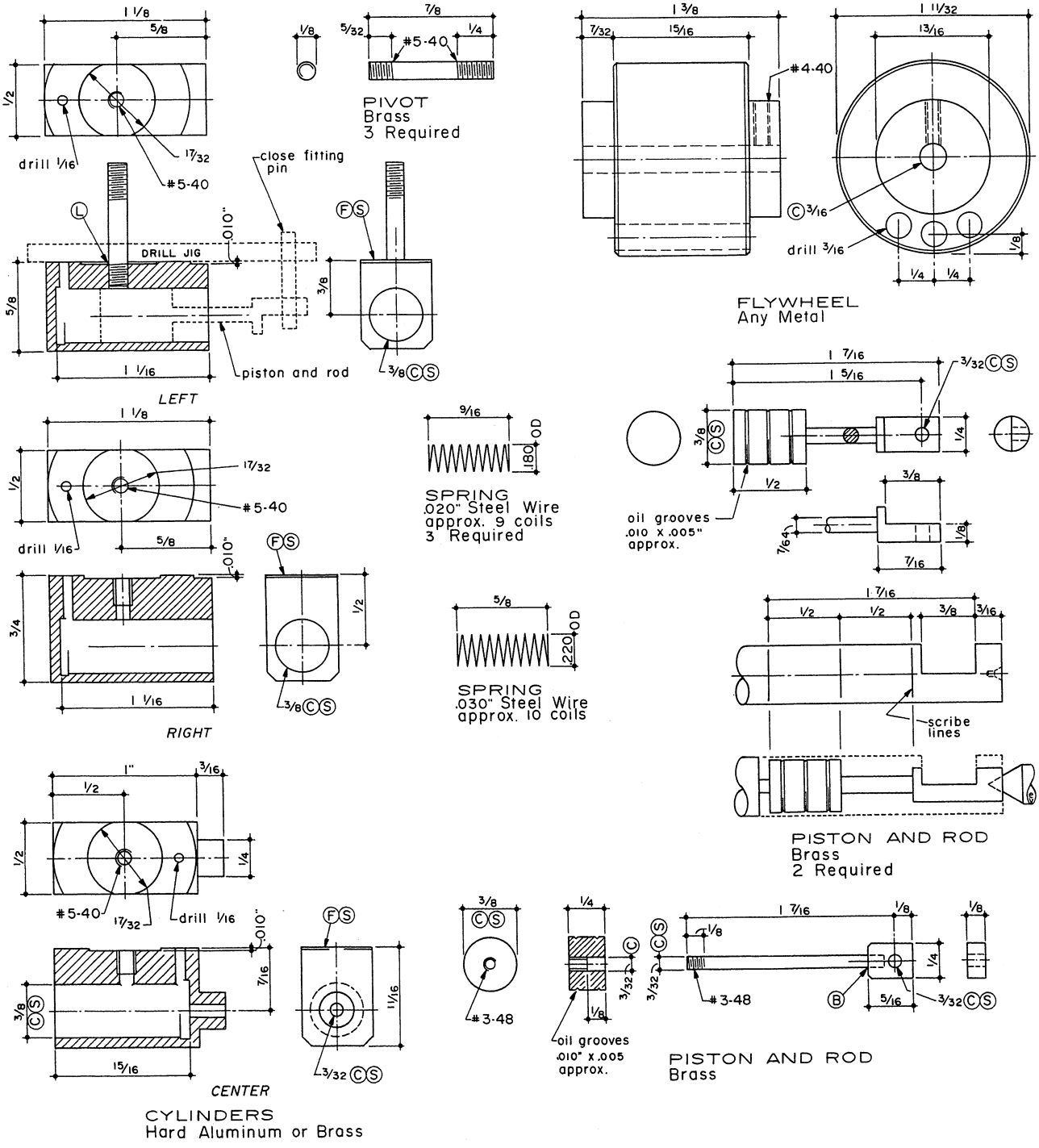


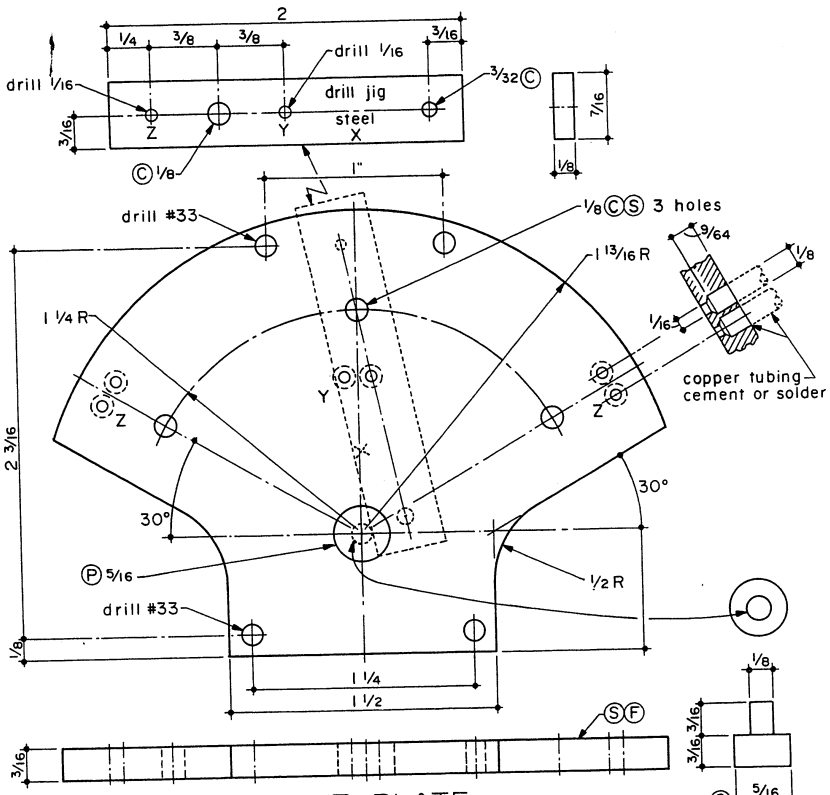
BACK PLATE
Any Metal



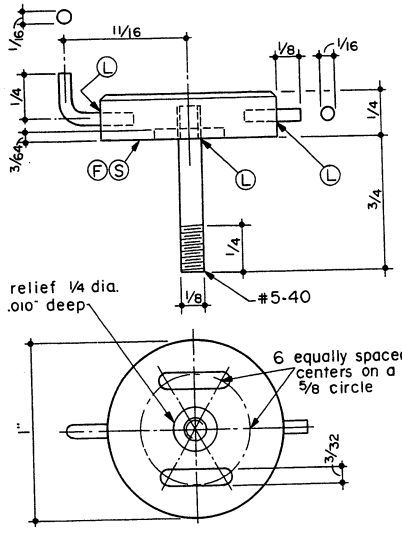
BUSHING
Brass

Ⓒ close fit
Ⓢ smooth
Ⓟ press fit or "Loctite"
Ⓑ braze or solder
Ⓕ flat
Ⓛ "Loctite"
MTP model taper pipe

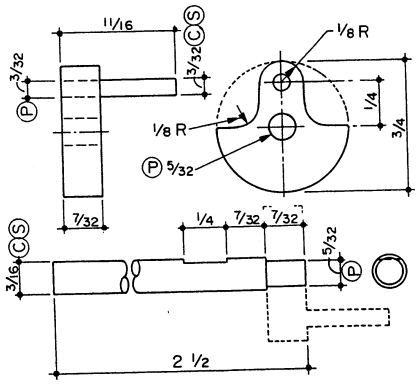

PIVOT
Brass
3 Required
drill 1/16
#5-40
close fitting pin
DRILL JIG
piston and rod
LEFT
RIGHT
SPRING
.020" Steel Wire
approx. 9 coils
3 Required
SPRING
.030" Steel Wire
approx. 10 coils
FLYWHEEL
Any Metal
drill 3/16
oil grooves
.010 x .005"
approx.
PISTON AND ROD
Brass
2 Required
scribe lines
#3-48
CENTER
CYLINDERS
Hard Aluminum or Brass
PISTON AND ROD
Brass



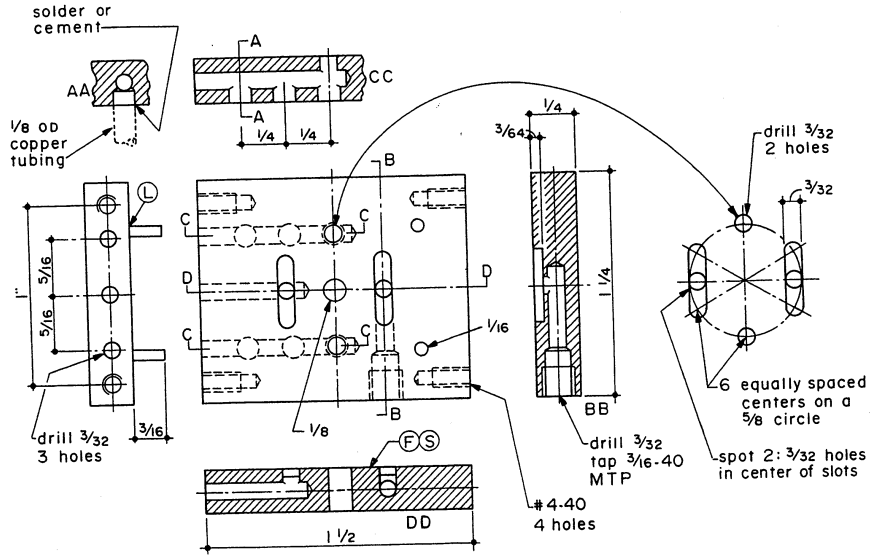
FRONT PLATE
Hard Aluminum *(cement)*
Brass *(cement or solder)*



VALVE
Brass



CRANKSHAFT
Steel



VALVE PLATE
Brass

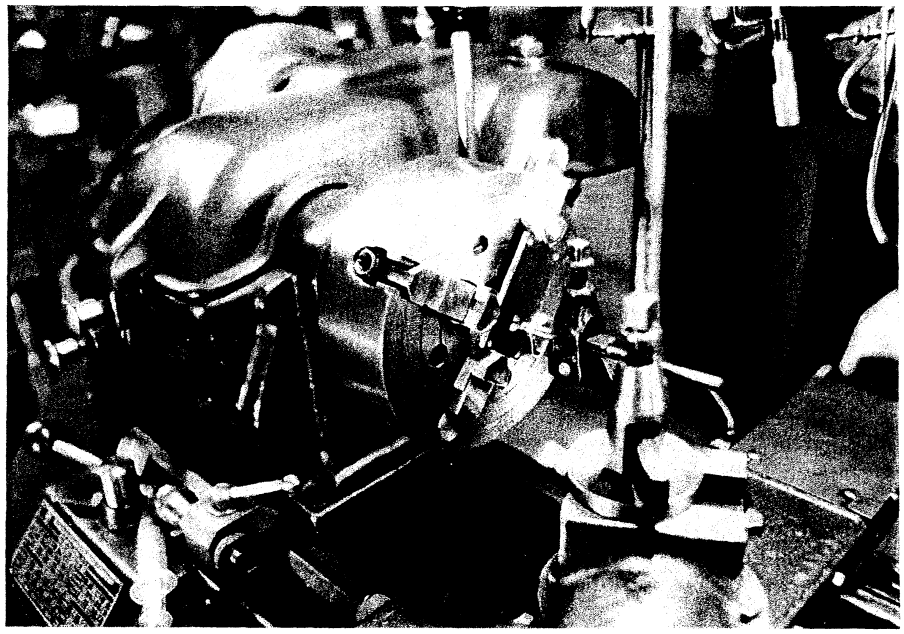
the passage gets stopped up by the cement. There is less chance of clogging the passages if brass parts are used. Fit and insert all the Tubes and melt tiny pellets of solder around each Tube end.

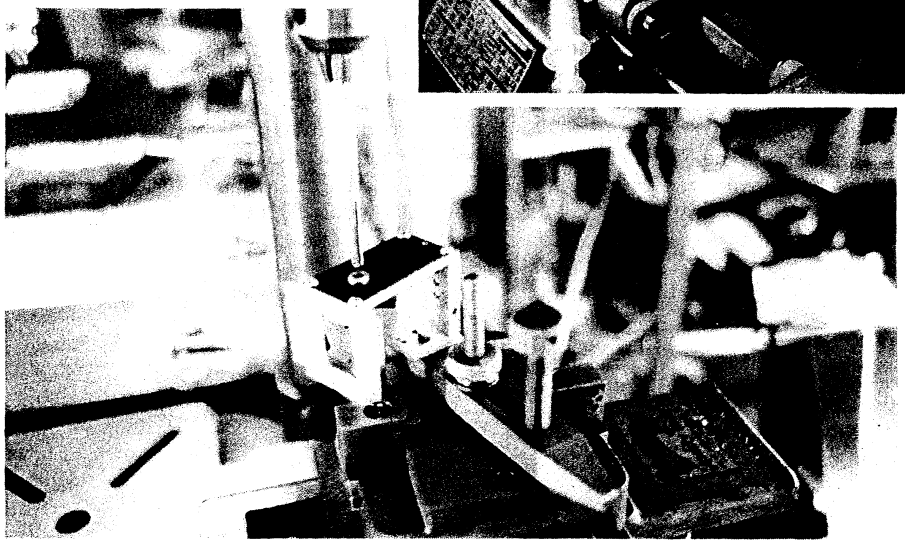
The **VALVE** is a disk, laid out with six spaces on a 5/8" circle just like the Valve Plate. Here, four of the centers are picked up and grooves milled as on the Valve Plate. The face must be smooth and flat for a good seal. While truing up the face, make an accurate 5-40 center hole for the Pivot Pin, perpendicular to the face. Turn the .010" x 1/4" relief.

Note the relationship of the **CRANKSHAFT** and **FLYWHEEL**. A 1/32" flat is made on the Shaft opposite the Crank throw. The set screw in the Flywheel is opposite the three counterbalancing holes. This puts the weight opposite the Piston and Connecting Rod, reducing a big share of the vibration.

Two of the **CYLINDERS** are the usual wobbler type. The center Cylinder has a Head on the end towards the Crank. This applies pressure to the Piston upward like a Cylinder down at 120° would give. One fault on this engine is the three different dimensions from the Piston centerline to the rubbing face. This turned out to be more of a problem than was anticipated. This was required to accomodate the Bearings at the Crank. The model made to these dimensions ran good at low pressure. Higher pressures lifted the tall Cylinder off its seat, though it did run. It

Boring the Back Plate for the Bushing





Reaming the Bearing holes.

is hard to reduce this dimension. Quite a bit of time was spent trying to solve this problem. Three different steps on the Front Plate would have been about as complicated. Decidedly offset Connecting Rods would apply an angling pressure to the outside Pistons. So, for a simple design that runs, this is what we have. Slightly more spring tension on the tall Cylinder helped reduce some of the trouble. Don't hesitate to try some of your own ideas here. In making the Cylinders, lay out the bore centerline on the end of a finished block and prick punch. Center in the 4-jaw, using a center test indicator and bore to a fine finish. Lay out the Pivot center and squarely chuck in the 4-jaw, using a protector over the bore end. Make a skin cut to a fine flat finish. Drill and tap for the Pivot and make the .010" undercut. The 1/16" port hole is made by using the Piston as shown with a close-fitting pin through the jig and Crankpin holes. All of these holes and pins must be close-fitting for accurately matching the holes in the Front Plate when the Cylinder rocks to each side.

The **PISTON** for the center Cylinder is quite plain and not unusual. Hold the 1-7/16" dimension from the Crankpin hole to the end.

The outside **PISTONS** start out with stock large enough to turn the O.D. to a close fit in the Cylinders. Mill the 3/8" wide cut to one-half the stock diameter. Center in the 3-jaw and add a center hole for tailstock support. Turn the Piston and Rod to shape and make the parting cuts. Center the 3/32" Crankpin hole in the width of the Bearing end. Use each Cylinder as a gauge and fit each Piston to its own Cylinder and keep them together. At assembly, check these Crank ends for rubbing against each other. You should see daylight between the three ends. In other words, they should float past each other and not apply any pressure that will add friction in the bore and tend to tilt the Cylinders.

The **SPRINGS** are from the odds-and-ends collection and seem about right for this job. Try some from your collection. The tighter you set these Springs, the more pressure it will take to run the engine. For showoff and a conversation piece, set them as loose as you can with the least leakage so it will start and run easily.

It may take a bit of filing and fitting to make it run free. It is an interesting model and a fair showpiece. At 15 to 20 pounds of air, it ran at a good speed.

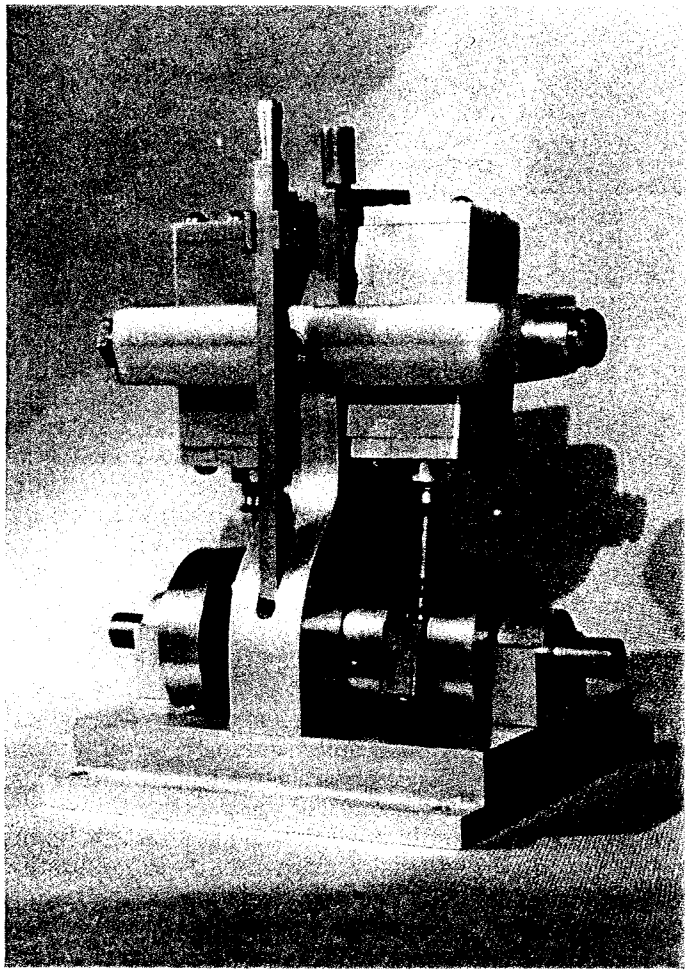
CHAPTER

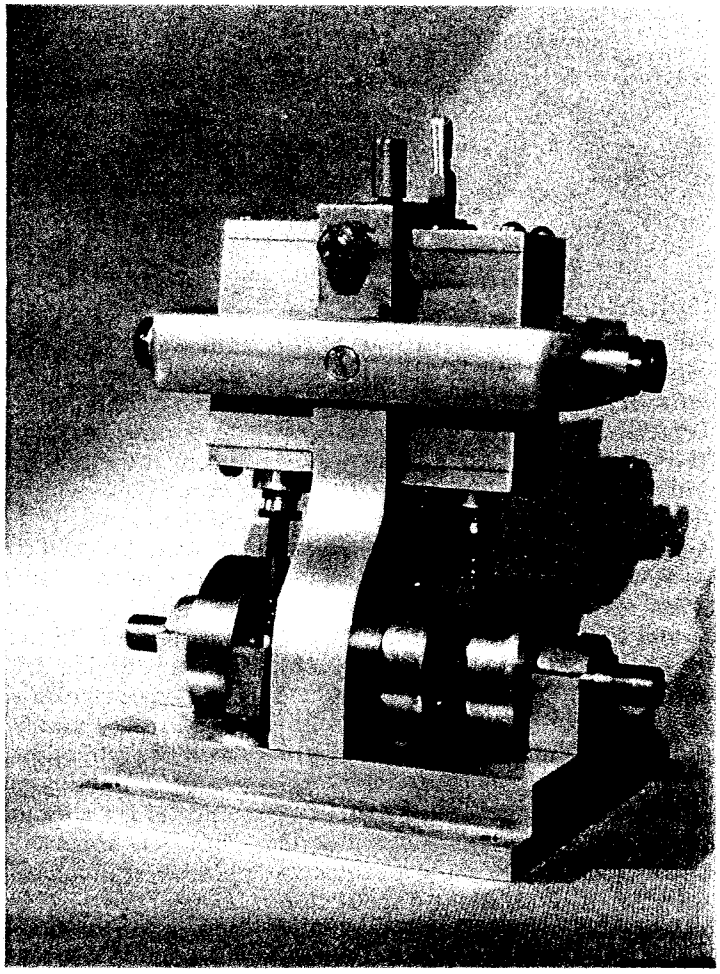
52 Reversible Vertical Twin Wobbler

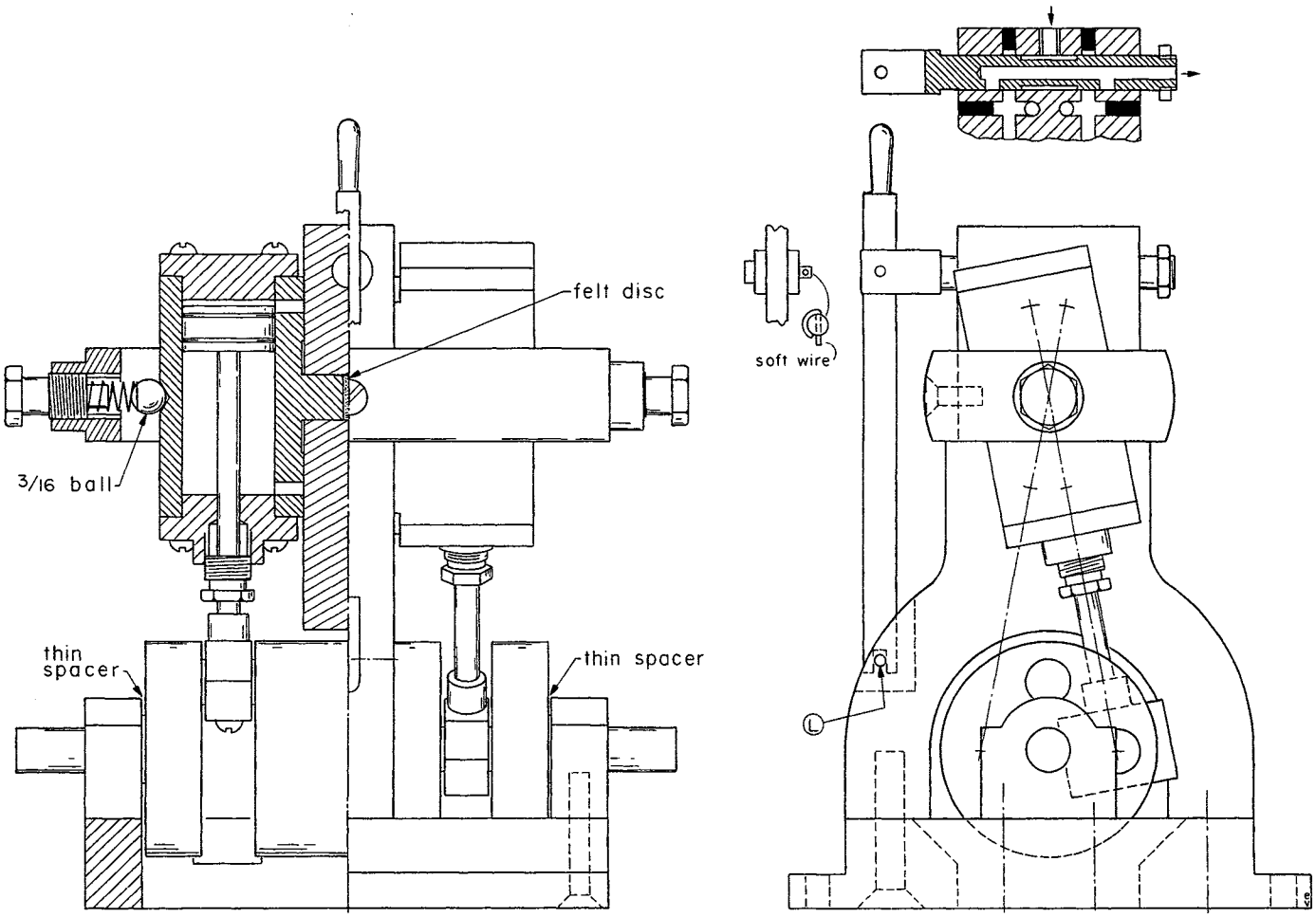
This could be a good engine for a boat. Efforts were made to keep it compact and light weight. Experienced boat builders will have to tell us if it is suitable. It is a combination of ideas from other engines. The Wobble Cylinders are common practice but with a different type of Spring pressure to hold them against the Valve surface. The Crankshaft serves as a Flywheel. The Column requires some careful layout and machining. Several steam passages are drilled and finally the ends plugged in order to get the ports in the proper location. The Reversing Valve is cylindrical and close fitting without Stuffing Box. There is no control for the exhaust. The Cylinders are double acting and the engine is self-starting.

The **BASE** is simple and no extra remarks are needed. As usual, on these engines, you can use your own ideas such as rounding some corners and cutting away the flange between the anchor holes forming four rounded lugs.

The **COLUMN** is about the most complicated part. Start out with an accurate 1/2" x 2-1/4" x 3-5/8" block. Lay out all the outlines and hole centers except the steam ports and oil hole. Bore and ream the two 1/4" holes. If the engine is to get some hard usage, the Pivot hole may be bushed. Make the drill jig. The jig is placed over the Pivot Pin and against the Pin at the Crank center. Drill the four holes **P** using the jig. Cut to the outline on two surfaces **Q**. Leave the lower end solid for now. Transfer the port hole centerline around to the sides and drill four holes **S**. Transfer the centerlines of the **S** holes up over the top and drill two holes **T**. Drill two holes **U** for the retainer. Do not break through into the steam passage. This will require a bottoming tap. Make the 3/16" Valve bore **W** close fitting and smooth. Drill and tap 1/8" steam connection at **V**. Chuck in the 4-jaw and bore the 1-5/16" hole at **X**. Complete milling to shape at **Y**. Next, tap the 8-32 mounting holes. Mill the Lever pivot slot and drill 1/16" at **Z**. Drill 1/16" oil hole at 20°, both ways off horizontal and vertical as shown in special view "**lubrication**". Avoid breaking into a steam passage. A close plug in the 1/4" bore will prevent drill breakage. Blow all chips and dirt out of steam passages and plug as shown, either press fit or Loctite.

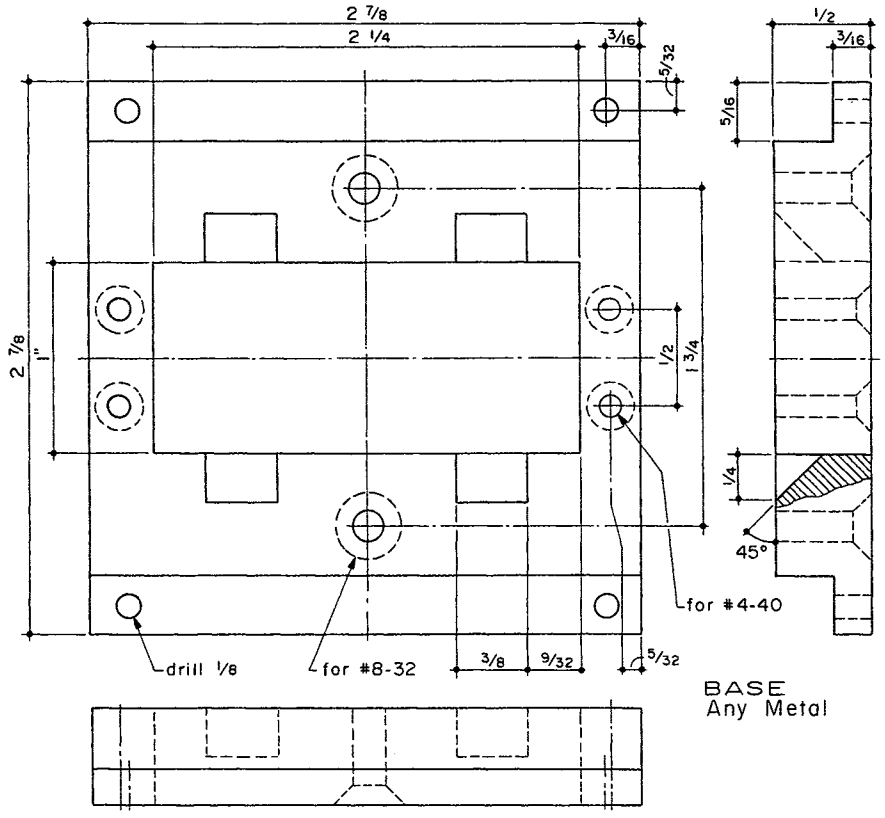






RVTW

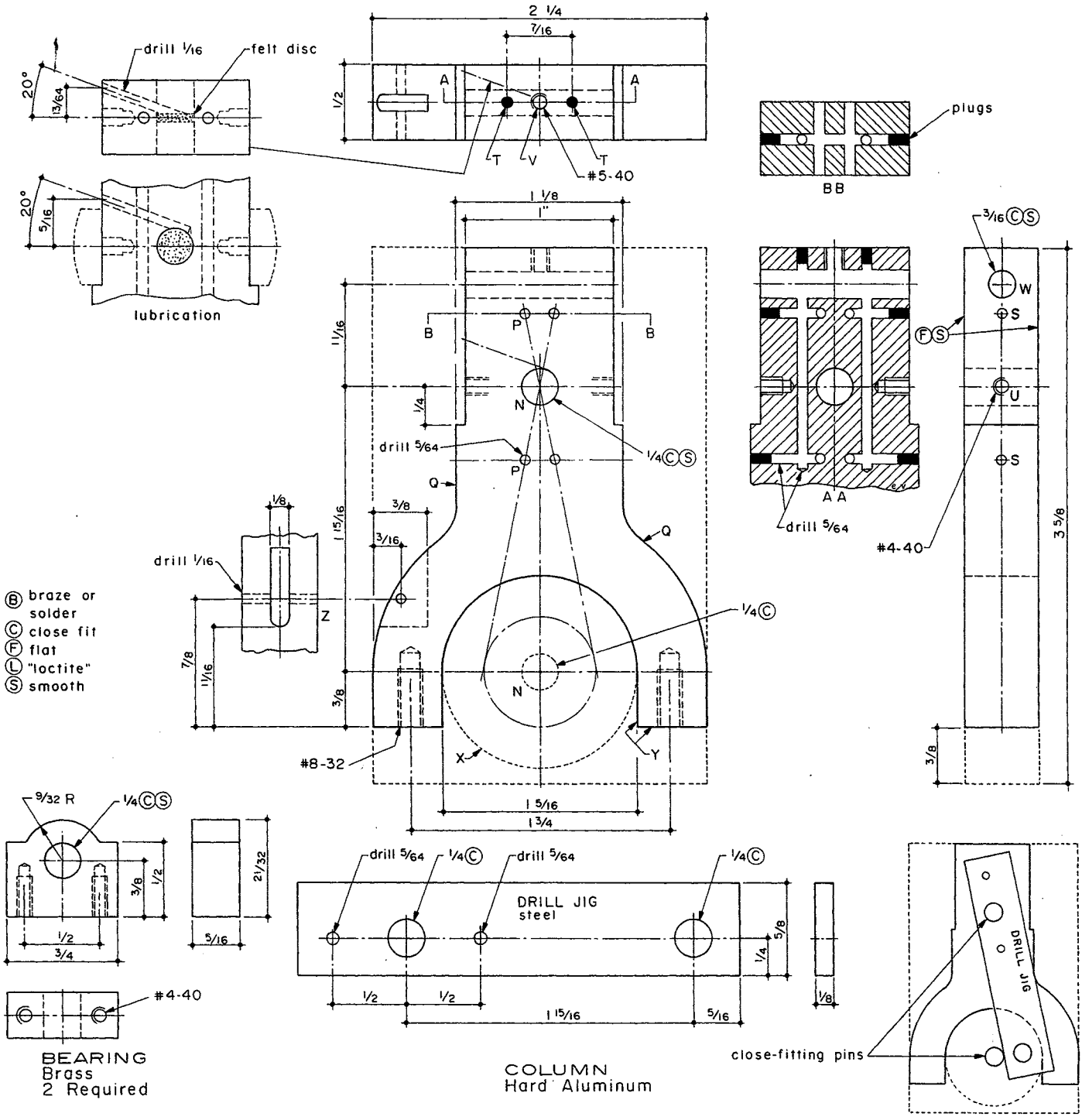
REVERSIBLE VERTICAL TWIN WOBBLER



Punch out a 1/4" diameter **DISK** from 1/16" felt for the lubrication at the Pivots. It will slowly feed the oil to the Pivots.

The **BEARINGS** need no explanation except bushings may be added if this engine may get some hard usage.

The **CYLINDER RETAINER** is perhaps more fussy than need be, though it adds a bit to the appearance, and is a dandy little exercise in turning. The drawing tells the story pretty well. First, on a 1/2" x 1-3/8" x 3-1/4" block, lay out all the outlines and centers. Drill the four 1/4" holes for the 1" x 2-1/2" center opening. Saw and file to shape. Drill lathe center holes in each end. Drill #32 for the 4-40 screws in the side. Countersink later. Turn one end. Reverse and turn the second end. The diameter across 1-3/8" is simple, but making the rounded corners is not so easy. The one shown was roughed out with

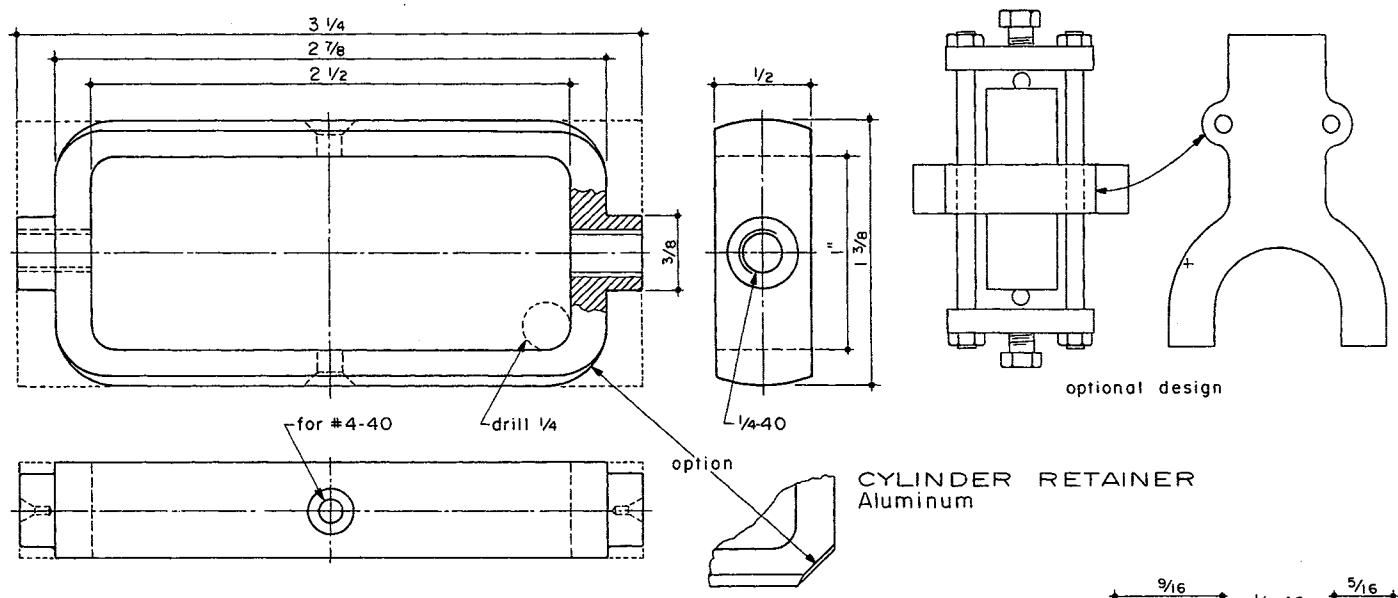


the lathe using fine cuts until it looked good, then brought to a final shape with a file and emery free handed out of the lathe. An option is to set the compound at 45° and make a simple bevel. Another is to make the Column wider and use rod and end pieces to retain the Cylinders. Countersink the 4-40 screw holes. Drill and tap the ends 1/4-40.

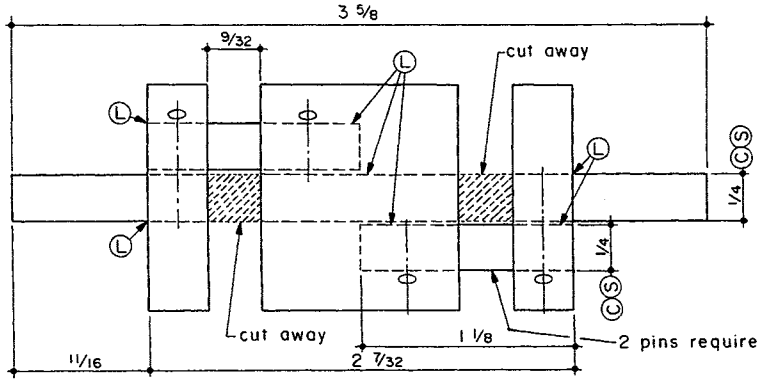
The **CRANKSHAFT** is pretty well covered in the drawings. A few notes will help. The short Shafts reach only half way through the center pieces. The open portion plus the 3/16" hole are an effort at counterbalancing. Loctite the short Shafts into the end pieces and allow to cure. After curing, assemble onto the long Shaft taking care with the spacing at 9/32" and 2-7/32". After final curing, add the spring pins if you wish and cut away the Shaft as shown.

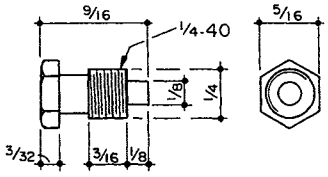
The **CYLINDERS** on the model shown are aluminum. This has aluminum running on aluminum which is not the best. Brass Cylinders would probably be better. Lay out all lines and centers on an accurate 3/4" x 1" x 1-5/16" block. Center in the 4-jaw and make the 1/2" bore smooth and accurate. Chuck in the 4-jaw, centering for the 1/4" pivots. Use protectors on the ends. Turn and make the .010" undercut. Use the drill jig as shown on the assembled Cylinder, Piston and Rod and Head, using close fitting Pin in the Rod Bearing and drill the port holes. Next, make the dimple for the 3/16" ball.

Make the **HEADS** and use them as jigs for spotting the Head capscrew holes. When making the Stuffing Boxes, try for good concentricity and a close fit on the Shaft and the Pack

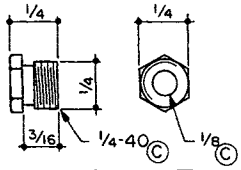


CYLINDER RETAINER
Aluminum

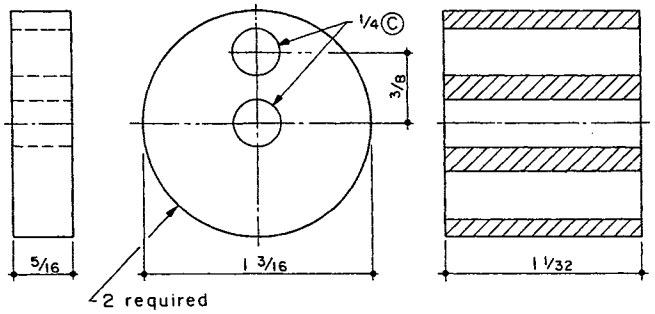


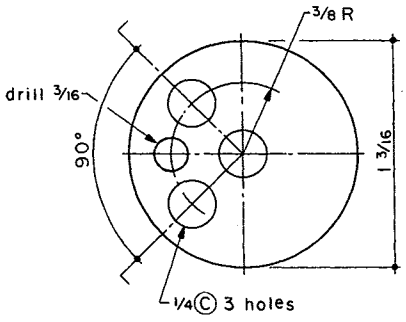


SCREW
Brass
2 Required

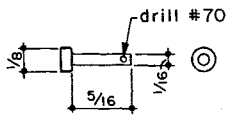


PACKNUT
Brass
2 Required

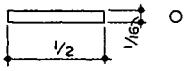




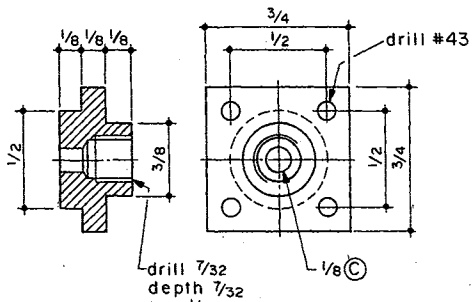
CRANKSHAFT
Steel



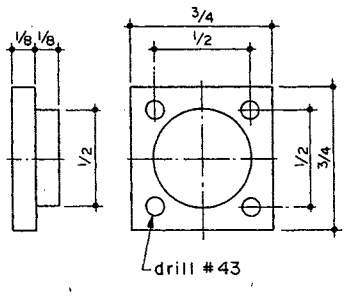
PIN
Brass



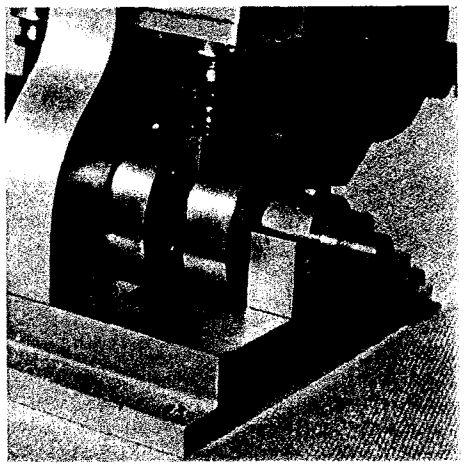
PIN
Brass

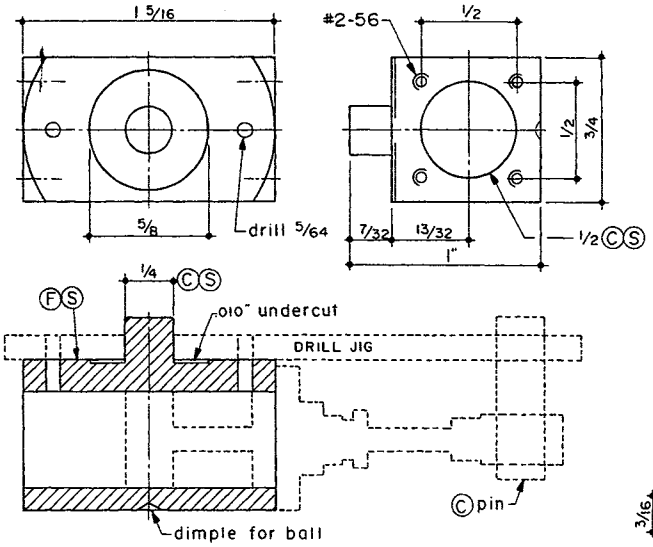


HEAD
Brass
2 Required

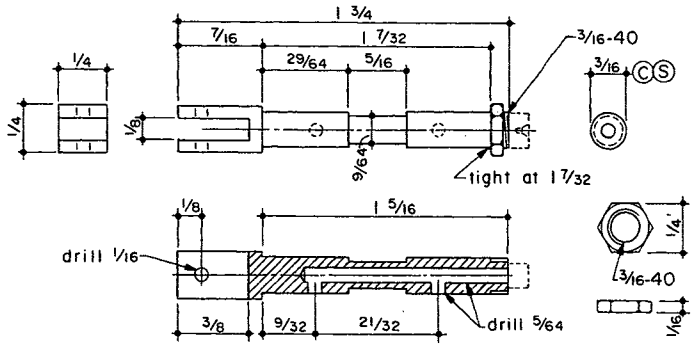


HEAD
Brass or Aluminum
2 Required

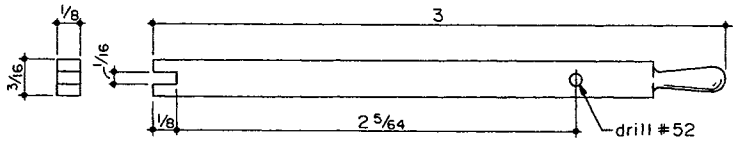




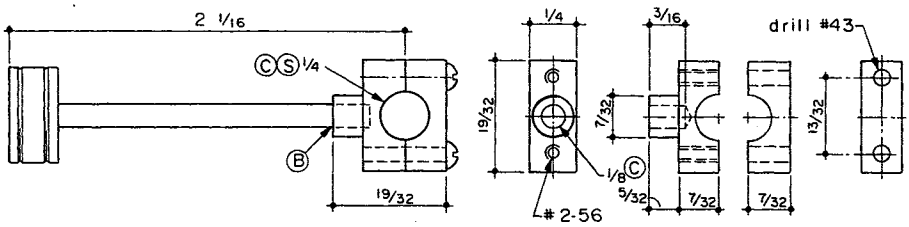
CYLINDER
Brass
2 Required



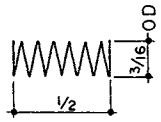
VALVE
Brass



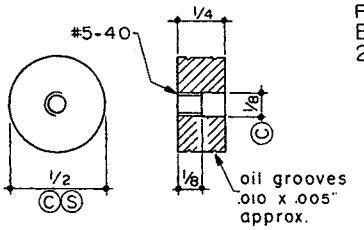
LEVER
Any Metal

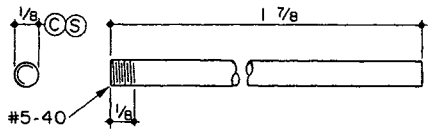


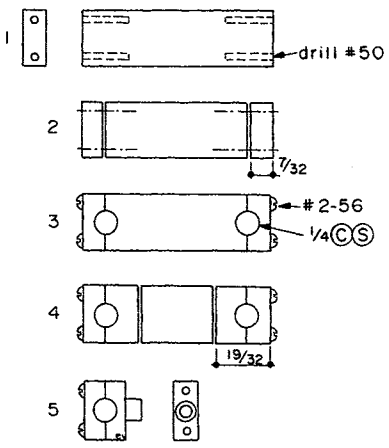
PISTON AND ROD
Brass
2 Required



SPRING
Steel
Wire dia. .025"
2 Required







Nut. When making the **PACK NUT,** open the die a wee bit to make a close fit at the 1/4-40 thread. The reason being that, since there are no guides, the Piston, Head and Pack Nut must take all the forces that keep rocking the Cylinder.

The **PISTON AND ROD** are pretty well covered by the drawings. Try for good concentricity at the Piston and Rod. A five-step layout shows how the Bearing ends of the Rod were made. After assembly, the 1/4" holes were centered on the joint. Next, the 19/32" assemblies cut off the ends are chucked in the 4-jaw and the hub turned and bored 1/8".

Make the 3/16-40 **NUT** for the Valve.

The **REVERSING VALVE** calls for some close fitting and spacing. Center some 1/4" stock in the lathe chuck with about 2-1/4" projecting. Make a small center hole and bring up the tailstock for support and turn the 3/16" diameter to the closest free fit in the Column that you can make. Make the 5/16" x 9/64" neck very close to dimension. Now, turn the 3/16" diameter down to about 11/64" at the end, 1-5/16" from the shoulder. Then mount the 3/16-40 die in the tailstock and thread it so the Nut runs tight at 1-7/32". This may take several "cut-and-tries". Drill 5/64" steam passage. Trim off the stub end at the 1-5/16" dimension and carefully lay out and drill the two 5/64" holes at 9/32" and 21/32". Cut off at 1-3/4" and make the 1/8" slot parallel to the two 5/64" holes you just made and make the 1/16" pin hole.

The **SPRINGS** used had the dimensions shown. Try some from your collection. You will get a feel for the drag and know when the tension is right. A hard steel ball coated with grease will serve well under the Springs.

Make sure that everything runs free and is well lubricated, and try on 10 psi air. The model shown ran on only a few pounds, just barely turning over and reversing easily.

APPENDIX

A collection of shop projects and tools by the author that can make your hobby shop work more convenient and enjoyable.

Here are some details to help you

Create Your Own Designs

Throughout the development of these engine designs, there have been certain details that were reused. They worked, they were easy to build and they were handy. They also simplified the preparation of the text for each article.

Although you see them through this book, we have grouped them here for those who might want to design their own engines, using these references and details.

There are the Symbols which indicate a condition that should be met at a certain point. There are two different Cylinders, a Steam Chest, Steam Chest Cover, Valve Plate, a Valve and Valve Nut. There is an Inboard Head and an Outboard Head, an Eccentric, two Pack Nuts, and a Flywheel which was used several times.

Check them over before you begin work on a new project and apply any of these parts to any engine you decide to build.

Once you are familiar with these, their relationship to the engine you envision will be clear and you can proceed in your project with utmost confidence.

SYMBOLS

(C)	CLOSE FIT	Close clearance between two parts. A close but free-running fit with no shake. Make one surface and machine the other to fit.
(S)	SMOOTH	A fine polished surface for minimum wear.
(F)	FLAT	Ground flat with very fine emery paper on a surface plate or plate glass for a tight metal-to-metal sliding seal.
(B)	BRAZE OR SOLDER	Silver solder in some cases; up to you and your equipment. Most soldering in these designs has been with 430° type solder.
(P)	PRESS FIT OR LOCTITE	Your choice. Loctite has been quite sucessful. Follow Loctite's instructions.
(L)	LOCTITE	Loctite recommended.
MTP	MODEL TAPER PIPE	Tapered pipe thread for model makers.
—	PACKING	Packing is mentioned in the text on some engines and stuffing boxes are shown. In all cases, use your favorite packing which can range from common cotton twine to graphited asbestos. Some models depend on only a close fit and a bit of lube to seal at low pressures.

The small symbols inside the circles shown at various surfaces and dimensions indicate a condition that that area should meet. They reduce the amount of data on the drawing and you will soon learn their meaning.

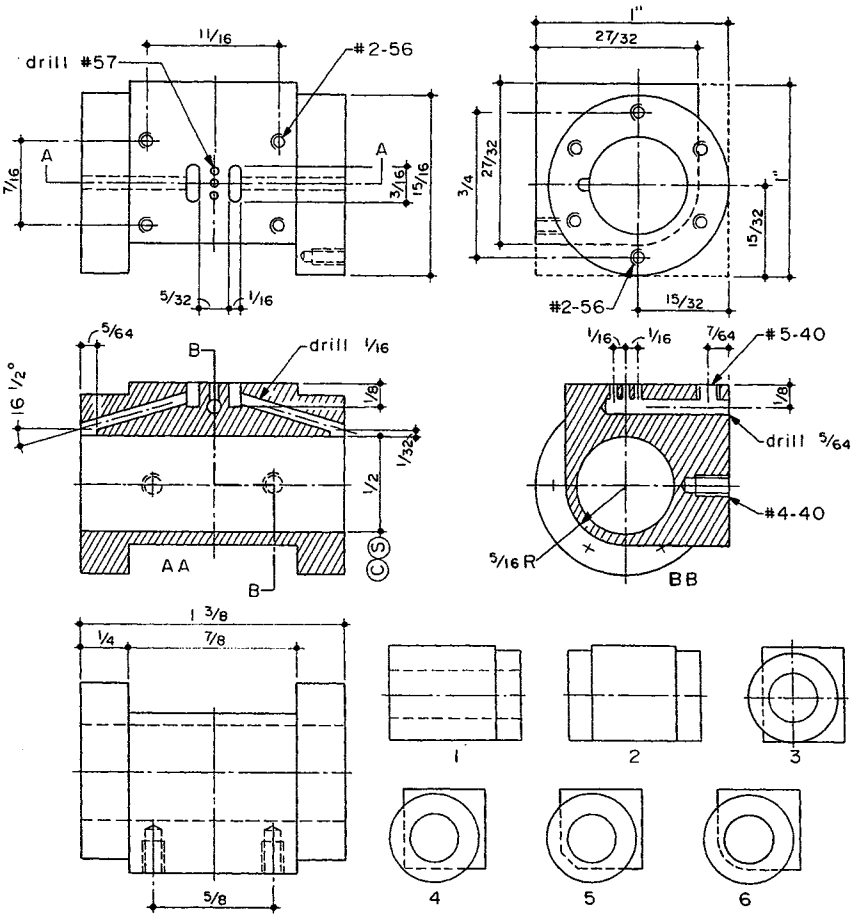
BASIC CYLINDER

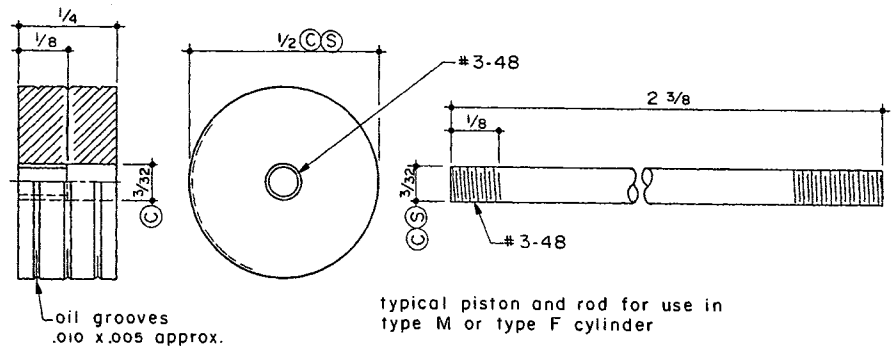
TYPE M

For those who like to work up their own engine ideas.

Material: hard aluminum, brass or fine-grained cast iron.
1/2" bore, 1" stroke using 1/4" wide piston.

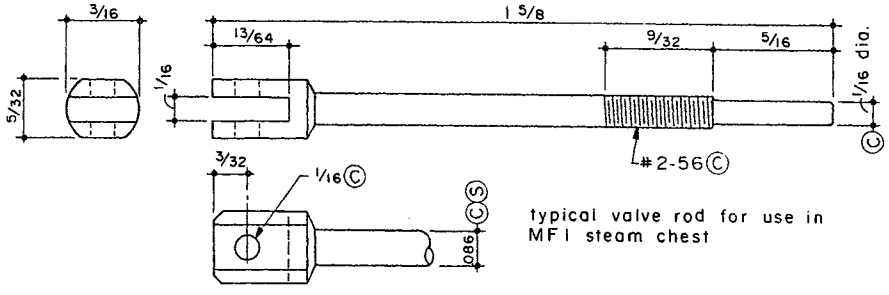
Make an accurate 1" x 1" x 1-3/8" block. Lay out all the centers and lines on all six faces. Note that the bore centerline is 15/32" from the faces at one corner. Complete all drilling and tapping while the block is square and easy to hold. Mill 1/16" ports. The head bolt holes can be made using the heads as jigs after the bore is made. Proceed with **Step 1**, chucking in the 4-jaw using a center test indicator. Bore 1/2" and turn the 15/16" diameter. Reverse in the chuck and turn the second end as in **Step 2**. Make a milling setup and complete **Steps 3, 4** and **5**. Rounding as in **Step 6** is optional. This will be covered if lagging is used. This type has its own foot for mounting on a base.





typical piston and rod for use in type M or type F cylinder

TYPICAL PISTON AND ROD FOR USE IN TYPE M OR TYPE F CYLINDER



typical valve rod for use in MF1 steam chest

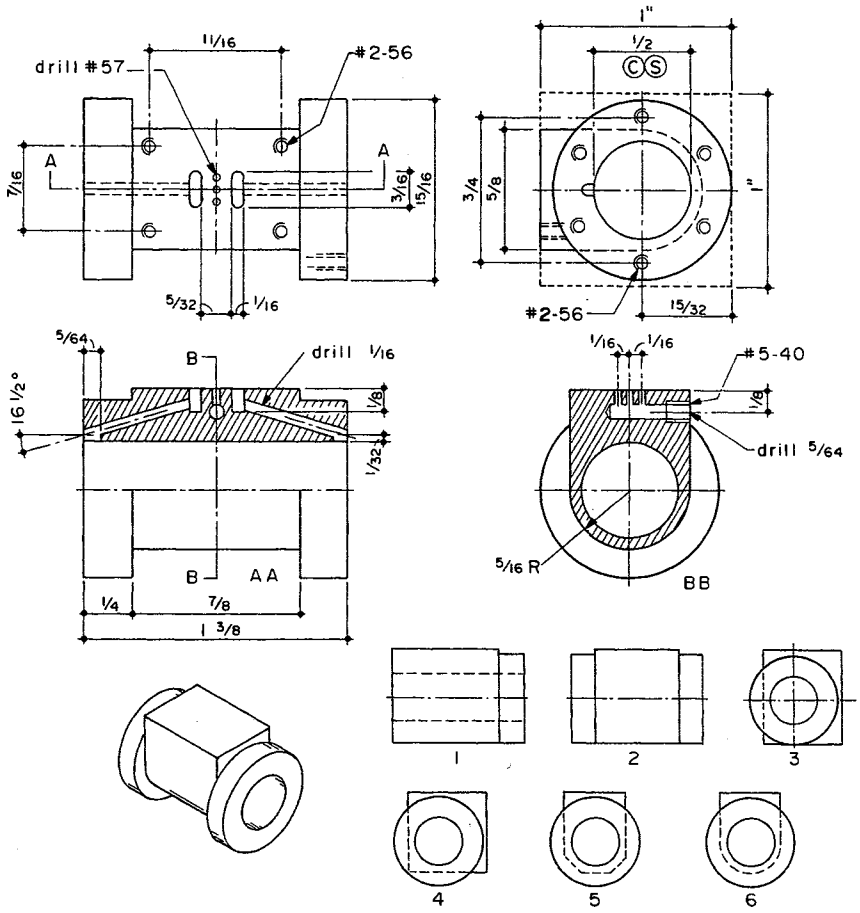
TYPICAL VALVE ROD FOR USE IN MF1 STEAM CHEST

BASIC CYLINDER

TYPE F

Material: hard aluminum, brass or fine-grained cast iron

1/2" bore, 1" stroke using 1/4" wide piston

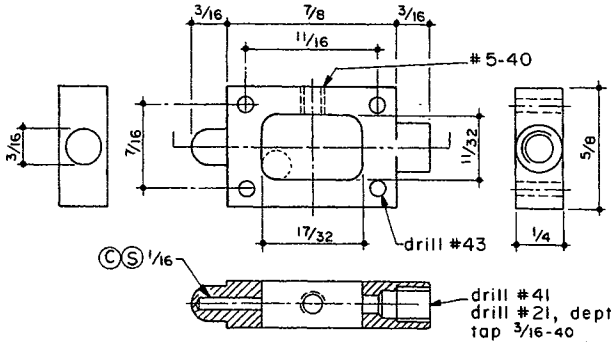


Make an accurate 1" x 1" x 1-3/8" block. Lay out all centers and lines on all six faces. Note that the bore is centered one way on the 1" square and 15/32" from one of the other faces. Complete all the drilling and tapping while the piece is square and easy to hold. Mill 1/16" ports. The Head bolt holes can be made using the Heads as jigs after the center is bored. Note: keep the bolt pattern parallel with the valve surface so the feet, when attached, will fit down on the base. Proceed with **Step 1** in the 4-jaw, centering on the bore using a center test indicator. Next, make the 1/2" bore and turn the 15/16" diameter. Reverse in the chuck and turn the second end as in **Step 2**. Make a milling setup and complete **Steps 3, 4** and **5**. Rounding as in **Step 6** is optional. This type of Cylinder can be flange-mounted or vertical on a table with screws up through the table and head.

The following parts fit Type M and Type F Cylinders

STEAM CHEST MF1

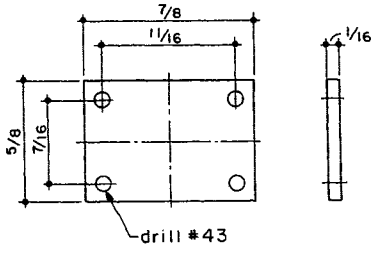
Material: aluminum or brass



The Steam Chest is first laid out completely on an accurate 1/4" x 5/8" x 1-1/4" block. Center in the 4-jaw using a center test indicator to turn each end and bore for the Valve Rod and tap for the Pack Nut. Use drilled holes to form the radius in the square center hole. Saw and file to shape.

STEAM CHEST COVER MF2

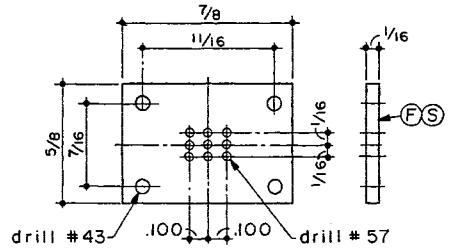
Material: aluminum or brass



Simple layout and drilling. The cover must be reasonably flat.

VALVE PLATE MF3

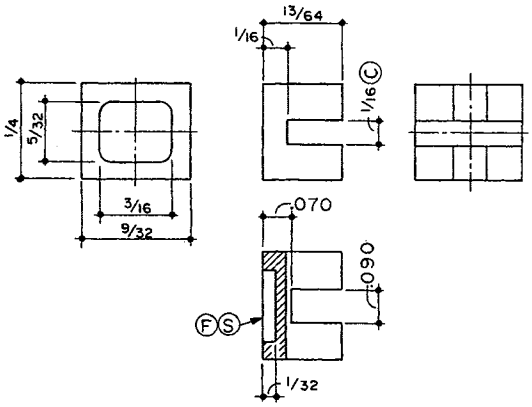
Material: brass



The face the Valve slides on must be very flat and smooth for a metal-to-metal sliding seal.

VALVE MF4

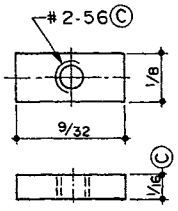
Material: brass



Make the Valve of 1/4" x 5/16" or 5/16" x 5/16" brass rod an inch or two long. Mount it in the cross-slide milling attachment and machine to 1/4" x 9/32" for about 5/16". While in the mill, make the 1/16" and .090" slots. Use a slitting saw and cut to a few thousandths over 13/64". Mount in the vise and mill the 1/32" recess with a 1/16" end mill. Dress the face down on fine emery paper on a surface plate to the 1/16" dimension at the 1/16" groove. Try for freedom on this part so it will just barely float on the seat as steam pressure holds it sown. At the same time avoid sloppiness at the Valve nut.

VALVE NUT MF5

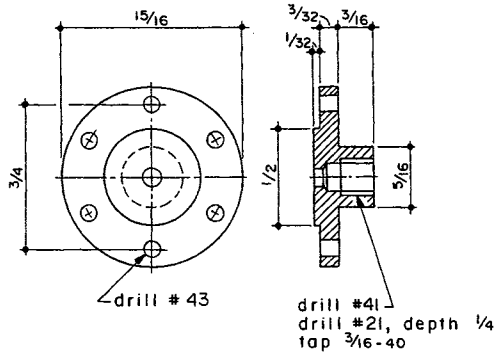
Material: brass



Make this part a close free fit in the Valve slot. Avoid sloppy thread for the Valve Rod.

INBOARD HEAD MF6

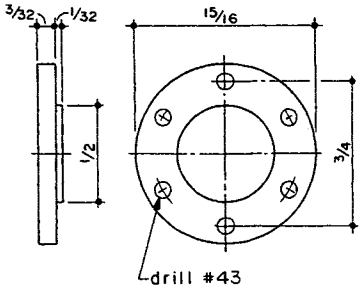
Material: aluminum or brass



Chuck a short piece of 1" bar stock in the 3-jaw and turn the O.D. and hub. Bore for the Shaft. Enlarge and thread for the Pack Nut. Part off at about 5/16" long and reverse in the chuck, gripping on the hub. Face and form the dowel a few thousandths under 1/2". Scribe the bolt circle, pace off six even spaces and drill for the bolts.

OUTBOARD HEAD MF7

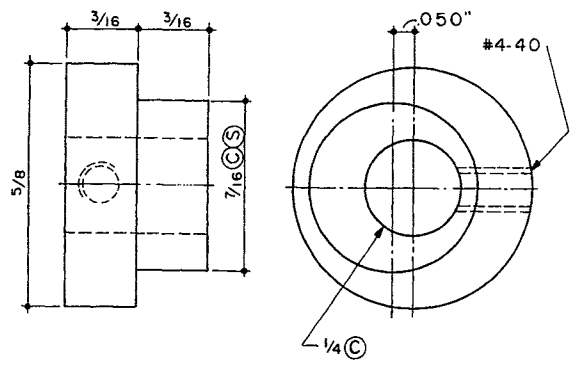
Material: aluminum or brass



Follow the INBOARD HEAD instructions, omitting the hub. Turn the dowel on the first chucking. Scribe the bolt circle. A fine pass with the parting tool before final parting may give you a good-enough finish, avoiding a second chucking. Dress down the outside face on a wide fine file and finish with fine emery on a suface plate.

ECCENTRIC MF8

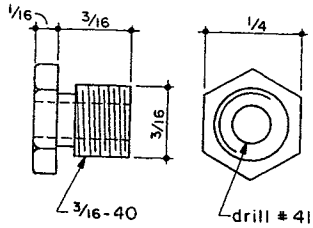
Material: steel
(.100" throw, .050" offset)



Chuck 5/8" diameter stock in the 4-jaw, brighten the O.D. and bore 1/4". Offset .050" and turn the 7/16" diameter. One way is to mount a square-ended bar in the tool post and bring it up against the stock. Zero the cross-slide collar and turn the chuck so two jaws are horizontal. Ease off the vertical jaws slightly and back up the rear jaw about 1/16". Push the stock back, using the front jaw. Advance the cross-slide .050" and ease the stock back against the bar using the rear jaw. Snug up all jaws. Now, when the high spot just kisses the bar and the chuck is rotated 180°, a .100" diameter rod should just pass between the bar and the low spot. You are now ready to turn a smooth 7/16" diameter. Spot the setscrew on the centerline through the bore and the offset. The hex key helps when timing the Valve.

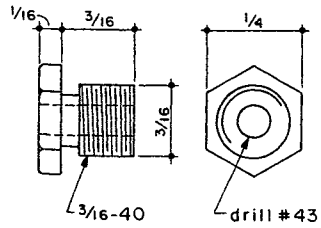
PACKNUT MF9

For 3/32" rod
Material: aluminum or brass



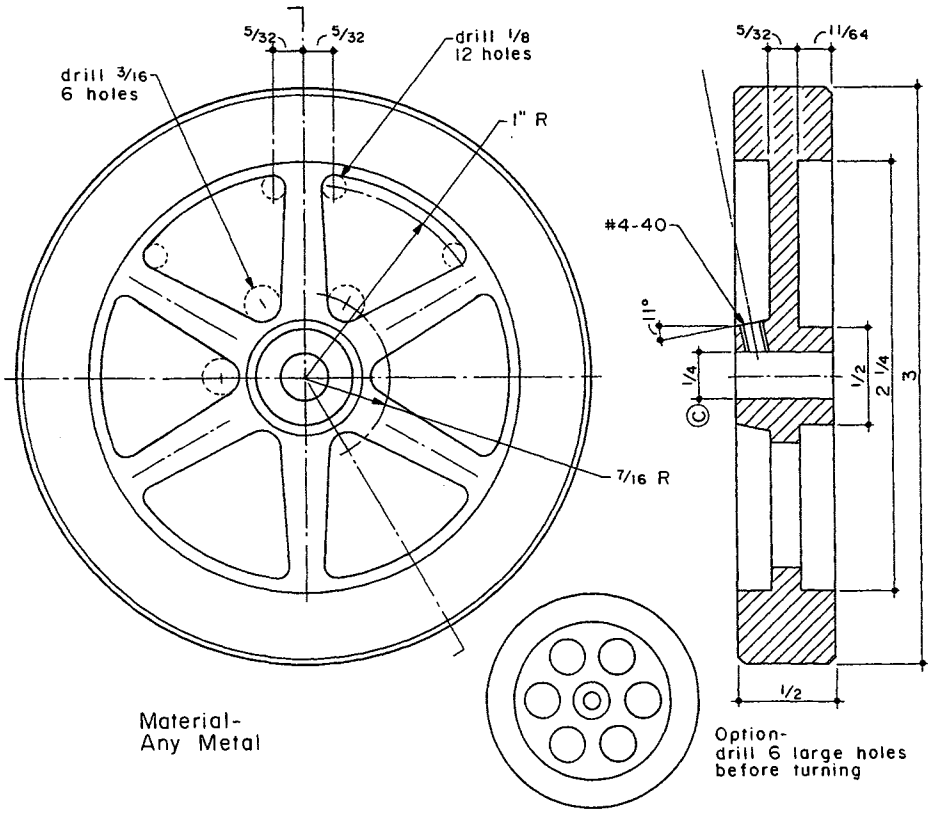
PACKNUT MF10

For .086" rod
Material: aluminum or brass



FLYWHEEL CONSTRUCTION MF11

Material: any metal



O&E/B

Odds & Ends for Beginners

A SIMPLE STORAGE SYSTEM

This is probably just a notion, but I like a simple storage system used for small screw assortments. Clear plastic hinged boxes about 3" x 4" x 1" are used. The screw size is labeled inside the see-through cover. The four main sizes are 2-56, 3-48, 4-40 and 5-40. Each box has the standard tap, die and tap-drill used for its contents. Also a dull tap was cut back, the end ground square and a one-thread lead added, thus forming a bottoming tap for shallow holes. The screws in each box are all of that thread size found in the entire shop, round, fillister, flat head, new, old, steel, brass, etc.

Radio Shack is a fair source for these sizes. Old TV and radio sets are sometimes a good source of salvage screws. It puts all related material together and reduces error and hunting time.

HEAD BAND MAGNIFIER

When you get as old as I am, your eyes need help reading the fine graduations on verniers, graduated collars, scribed layouts, etc. The greatest help has been a head band magnifier. Jewelers and many other professionals use them, so don't let it bother you to be seen using this help.

One big advantage is, it frees both hands to manipulate the part and the tools. I have made a layout of a bolt pattern on a cylinder and another on a cover and brought them together and all the screws entered through both parts. This layout, of course, was made on a surface plate, using a vernier height gauge, which produces very fine layout lines. The clearance holes in the cover were about .008" over the actual bolt diameter.

Using the magnifier and a sharp scriber, a tiny prick can be made where the layout lines cross. A sharp prick punch then picks up these prick marks and next the centerpunch. It takes a bit of patience but it is surprising close.

This method may require marking the parts and always assembling in the position in which it was drilled. It doesn't mean, however, that you can't use the cover as a jig.

PRE-JIGGING

Many irregular-shaped parts are hard to hold in ordinary vises, etc., so pre-jigging is a solution. The part may be shimmed and bolted to a block of metal and, from then on, layout and holding are related to this block. The block allows the part to be held in a vise or bolted to an angle plate or face plate. It is also the means of gripping in a 4-jaw chuck. This block may require milling to "nest" the part. Tapped holes may be needed in a hidden face of the part to be worked so it can be bolted to this block. Maybe one face of the part lends itself to filing a flat and that surface, then, soldered to a plate or block which can be gripped in a vise, etc.; later heating to free the solder.

When you hold a part in a V-block which has a clamp, you are doing about the same thing.

Sometimes an irregular-shaped part can be blocked and shimmed in a small tool makers' vise and this vise held in still another vise squarely or at an angle to suit. This small vise can be fastened to face plates or angle plates for odd milling and drilling conditions.

A very slender or fragile part can be soldered to a stronger piece of metal and, when done, heated to free the solder.

Along this line of thinking, a method was once described by Dr. James Senft to drill a part in a modelmakers lathe. He *taped* the part to a face plate! Very clever, and it shows there is no limit to the ideas you can come up with to do odd jobs.

Pre-jigging is actually a jig within a jig. You might say a part was held in a jig which was then held in the drilling or milling jig.

PIPE CLEANERS

It's a good idea to keep pipe cleaners handy in your shop area. They will wipe the chips and cutting oil out of drilled holes or grooves. They can reach into corners to clean or apply oil or other fluids.

Most layout dye containers have a brush in the cover which often is too large or applies too much dye. Touch a pipe cleaner to the brush and transfer a light dab to your small parts. Snip off the end of the cleaner and it is ready for some other job.

The same applies to soldering acid flux. By cutting off the end, it is reusable and less apt to rust tools and parts it might touch.

MEASURING

If you wish to work to close limits, develop good measuring habits.

Measure by eye with a scale and then check it with a mike, even though the tolerance isn't that close. It is good practice.

Measure parts with a vernier caliper and then with a mike. If they don't come out alike, use a magnifying glass and study the vernier scale to see if you would now read it differently. In other words, use the mike and vernier a lot.

When you are approaching the final cut, you always make lighter cuts and measure often.

Somewhat the same applies to the square. The tolerance is generous but try it for squareness anyway. It will take a bit of time but it tells you how good your machine is and how well you are doing on your lathe or milling machine.

My father was a millwright and carpenter. When I was a kid, making bird houses, etc., he said to me, "Make all the cuts to size and square. When you put it together, it will be square." A bit simple and homey but it applies to machine shop, too.

If it doesn't come out square, there may be a small chip clamped under one corner, or you didn't get the vise squared up on the machine. Maybe the keys in the vise are too sloppy in the T-slots. Use a junior indicator and check to see if the vise jaws are parallel to the table travel. If you are

doing repeat operations, you always brush out the holding device before inserting the next part.

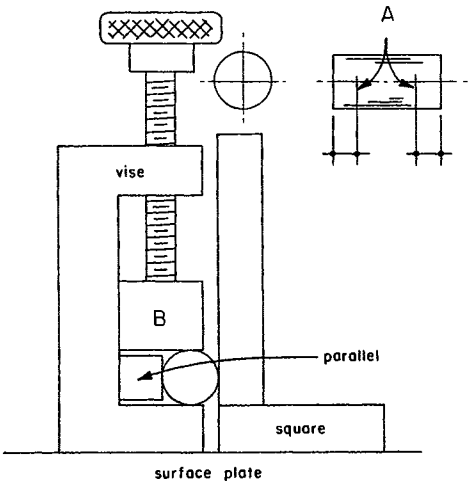
LAYOUT HINT

A very handy item in your shop is a vise that is square in all directions. Square, that is, so an object held in the jaws can be squared up with a face of the vise and the vise used in the normal position or on its side or on its end.

This item will show a quick way to center a drill on a round part:

Often you wish to drill through the center of a rod and struggle to locate the punch mark centered between the jaws.

Apply layout dye to the surface you wish to drill. Scribe the cross lines for locating the holes lengthwise on the part as shown at **A**. Mount in the vise as shown at **B** and lightly slide the square along so it will just make a mark in the dye, crossing the lines **A**. Use a magnifying glass and prick punch on the crossed lines; centerpunch, and the part is ready, mounted and punched for drilling. The drilled hole will be very close to rod center.



CUTTING OIL BRUSH

Cut the two outside rows of bristles and the plastic off a 3-row tooth brush, leaving just one row of bristles. You now have a handy way of applying cutting oil to a parting cut.

Load the bristles with cutting oil and hold in the groove. It will continue to supply oil to the cut for some time. Keep this brush, loaded with oil, handy on any cutting job on steel. A light pass over the surface makes for better cutting.

While on the subject of cutting oil, we might mention that newcomers to machine shop can obtain cutting oil at most hardware stores. Ask for "pipe thread cutting oil" in the plumbing department. It is dark colored and looks messy but it does a good job. Some people are sensative to this oil and may have to avoid it.

Another source of cutting oil I have been using for brass and aluminum is a popular liquid for loosening nuts on machinery, *Liquid Wrench*. Some handbooks mention kerosene for these metals. This stuff appears to me as deodorized kerosene. It is already in a spout can for easy application.

CUTTING COMPOUND

The next time you work aluminum, try Isopropyl alcohol (rubbing alcohol) as a cutting compound. My son works in a factory that makes relays, solenoids, etc. They often make test fixtures and prototype models to try in test cars. This alcohol is used out in the factory so it was tried for working aluminum. It carries heat away, there is no build-up on the cutting tool and it is inexpensive and clean. A hypodermic syringe is handy for this. Cut off the sharp point.

The alcohol will wash off surrounding layout dye. So, if you have further use for the dye and layout marks, a bit of care is called for to reduce the loss of the dye. Perhaps the sequence of operation can be changed to reduce this problem.

SOURCE FOR ROUND RODS

A good source of 1/16" and 1/8" round rods is Sears welding supply department. These rods are steel (copper coated) and bronze. The diameters are quite consistant, .062" and .124" for their entire length and straight enough to be used for small shafting applications. Of course, "shafting" this size means very small models, but you will find many uses for these in your shop. They polish up nicely and solder easy. Welding supply shops have more sizes and longer rods.

TIN-PLATED STEEL

If you have need for a small piece of fine tin-plated steel, try the containers of a popular vegetable shortening. Cut off the ends carefully to avoid a crinkled edge and flatten. It solders beautifully.

MARKING PENCIL

A handy item to have in the shop is a red china pencil or a grease pencil, one that will mark on glass or a polished surface. When you wish to return to a certain setting of the cross slide, note the collar reading and mark it with chalk on the compound body or some nearby flat surface. At the same time, use a red china or grease pencil to mark the collar at this setting. It is like a flag to catch your eye when returning to that setting. You can remember times when a mark or dimension would have been a handy reminder in later operations. It is not hard to rub out the pencil marks on smooth surfaces when the project is completed.

STARTING A JOB

When you are about to make a part for a model, sketch that part completely on a sheet of plain or cross-sectional paper. Make every line and dimension so you can work from it at the bench. This keeps your original print or magazine in clean condition.

The greatest advantage, however, is that you become thoroughly acquainted with the part and every little detail will show up. By checking your sketch against the original, you become very familiar with all details. This helps you with related parts

If you use a vernier height gauge and surface plate to make layouts, this gives you a place to red-pencil the vernier readings, make side notes, etc. By using this procedure, you will become quite proficient at sketching which is always handy if you see something at a show you wish to pursue further. It is like writing a name or date to impress it better on your memory.

A ROCKING CHAIR

I am not a young man and, after a couple hours at the bench or lathe, I like to sit in one of two old rocking chairs I keep in my shop.

After a short rest studying the part or print (maybe sometimes dozing), I feel like going on with a project.

These chairs also serve when I have visitors, at which time I drop everything I am doing as the chatter may be distracting and could cause mistakes or accidents.

The best thing to do is to start the air compressor or fire up a boiler and

show off some models and talk shop.

It requires a very special visitor to avoid distraction. He knows what you are doing and when to speak and how to lend a hand. He is fun to have around because he talks your language. It is also fun to visit his shop.

Maybe the best thing to do is to avoid anything too comfortable for visitors.

SUPPLIERS' CATALOGS

Many complain that suppliers charge too much for their catalogs. This comes about because people send for them and often never buy anything. They use them as dream books or wishing books to get ideas or just simply to get something in the mail.

Now, that is exactly what I like to do, so I have paid the price to several of the best dealers. I like to know what is available and compare prices, etc., and study them to get ideas.

A well-illustrated catalog costs money. The price of a catalog is about equal to the cost of a couple of paperbacks which are eventually thrown away or soon given away.

If you are a model nut like I am, you will use it for years, even save the old one when a new one is issued. I have one that was issued six years ago and has been patched up a couple of times. I feel I am less obligated to buy if I paid their price for the catalog. However, I do buy from most of them, though not in as large quantities as they would like.

Questions are asked by readers that would have been answered if they were acquainted with these catalogs. I consider some well-written catalogs as a small textbook of a sort and have learned quite a bit from them.

A CLEAN SHOP

In **MODELTEC** Magazine for June 1985, an item in the **Dots & Dashes** column contained a "puzzler" by David Farmer. It was a message written out in dots and dashes and it turned out to read, "How does Elmer Verburg keep his lathe so dog-gone clean?" This would be my reply.

Back in 1980 or 1981, Miles Snyder ran a series of articles on photography which I read and tried to use some of his methods and suggestions.

One of the articles dealt with the subject of "Photos Around the Shop" in which he stated, "Clean up the area you're going to photograph. Bring out the shop brush, get most of the chips off the lathe and sweep them into a dust pan. Then unlimber the Shop-Vac."

Now, I still need a lot of practice to make good photos but I hope my efforts are helping get across some of the steps in making models. I chose the clean setup, but it is hard to match the photos made by an expert like Miles.

If you are demonstrating an operation, the visitor will see the chips and all the clamps, bits of metal shims, and odd screws that got you by in a one-time setup. Is this more natural? Should this be photographed?

This gets into an interesting subject. We all like to visit other modeler's shops. Is it more fun to visit, say, a woodworker's shop and find a vast confusion of stock and trimmings leaning, stacked and underfoot, well-covered with find sawdust — and here and there a half-finished or abandoned project and some mysterious looking tool or jig that gets your curiosity worked up? You can't walk through it without getting dust spots on that dark blue suit and the whole thing is in orderly confusion so that only the owner can lay his hands on anything he needs.

Or is it more fun to visit a "spit-and-polish" shop? They both have interesting points. Is one a jolly fellow who always welcomes you and can dig out interesting projects to talk about, or perhaps is the shop a hobby and not what the shop can produce?

The same applies to a machine shop with metal chips, oil, bits of rust and dust. I consider my shop as a happy medium since it is in the house and you know I have to be careful about tracking chips around about. A visitor in a slicked-up shop may feel out of place though he can most likely solve problems quickly and as well with his own methods. He can work wonders with an old restored lathe.

BUILD A BOX BASE FOR YOUR MODELMAKER'S LATHE

There are some simple modifications you can make to a modelmaker's lathe, such as a Unimat, which makes it easier to use.

Start with a box base made from thick material which gives some weight and body as well as providing storage space for attachments.

The outside dimensions of the box base for my modelmaker's lathe are 17" long, 9" wide and 5-1/4" high, You can start with those dimensions and modify them to suit your equipment.

The corner joints are rabbeted, glued and nailed. The drawer front is 3/4" thick and the sides and back of the drawer are 1/2" thick. The drawer bottom is 1/8" hardboard, set in a groove. Squares of rubber were cemented to the bottom to prevent skidding and marring table tops. Handles at both ends make it easy to carry while a push button catch on the drawer prevents it sliding open if the box if tilted while moving it about. The size of the drawer is such that the vertical column and arm will fit inside easily.

A cloth cover is arranged to fit into clips at the back when the lathe is in use. It is made from upholstery material.

This box base has greatly improved the setup time as all attachments are always with the lathe and ready at all times. The weight of the attachments also adds to the stability. A final point in favor of this base is that the increased height brings the work nearer eye level.

I didn't like changing those tight belts, so I made a speed control for the motor. This was attached to the idler pulley mount. Last of all, the line switch which came with the lathe seemed unhandy, so the motor switch was built into the speed control.

SOURCE FOR SPRINGS

Scrounging is an important part of participation in metal working hobby activity. As you will note in these articles it is often suggested that you "search through your spring collection" for example.

A good source for springs can be found in present-day typewriter ribbon and computer ribbon cassettes or cartridges. The plastic cases can be pried apart easily with a screwdriver and you will often find two or three small springs used to keep tension on the ribbon.

Another source for springs is found in worn-out ball point pens. These often have a long, small-diameter spring to actuate the extension and retraction of the point.

If you don't have direct access to discarded ribbon cassettes and cartridges, check with the secretary at the office, family members or friends who hold jobs where it would be no great problem for them to watch for these sources. Thousands of fine small springs are thrown away every day! They are mighty handy in your shop.

Cutting a Tapered Keyway

The flywheels for a small hit-and-miss engine called for tapered keyways. This is how they were made.

A small bar, similar to a boring bar, was made. The cutting bit was made the width of the keyway and the bar mounted in the boring tool holder, carefully centered. The tiny cutting bit was set to cut when pulled (not pushed) through the 5/16" shaft bore. As shown, a pin was built into the cutting bar at 90° from the cutting bit to serve as line-up for setting the bit on the horizontal center. The pin was sighted parallel to a square resting on the lathe bed.

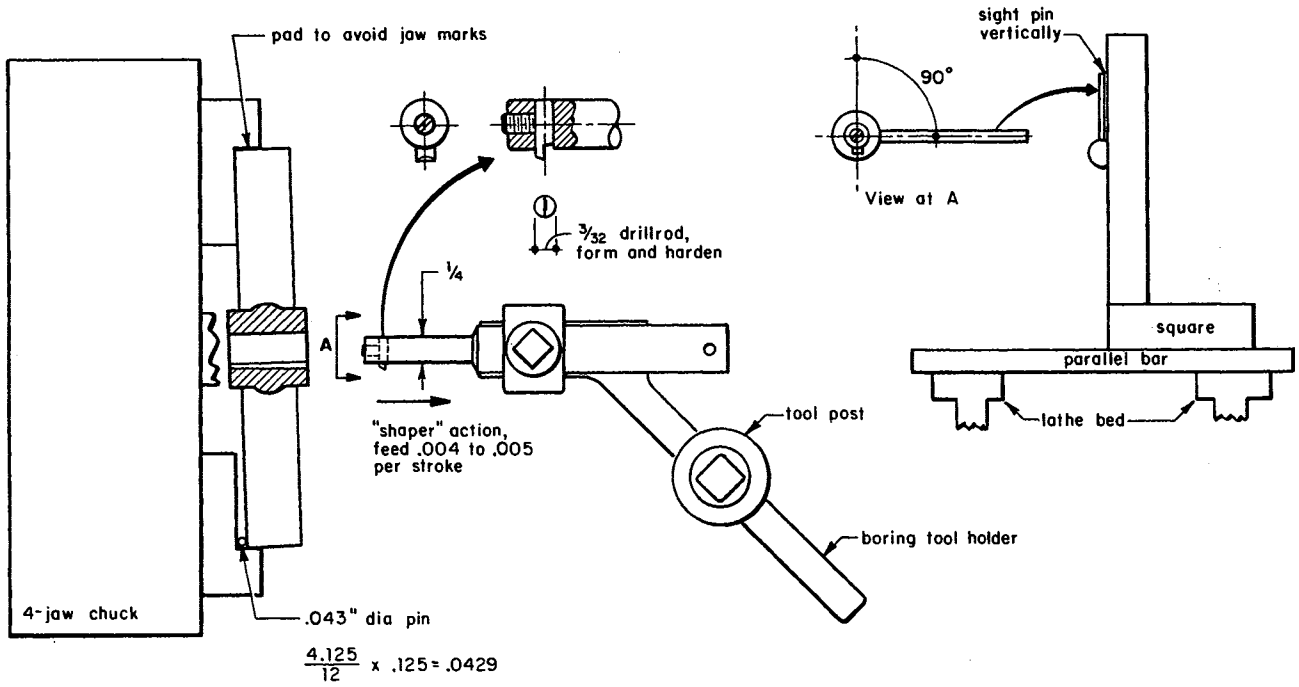
The flywheel was centered in the 4-jaw chuck and rotated so two jaws were horizontal, then the spindle locked in backgear. The top and front jaws were backed up only enough to be able to move the gear. Note the counterweight that was built into the casting and centered on the front jaw. The keyways in the engine crankshaft were centered opposite the crank throw so, when assembled with the flywheel, the counterweights were in the right relationship to the crank.

A .043" diameter pin was placed under the flywheel at the front jaw and the two jaws carefully tightened. This .043" pin positions the flywheel at an angle of 1/8" taper per foot.

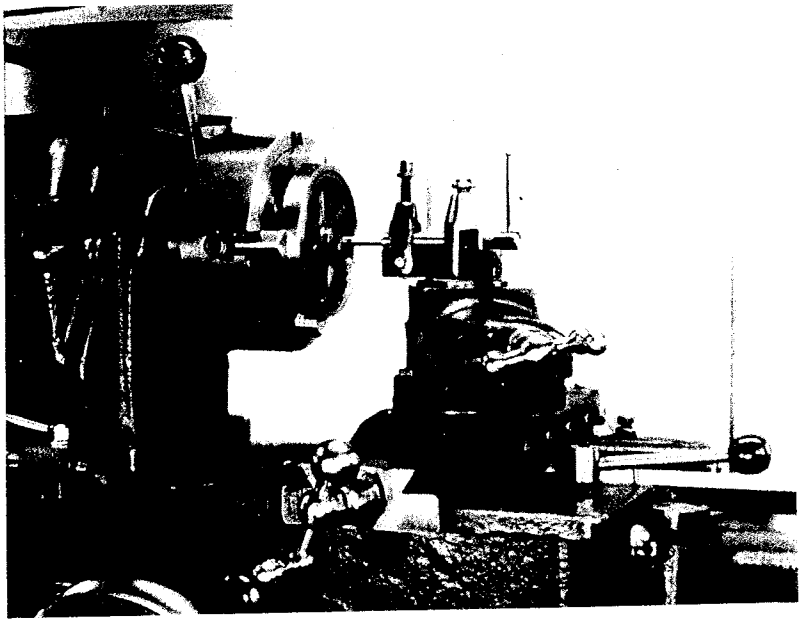
The lathe cross-slide was backed up until the cutting bit just touched the 5/16" bore at the outer face and the collar set at zero. The bar was run through the hub, backed up .004" to .005" and the bar drawn out of the bore. By taking the light cuts, using the lathe carriage like the ram on a shaper, the passes were made until the tool was backed up a total of .047". An inside measurement across the bore plus keyway depth should be 5/16" plus 3/64" equaling 23/64" at the outside edge (.359" measured with a Vernier caliper.)

The gib-head key (you just learned another machine term) was made parallel at 3/32" and tapered carefully with a file, bit by bit, until it fit the keyway in the assembled flywheel and crankshaft. Only about .008" had to be removed at the narrow end.

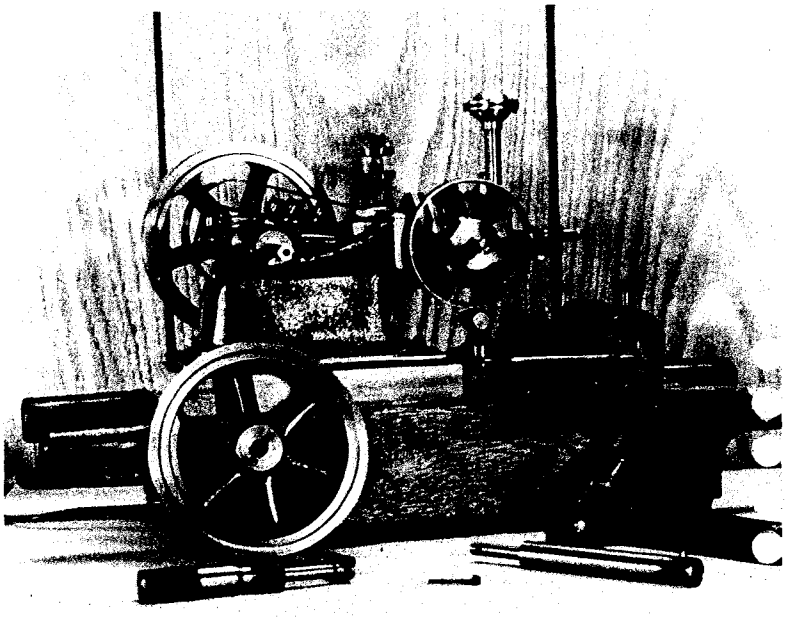
An expert with a tiny file may be able to file the .008" taper after making the keyway to the shallow depth. This method described above seemed more accurate. You may have use for this bar again some day. Setting the compound at 35 minutes, 47 seconds, might be difficult and you don't have much leverage for pulling the bar through the cut.



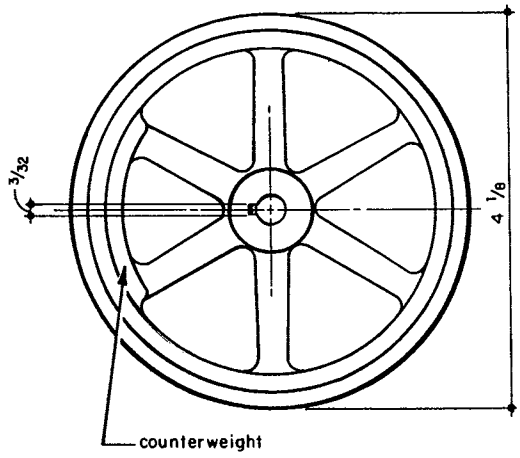
ref. 1/8 taper per foot = 0° 35' 47" included angle
ref. taper in 13/16 hub length is .0085 approximate

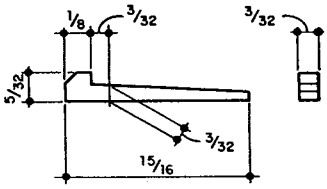


The flywheel and tool mounted on the lathe.

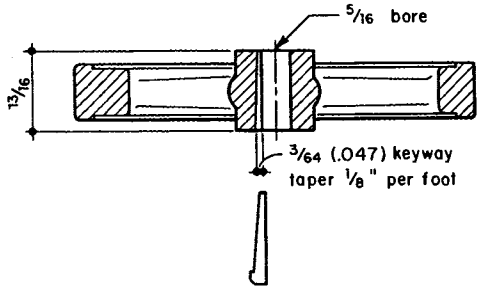


The hit-and-miss engine, flywheel and tool.





GIB-HEAD KEY



Modelmaker's Depth Gauge

On most Depth Gauges, you must hold the body of the gauge and also hold the Plunger down while tightening the Thumb Screw. This one is spring-loaded and you are more sure of the measurement. The Thumb Screw is up away from the work and easier to tighten. The 1/16" diameter pin reaches into holes as small as the tap-drill hole for a 2-56 thread.

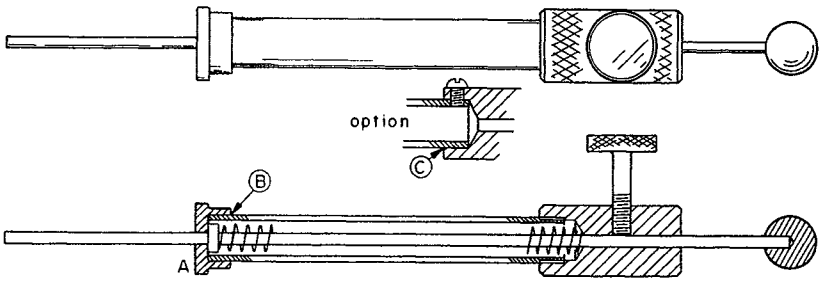
The material is optional. On the Gauge shown, the material is steel except for a brass Tube and Ball.

The construction is mostly straight machine shop turning and threading. The face **A** of the **LOWER CAP** should be square with the axis of the Pin. The main **TUBE** is soldered into the Lower Cap and threaded 1/4-40 into the **UPPER CAP**. The 40 series taps and dies are great to have on hand for threading thin wall tubing and threading close to a shoulder as on a packnut. If you don't have 1/4-40, you might try a short 2-56 or smaller screw as shown. The Tube should be a close fit in the Upper Cap.

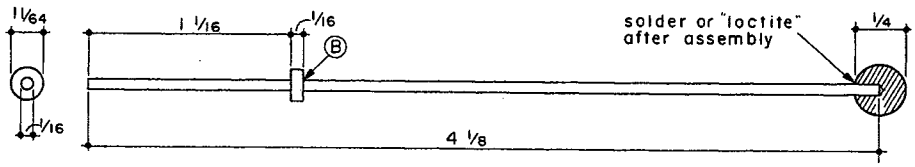
Before final assembly, give all the inside parts a coat of light grease. If you choose to knurl, a squeeze type of knurling tool is almost a must. The 1/4" Ball is optional. This can be a fancy little turning if you wish.

The **SPRING** used here has the proportions shown. If anything, it is a bit stiff. The wire diameter could be reduced about one gauge size. Try one of the springs in your collection. You may have just what it takes.

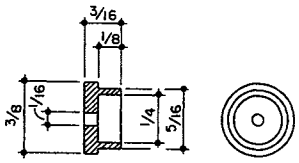
You can use the depth-measuring slide on your vernier caliper to measure the projection on this gauge and have the dimension within a few thousandths of an inch.



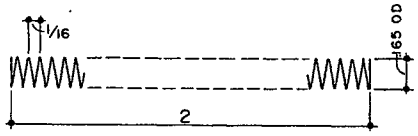
DEPTH GAUGE



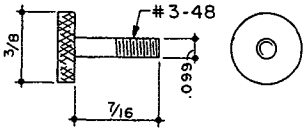
PLUNGER
Steel



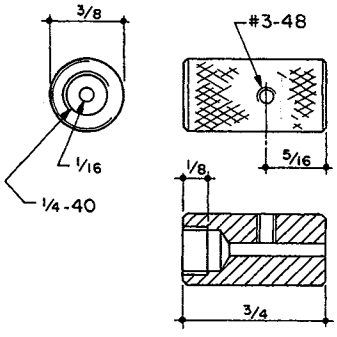
LOWER CAP
Steel



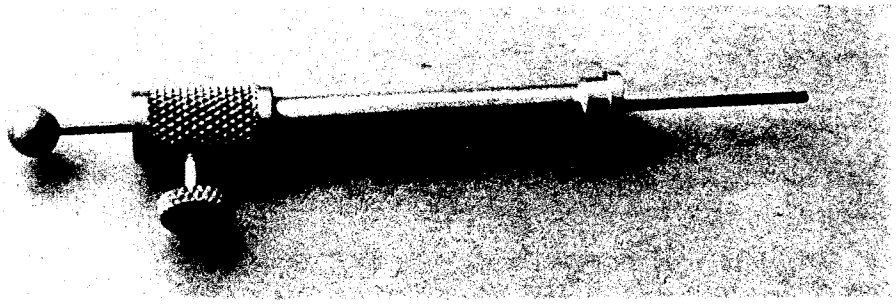
SPRING
Steel
.020" wire

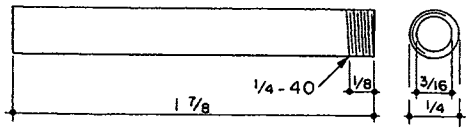


SCREW
Steel



UPPER CAP
Steel





TUBE
Brass

Modelmaker's Thickness Gauge

This is a gauge or caliper for measuring in places a standard caliper or mike cannot reach. It is a companion to the Depth Gauge on the opposite page. This tool can be spotted on the part you wish to measure and it will cling so it is quite self-aligning.

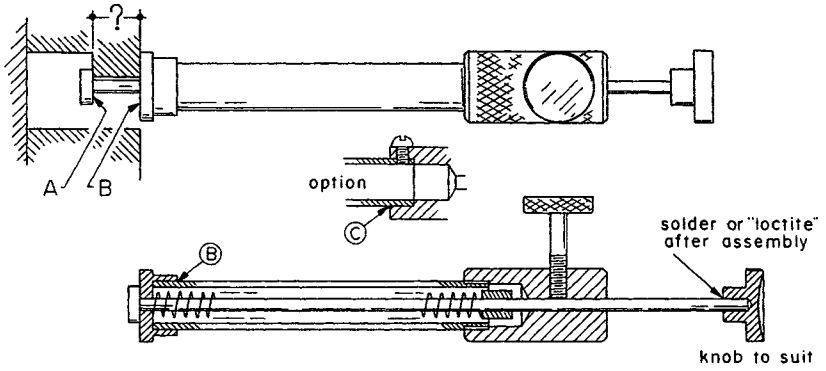
The material is free-machining steel except for the brass Tube on the one shown here. The machining is mostly standard machine shop practice and duplicates the procedures for the Depth Gauge. Any exceptions will be mentioned below.

The **LOWER CAP** and **SCREW** are the same as shown on the Modelmaker's Depth Gauge drawings.

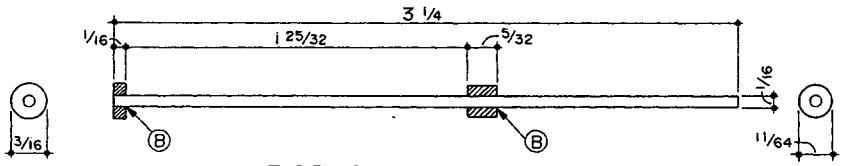
The inside face **A** of the Rod Flange and outside end **B** of the Lower Cap should be flat and square with the axis of the gauge for best results.

Assembly of this gauge is a bit of a problem. Make the 1/16" **ROD AND FLANGES** as shown. Solder the end flange and "true-up" the inside face if necessary. When you are satisfied with all the parts, assemble the Tube, Rod and Spring with a coat of grease. Wipe the Rod clean at 1-25/32" area. Slide the 5/32" Flange in place so it enters the Tube about 1/32" (this is to prevent catching on the end of the Tube). Hold the Rod in a vise or clamp in this position and add a drop of solder. A 1/4" length of about 1/8" aluminum wire between the 5/32" Flange and the vise jaw will give you a more open soldering condition with less heat conducted away by the vise jaws. The Spring pressure will hold it in place while soldering.

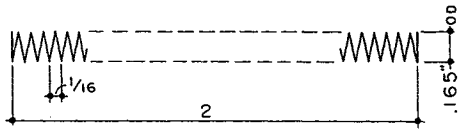
Measuring this gauge with the inside jaws of your vernier caliper will give you readings accurate to within a few thousandths.



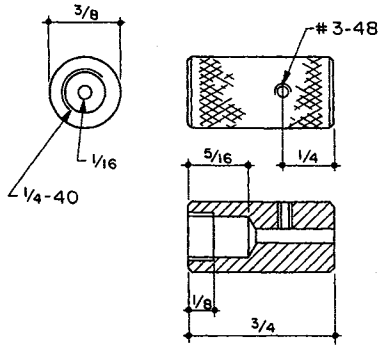
THICKNESS GAUGE



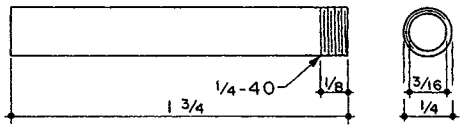
ROD AND FLANGES
Steel



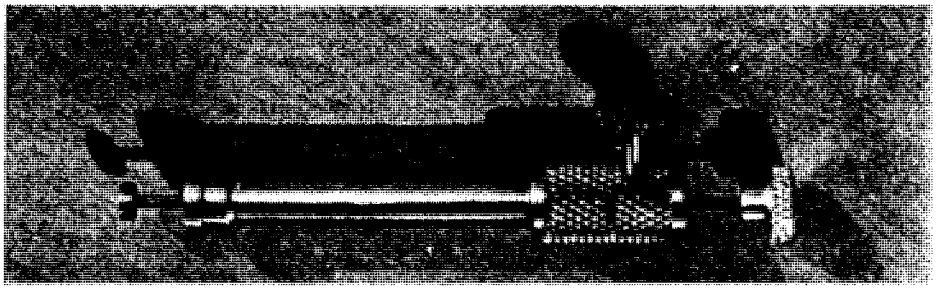
SPRING
Steel
.020" wire

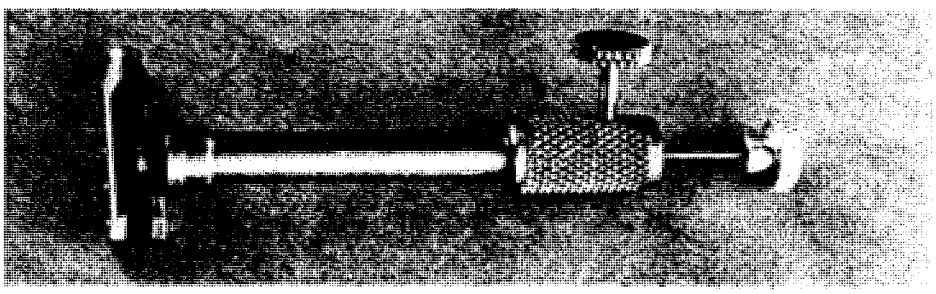


UPPER CAP
Steel



TUBE
Brass





The Modelmaker's Thickness Gauge is shown in the upper photo and in use, measuring the thickness of a brake clevis, in the lower photo.

Sheet Metal Punch

This is a general description, with a few dimensions, of a punch made several years ago. It was made almost entirely of salvage material. You may feel that you don't need as great a throat capacity and you can build it to suit your needs. The photo shows a brakelining tool conversion which started this project. It did a pretty good job, but had a few shortcomings.

The greatest feature on this Punch is at **A**. Most simple punches do not provide a point where pressure can be applied with the fingers while spotting and striking with a hammer. This feature of being able to hold the sheet firmly makes it possible to punch out washers, especially thin ones, for tiny models.

Say you want a .004" spacer 1/4" I.D. x 3/8" O.D. First, punch a 1/4" hole in the shim stock. Remove the 1/4" die and insert the 3/8" die. Run the 1/4" punch down through the 1/4" hole just punched. Hold the sheet in place and remove the 1/4" punch. Insert the 3/8" punch with your other hand. Strike a sharp blow and you have an accurate spacer if the punch and die are sharp and clearances small.

About those clearances just mentioned: on the examples shown, only about .001" was allowed on the diameter. According to the handbooks, the clearance goes up as the metal to be punched gets thicker. This outfit has been used many times on material from shim stock to common galvanized steel and from a plastic billfold calendar to 1/32" rubber and fibre gasket material. The more clearance, the more ragged the hole.

Punches **B** and **C** show a mild steel body with hardened drill rod pressed into the end. Punch **D** is all drill rod with a mild steel cap. **E** shows a typical die that should be made of tool steel. The dies on this outfit are case-hardened steel since no tool steel was on hand at the time. Punches **C**, **D** and **G** show the cutting edge curved to start the shearing action. Detail **K** shows how this was done on a small grinder. **G** shows a tapered shank which was not included in the punches made originally but will be considered next time to make it easier to pull the punch out of the sheet stock. About 1° taper should help. **F** shows another type of cutting edge that is turned to provide a center point which gives aim at a prick punch mark or centerline. It doesn't lend itself to resharpening.

Another point in favor of this tool is the guide which takes away one lineup problem. By holding the stock against the guide, you can make a series of holes located accurately from one edge. You only have to spot in one direction.

The extra removable bar, **H**, makes it possible to actually scallop the edge of a sheet.

Note the 3/16" dimension at **J** which is equal to the 3/16" dimension at the top of die **E**. Any size punches you wish can be made up to 3/8" diameter.

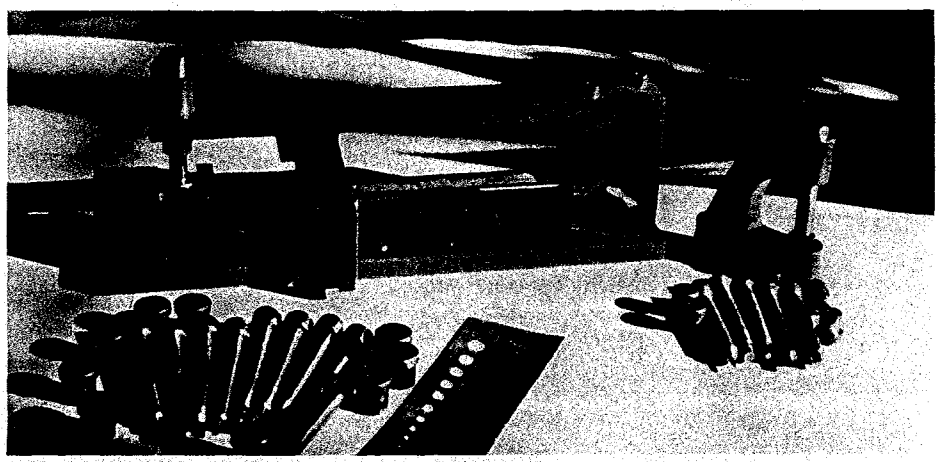
A future possibility for this tool is a rest block which would straddle the base and a slide block on the upper arm, held with a thumb screw. The slide block would have a spring-loaded, sharp-pointed pin to enter a prick punch mark in the center of a circular blank so a series of holes could be made in a circular pattern.

Another future addition could be a lever, perhaps like a crowbar, to help pull the punches out of the sheet metal. On some material, it is hard to remove the punch. Punch presses have strippers for this purpose.

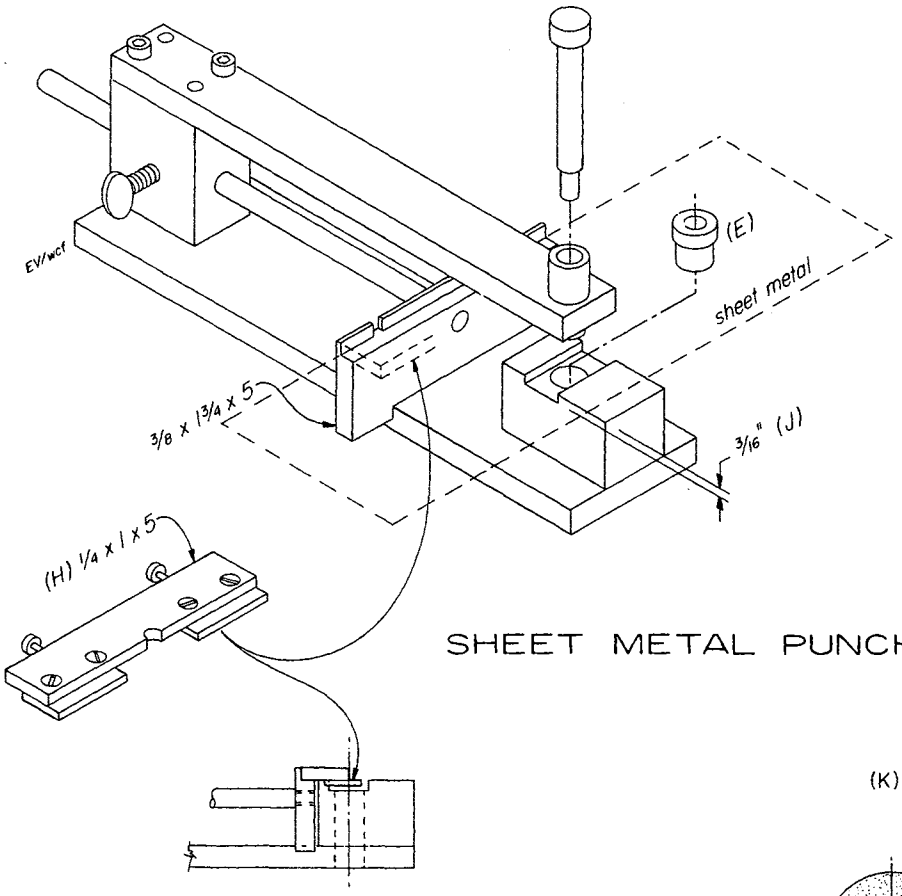
The kind of material, thickness, clearance, sharpness and punch alignment all affect the quality of the resulting hole. Out in industry, each punch set is designed to meet the material and hole quality called for in the part. Here, we have a single outfit for a variety of materials. This has been a good, all-around tool for light duty.

By turning some special punches, it would be possible to set snap fasteners, eyelets and rivets. The kits of eyelets and snaps have a tool that could be inserted in a special punch and die. A flairing tool for hollow rivets and a hemispherical header for solid rivets can also be added.

This tool came in very handy when making the sheetmetal lagging for small engines and boilers. Why not start one now for your shop? It will be a most useful addition to your shop equipment.

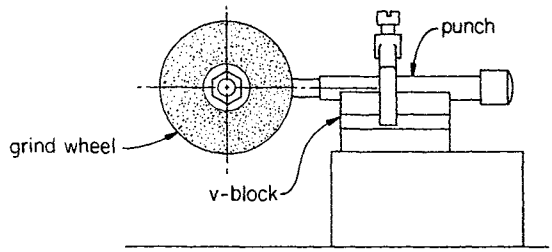


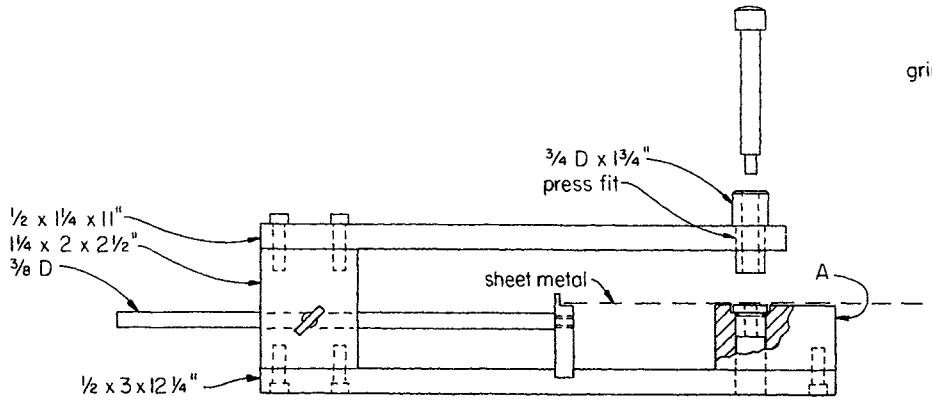
Safety First — and Always

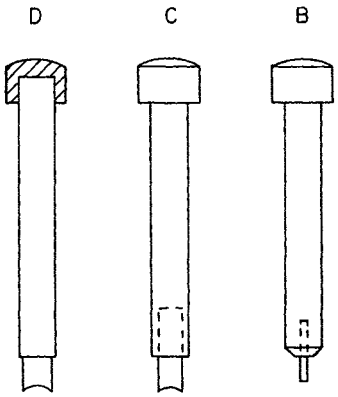


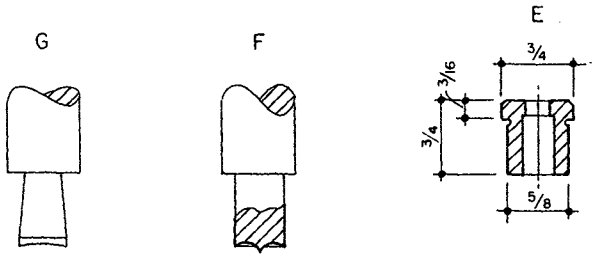
SHEET METAL PUNCH

(K) Punch D clamped to V-block and shimmed to center on grind wheel

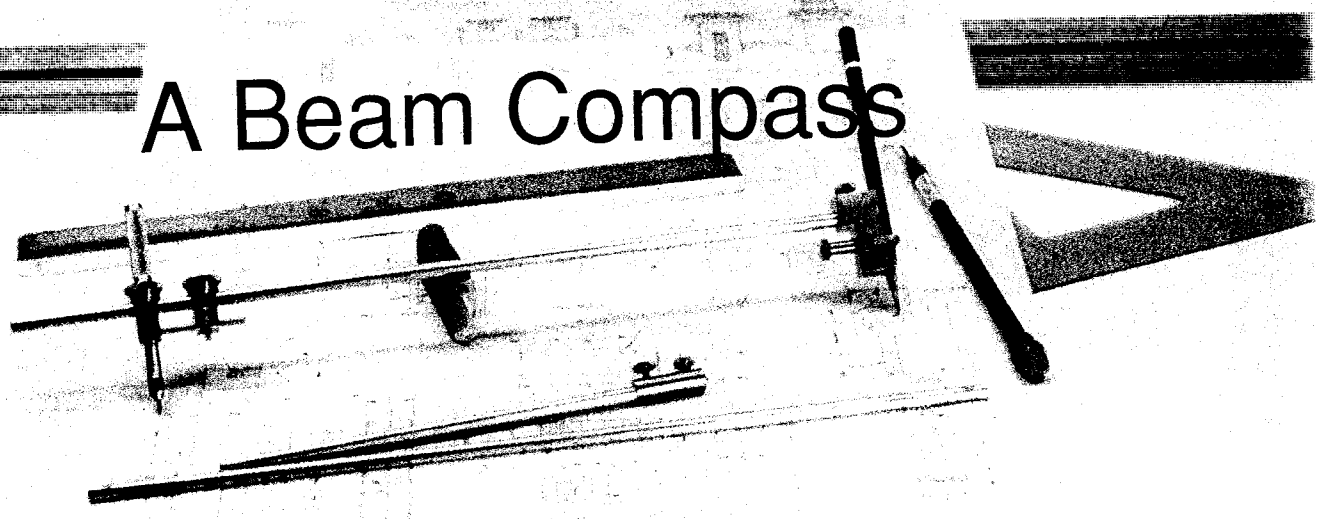








A Beam Compass



A Beam Compass is a project in some shop classes. This compass is different and has a feature not found in other designs. This one has a means to hold many different types of scribers and cutters.

The construction is common machine shop practice. The material is mostly aluminum with brass screws. The micrometer screw is steel.

The flats on the **BEAMS** can be filed by hand or milled in a cross slide milling attachment in the lathe.

The **VEE BLOCK** starts as a 3/8" x 3/4" x 1-3/8" block. All lines and centers are scribed and the three holes drilled. The V cut is either milled or done in the shaper. The slot for the Loop is centered on the 9/64" hole and finally the 1/4" x 13/16" corner cut away.

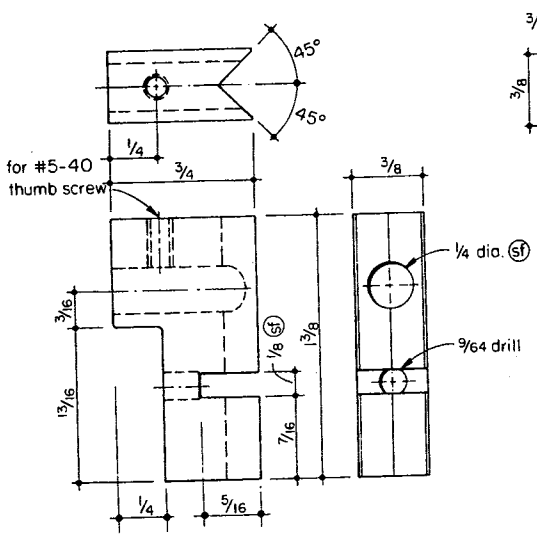
The needle shown is found among common drafting compass material.

Make several **LOOPS** to adapt the various scribes you will be using. The 21/64" hole is about right for general purposes.

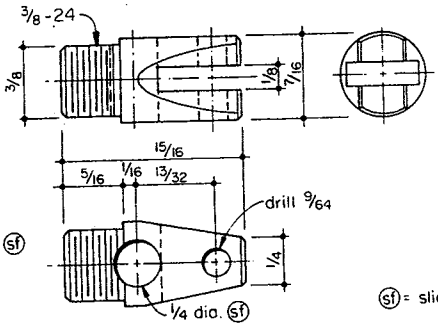
On the **CENTER SPINDLE**, lay out and drill the 1/4" and 5-40 holes first. The drill will catch on the shoulder if you thread 3/8-24 first. Turn, knurl and thread 3/8-24. A squeeze-type knurling tool is required to get a deep knurl. Chuck on the 7/16" diameter and turn the needle end.

The **ANCHOR** is first drilled 1/4" and 9/64", then the end turned and threaded 3/8-24. Grip in a V groove in the milling vise and mill the 1/8" slot. You don't have much of a grip on this piece, so take it easy. File or mill the taper.

This is another tool that will give you a few evenings of pleasure in your workshop and many years of service.

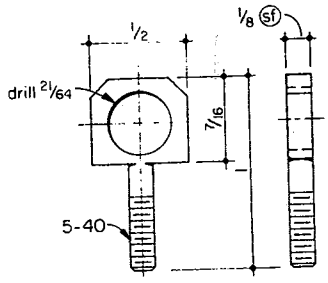


VEE BLOCK

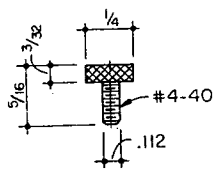


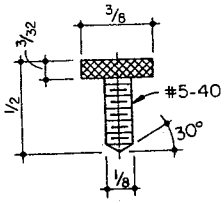
ANCHOR

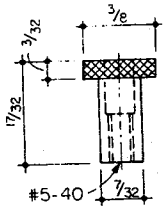
(sf) = slide fit



LOOP





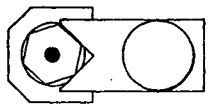


1 Required for Center Spindle

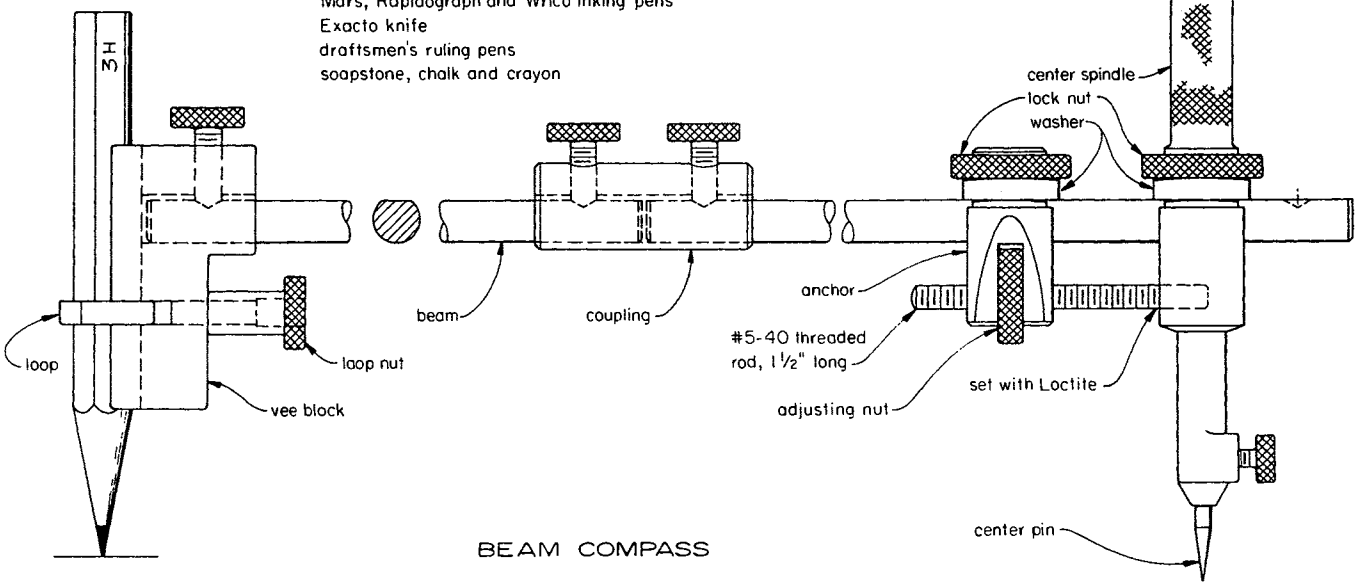
3 Required Coupling and Vee Block

THUMB SCREWS

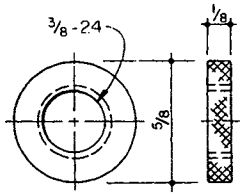
LOOP NUT



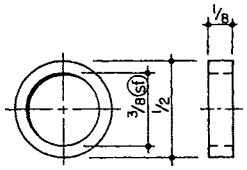
also can be adapted to accept
ball point and felt tip pens
steel scriber
Mars, Rapidograph and Wrico inking pens
Exacto knife
draftsmen's ruling pens
soapstone, chalk and crayon



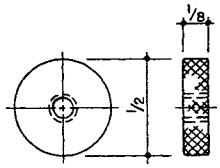
BEAM COMPASS



LOCK NUT
2 Required

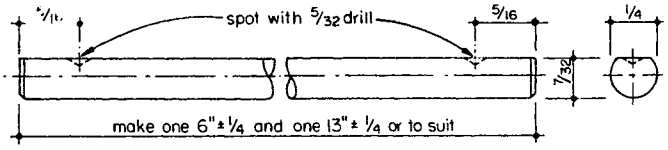


WASHER
2 Required

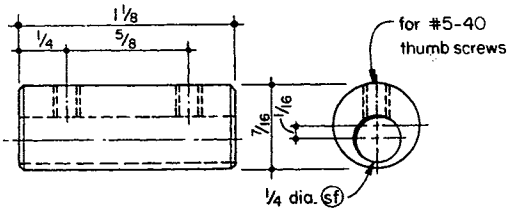


ADJUSTING NUT
1 Required

CENTER PIN
1 Required

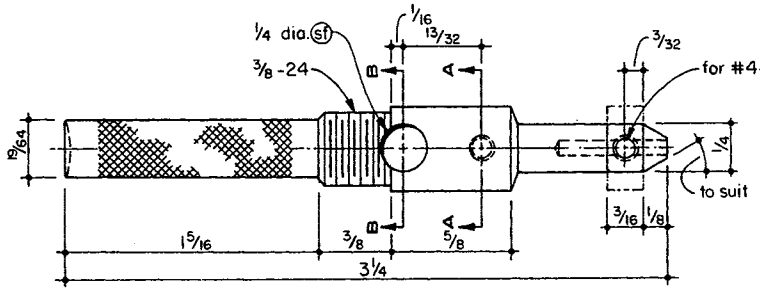


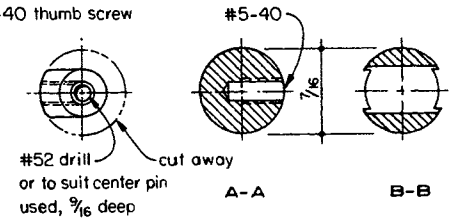
BEAM
2 Required - lengths as indicated



COUPLING
1 Required

(sf) = slide fit

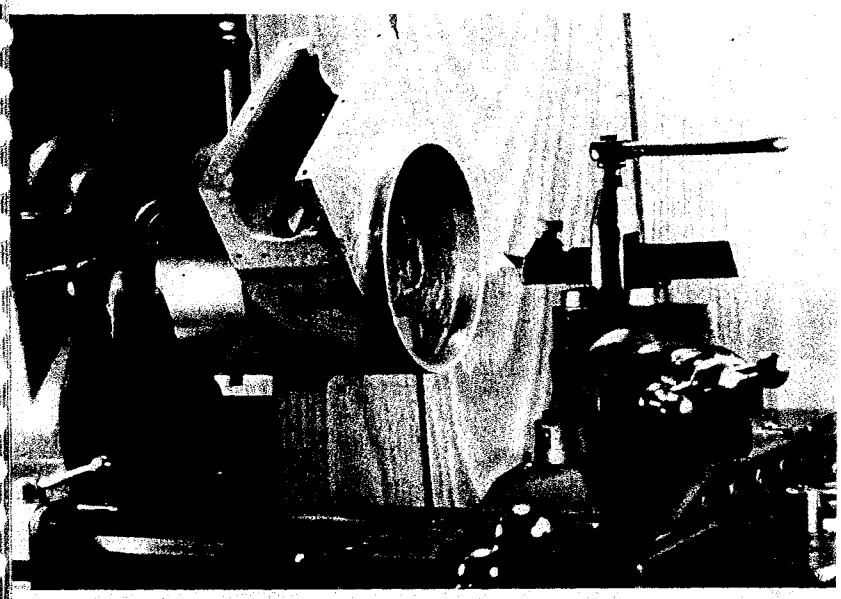


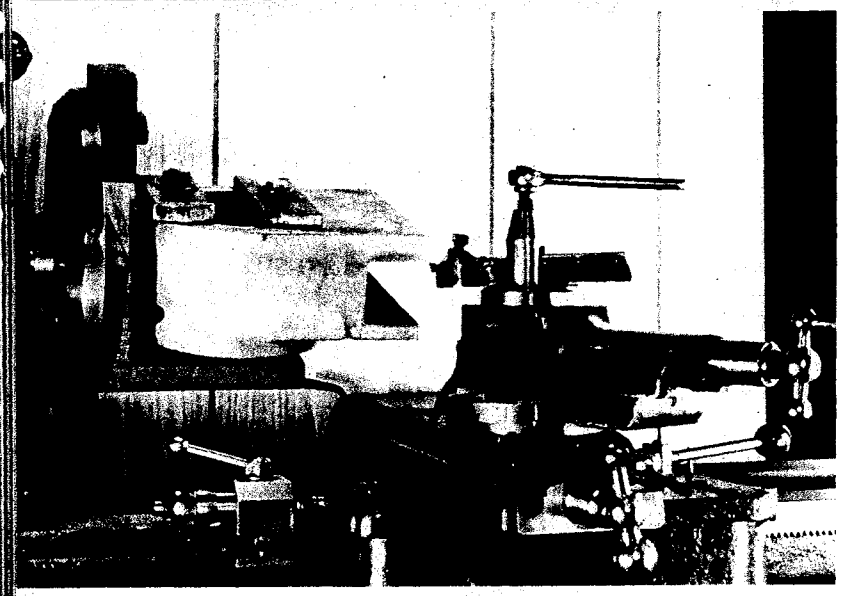


CENTER SPINDLE
1 Required

EV/jlw

Simple Turning and Machining Hints





A one-piece aluminum locomotive smoke box required machining on a flange that meets the boiler. After cleaning up the casting with a file and checking for squareness, etc., it was ready for turning. The 8-1/2" face plate on my 12" lathe didn't leave much room for clamps.

A 6" 4-jaw chuck was finally used. Two jaws gripped the outside and two jaws the inside of an opening opposite the flange to be turned as shown on the sketch below and the photo at the left. It held good and, with light cuts, the flange was turned to size. You have to study and try ideas for such jobs. You will not find anything in a book telling you how to do such an operation. This was a simple solution that didn't require any special clamps or fixture.

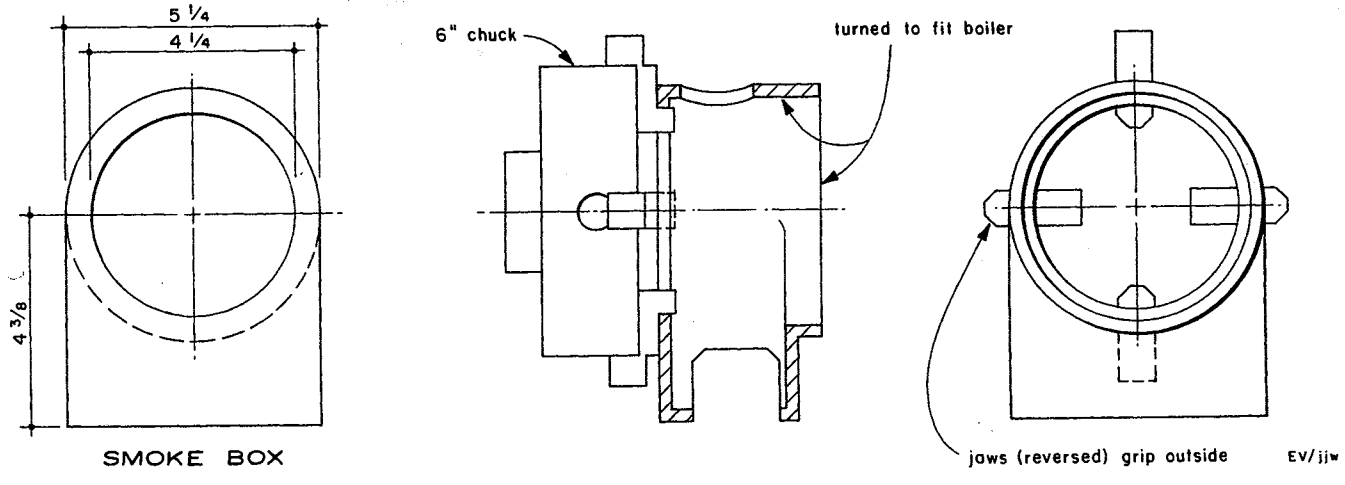
The next operation required the bottom edges to be machined square with the axis of the box and a definite distance from the boiler centerline.

The 8-1/2" face plate and an angle plate were used as shown in the lower photograph. A sheet of brown kraft paper between the work piece and the angle plate can reduce the threat of slippage.

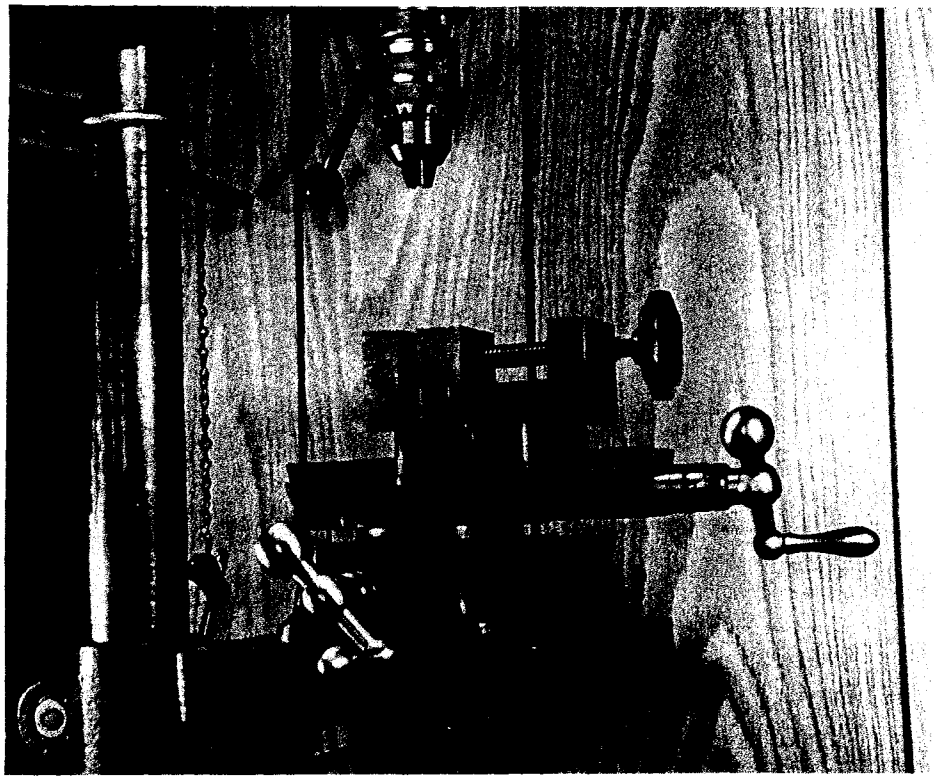
The process required a jump cut; but, by taking light cuts and a bit of time, the bottom was machined to print. Note how much overhang there is and the need for extra care.

Good use was made of the carriage stop. It was backed up .015" to .020" for each cut and no great shocks went through the piece while turning. Also, a heavy block of steel was clamped to the face plate to help counterbalance the offset weight.

This is just another tip to keep in mind, along with a word of caution for a clumsy, whirling, knuckle-buster.



Adapting



If you have the #965 slide rest for the Delta #1460 12" wood-turning lathe, you have the base for a cross-slide vise for your drill press.

Remove the bottom lathe adaptor plate and mount the slide directly on the drill press table. Fit a bar in the top slide T-slot and attach a small drill press vise to it. You do not drill or otherwise alter the slide so it is always available to return to the lathe.

Your vise will determine the type of clamping you will use. Two 1/4" set-screws hold the bar in the slide and two special clamps engage slots in the side of the vise. Keep the top of the bar below the top of the slide so the vise will bear on the slide when clamped.

This is still another way to get additional use out of your shop equipment that might otherwise be setting idle.

O&E/B

Hardening

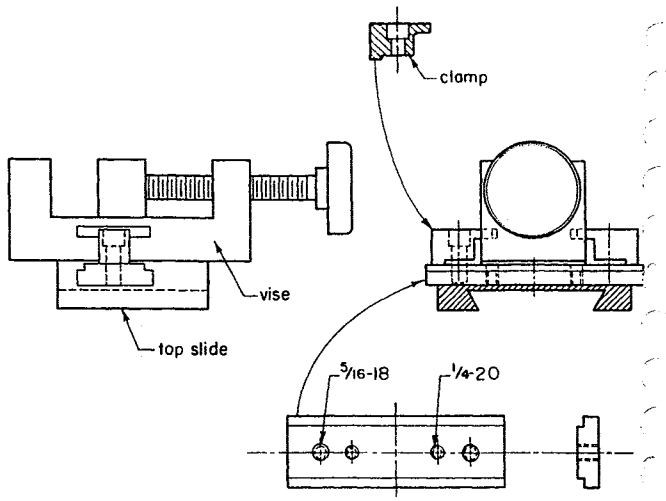
As an amateur tool maker, I spoiled more hours of work than I care to remember, trying to harden drill rod products by heating them to "cherry red" as specified in various articles. You don't have to misjudge the color by very much to "burn" steel by overheating it.

When steel reaches its critical temperature for hardening, it loses its magnetic properties. This fact of life provides us with a nearly foolproof method of indicating that it is hot enough. As you heat the part, just keep touching it with a magnet. When the magnet ceases to attract it, the part is the right temperature for quenching.

Frequently, I find it convenient to hold parts similar to the centering pin (i.e., special milling cutters) in a holding device in the chuck of my drill press, and then lower it into the quench when it reaches critical temperature.

I've been batting a thousand in my hardening operations since I adopted these methods.

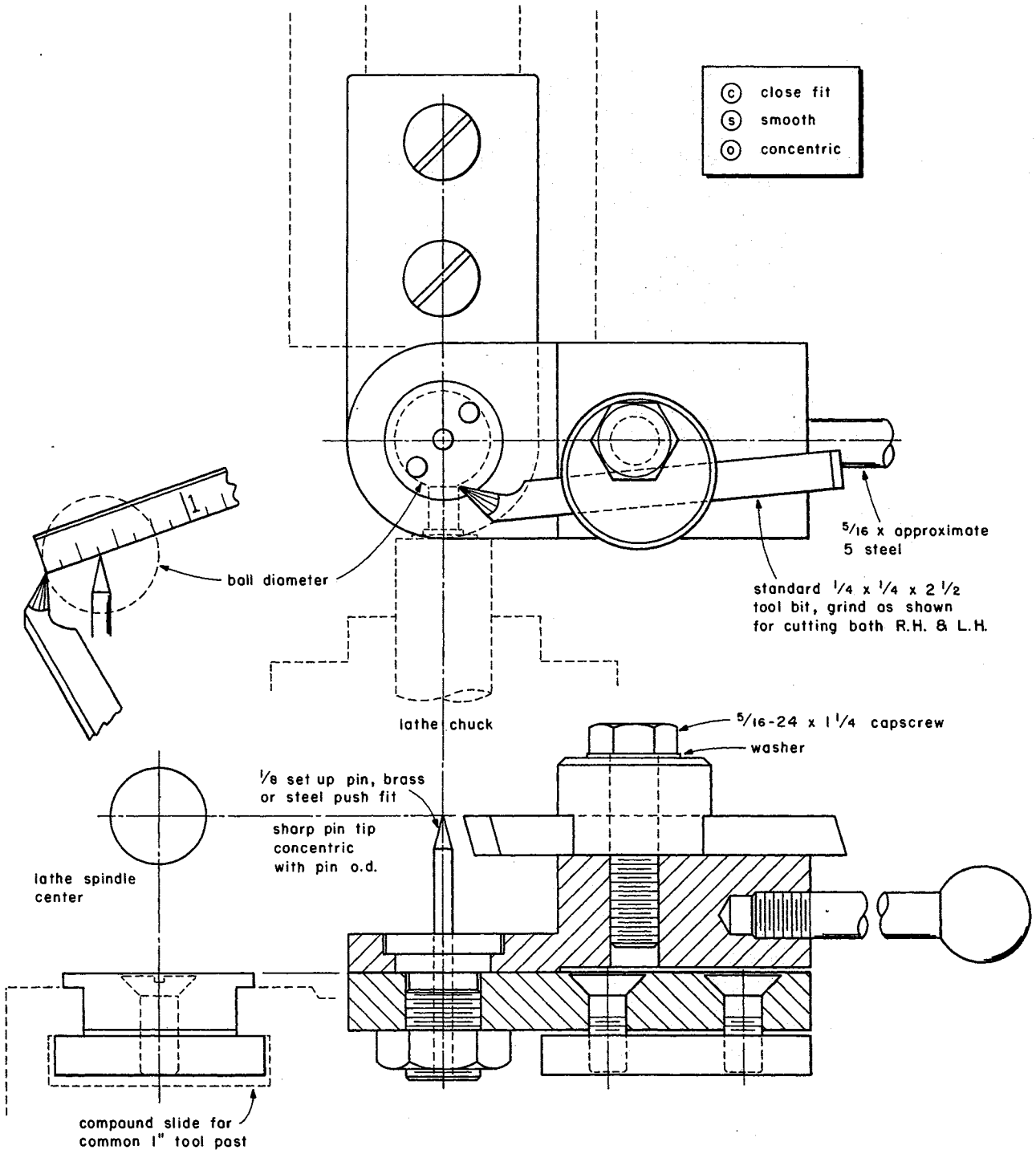
Luke Lukins



Ball Turning Tool

This is a handy item for the metalworking hobbyist; it is not a production tool. A 1" diameter ball can be made with surprising accuracy and finish. Unlike some ball turning attachments featured in past shop articles, this one does not require removal of the compound- or cross-slide. It goes into the tool post slot in the tool rest and requires about the same setup time as a boring or threading tool.

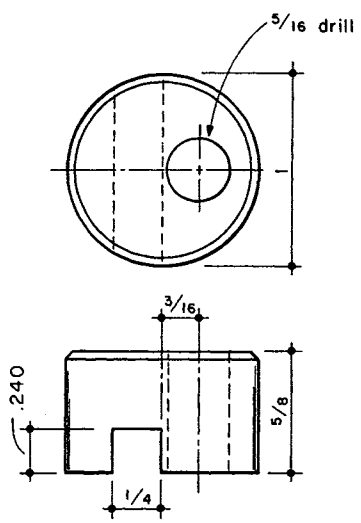
Some proportions have to be adapted to your lathe since this design is for lathes that have a 1" diameter tool post. The closer you make the fit of the rotating block, the better will be the accuracy and finish of the



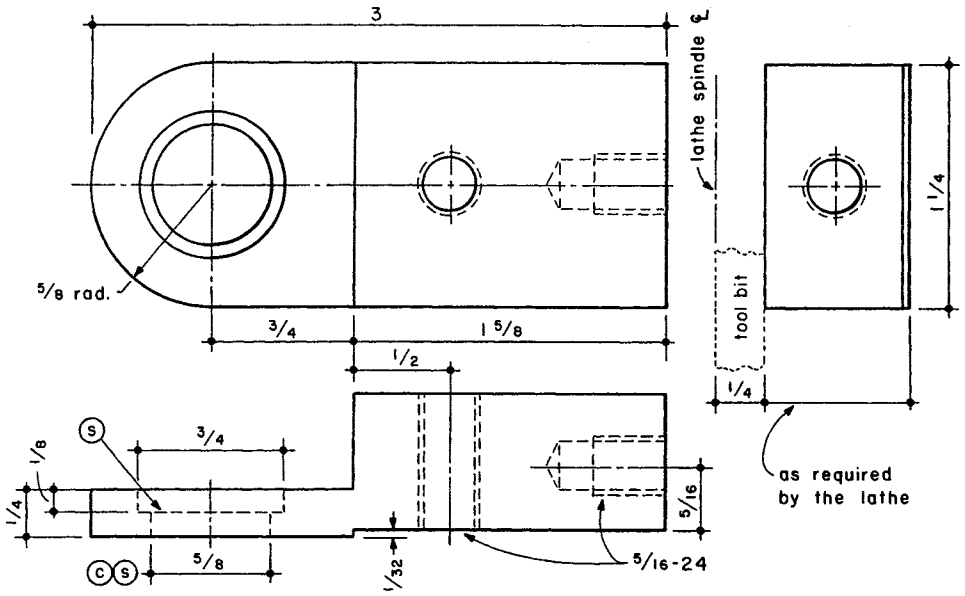
ball. There should be no looseness in the **TOOL BLOCK**, and concentricity is quite important between the shoulder screw bearing diameter and the 1/8" hole for the setup pin.

To make a **BALL** for the end of the Lever for this tool, a "squarish" oversize ball is roughed out by eye with standard lathe tools. This is faster since the Ball Tool is not a roughing tool. The "neck" left supporting the ball can be quite thin because the final cuts will be very light. Bore about 2/3rds through for a drive fit on the Lever Shaft. Chuck the Lever with the rough ball about 1" from the jaws.

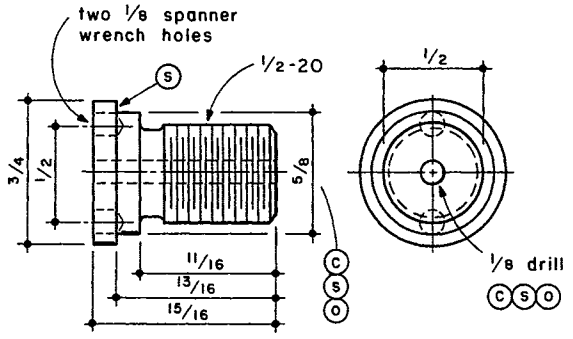
Mount the tool on the tool rest, overhanging to the left. Insert the setup pin and run the cross-slide in until the sharp tip just barely touches the sharp point of the tailstock center. A magnifying glass is handy here. Set the cross-slide collar to zero. Now set the tool bit half of the desired ball diameter away from the sharp tip of the setup pin, well to the left so the tool body will not strike the chuck before completing the left side of the ball. Remove the setup pin



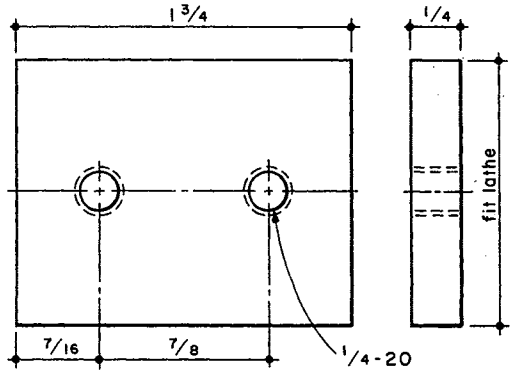
TOOL POST
Steel



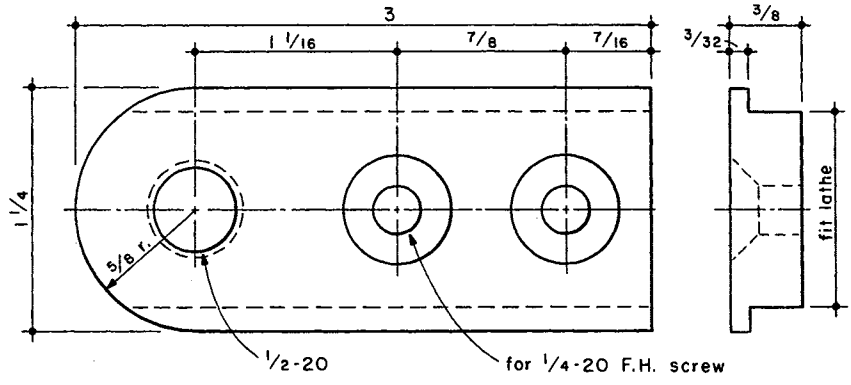
TOOL BLOCK
Steel



PIVOT SCREW
Steel



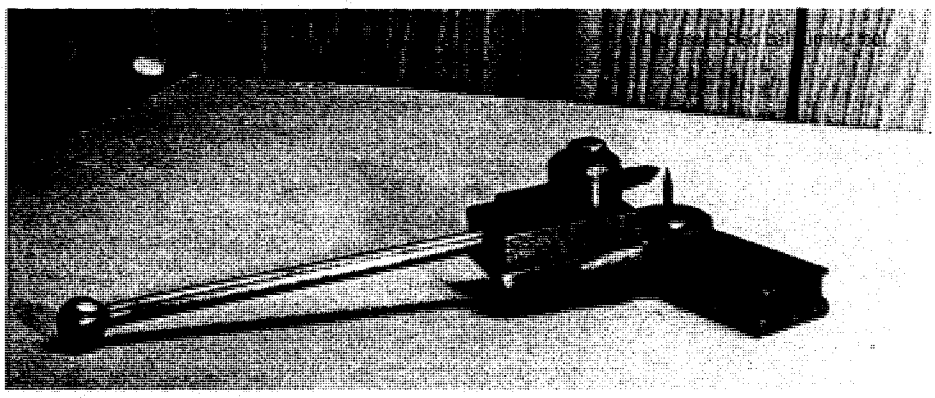
CLAMP
Steel

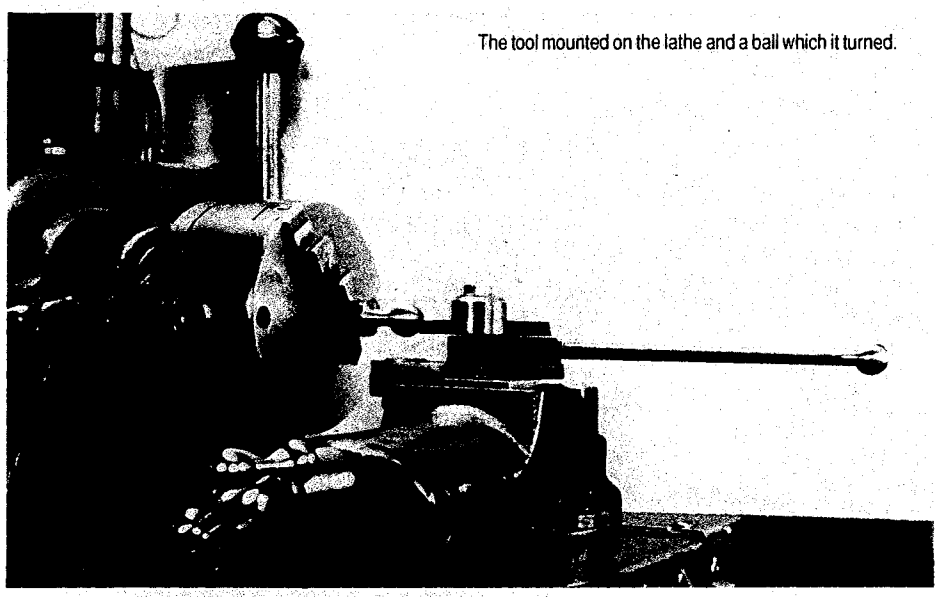


BASE
Steel

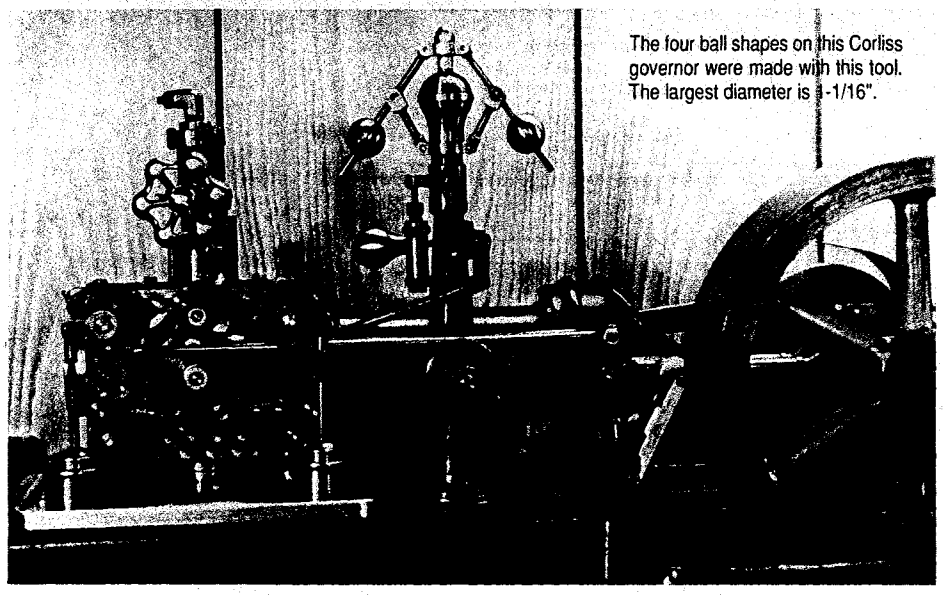
and, with the tool bit to the right, run the carriage until the tool pivot is under the rough ball. Use a 5/16" bolt as a temporary lever. With the cross-slide still at zero, stop the carriage when the cutting tip of the tool bit just touches the rough ball at the spindle centerline. Back the cross-slide away and move the carriage left .010" to .015" and lock it. This leaves "finish" on the right hand side of the ball. Now start turning the ball with very light cuts. Advance the cross-slide slowly, at the same time rotating the Tool Block, looking for the first sign of cutting. Make 180° turns of the Lever after each advance of the cross-slide.

As the ball takes shape, you can compensate slightly right or left with the carriage to "clean up." When the cross-slide reaches zero, you should have a round ball close to the desired diameter.





The tool mounted on the lathe and a ball which it turned.



The four ball shapes on this Corliss governor were made with this tool. The largest diameter is 1-1/16".

O&E/B

Close Tolerance Holes

There are times when a hole is needed with a minimum amount of clearance between it and the mating part. A reasonably close tolerance can be held, using a couple of drills and an end mill.

A drill press can provide accurately drilled holes, but if accuracy of position is also needed, a mill or lathe is needed.

Drills have a tendency to cut oversize. This is more noticeable with a drill bit that has been reground. The main cause is due to different lengths of the cutting surfaces, regardless of how small the difference.

To get around this problem only requires a couple of simple steps. First, drill a pilot hole to within 1/16" of finish size. The second step is to use an end mill whose diameter is within .010/.020" of finish size. The end mill will cut like a boring tool and align the hole true to the spindle. This should be done at a slow feed to reduce any tendency to deflect.

Caution — when doing these steps, the part must be held firmly on the machine because the end mill will have a tendency to throw the part when it first enters.

The last step is to drill to final size with the correct drill bit.

Doing these three steps will eliminate the effect of the differences in the cutting lengths of the drill bit and save the cost of buying a reamer or the time and effort needed to bore the hole to the finish size.

Larry M. Boyce

Carriage Stop

When converting an old 9" lathe to a milling machine, I needed a Carriage Stop. When a cut is completed and measurement shows say .005" more should come off, this Stop can be advanced or backed up .005" and a light pass made.

The lathe has flat ways so the Stop is simple. The **BODY** of the Stop is tap-drilled for the 1/4-20 Stop Screw and then used as a guide in drilling into the carriage for a Stop Button, using a small electric hand drill. It can then be tapped 1/4-20 for the Stop Screw. Try for a close fit on this thread to reduce backlash when making a setting. This is an opportunity to cut a thread in the lathe, using the Block as a gauge. When the Stop Screw starts to enter the Block, take very light passes until it will enter the Block with a close fit.

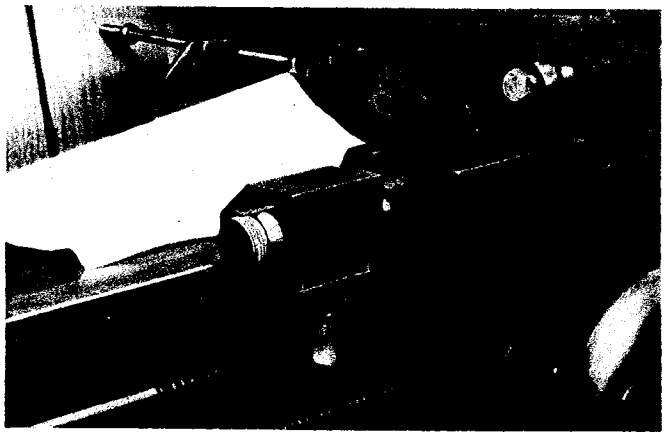
Twenty threads per inch is a good size for measuring in thousandths; one turn of the screw advances .050". The collar being small, only 25 divisions were made. It is easy to estimate 1/2 a space for .001". One space is .002".

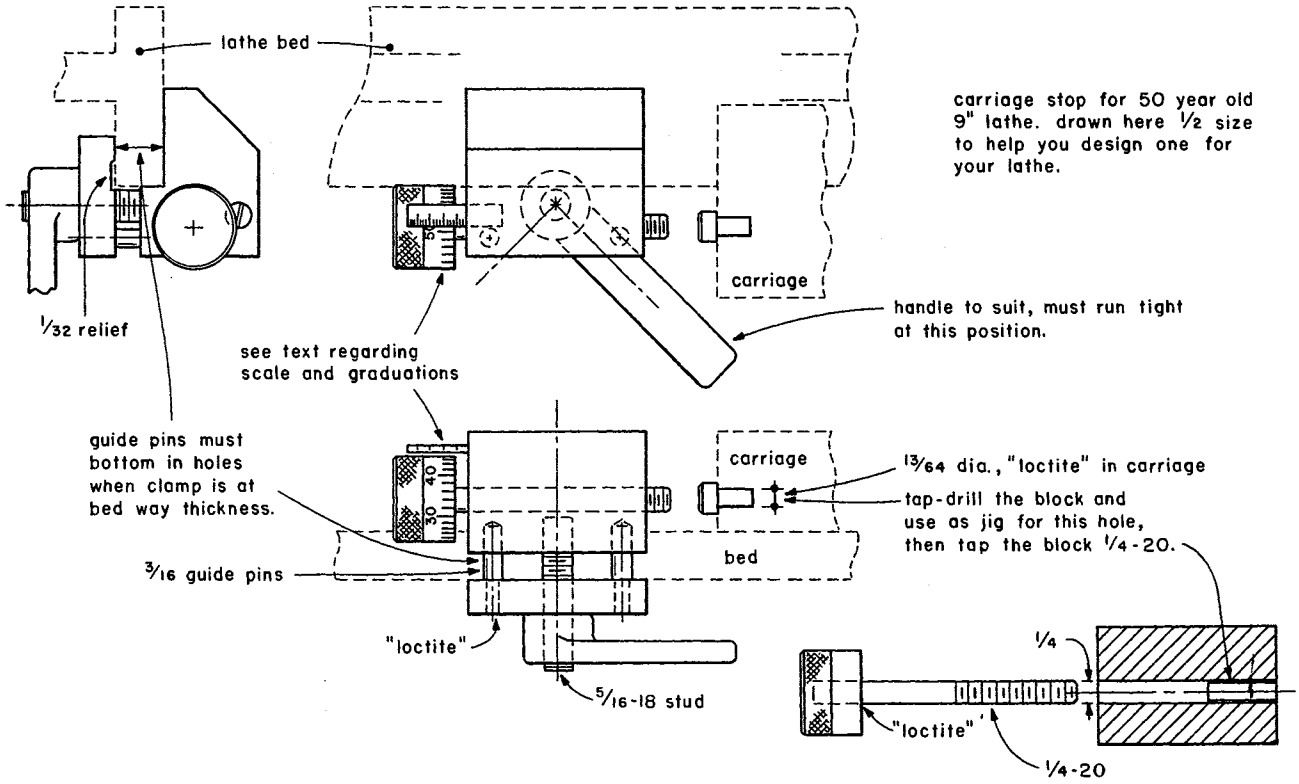
The Bar for reading the Collar is a short piece of a broken 1/4" wide pocket scale. It is a light drive fit in the hole. The centerline of the hole is 1/32" above the Collar and 1/8" back of the Collar centerline. Start the Scale in the hole and bring "0" around to the Scale edge and the Collar face approximately 1/8" from the Block. Drive the Scale in until a 1/8" mark is even with the face of the Collar while "0" is at the edge. It is good if the Scale is bearing slightly against the Collar to reduce creeping of the Screw.

Note the 3/16" Guide Pins also serve to back up the rear of the Clamp. This is a cut-and-try operation. When you are satisfied, set the Pins in the Clamp with Loctite. The ends of the Pins can be cone-shaped to match the drill point in the holes.

A thin washer may be needed under the Clamp Lever to bring it up tight at the right of center.

It is rare that your lathe has the proportions of this old lathe, so you will have to adapt to your lathe. This is a simple but quite accurate addition to your lathe.





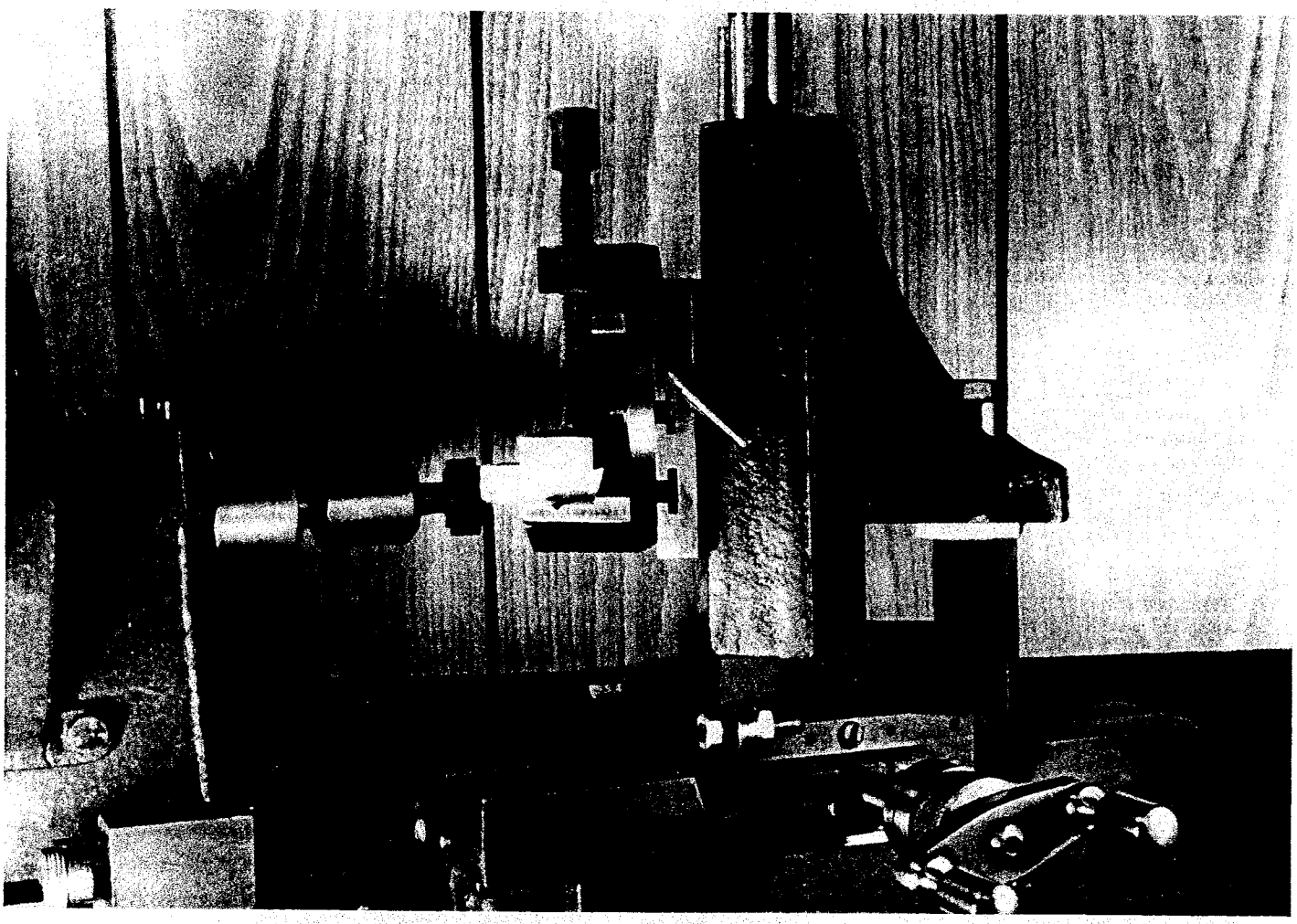
Cross-Slide Milling Attachment

I have a 12" quick change lathe that used this cross-slide milling attachment. Also, a simple 9" lathe purchased some fifty years ago was standing idle so the above attachment was permanently adapted to it.

The heavy angle block was salvaged from a scrap drill jig. It required a bit of shimming and fitting to mount the milling slide squarely. The cone-shaped anchor for the lathe compound was attached to the bottom of the heavy angle block. This allows the unit to be swiveled the same as the compound did.

The critical part is squareness. When you are done, the indicator must show zero in all directions of travel on the cross-slide.

Also, two stops were added (one shows clearly in the center foreground of the photo) so the unit can be turned 90° and the mounting face is either exactly parallel with the lathe bed or at 90° to the bed. Of course, the vertical travel must be square with the bed at all times.



Rule Safety First

Scribing Bolt Circles

For accuracy and concentricity, it is worthwhile to scribe a bolt circle while the workpiece still is mounted in the lathe. With a tool made as shown from a standard blank — or even from a broken drill or tap — both locating and scribing the bolt circle becomes a simple matter. There is no pressure on this tool, so it is not necessary for it to be very strong.

In use, first approximate the location of the circle on the workpiece and spin a band of layout dye on the face. Measure the O.D. of the piece with a micrometer and subtract the bolt circle diameter from it. Divide the remainder by two. This will be the amount you feed in when locating the bolt circle. Set the tool bit on the lathe spindle centerline height and *tangent* to the O.D. as shown. This is important. The side of the sharp tip must touch the surface.

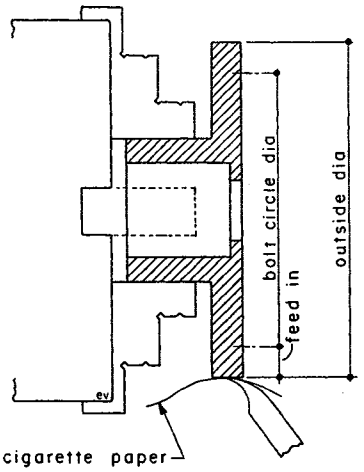
Use a cigarette paper to set the bit. Cigarette paper is .001" thick. Very, very slowly, feed in while constantly moving the paper between the bit and the workpiece. The instant the paper catches and will not move, you are .001" or less from the surface. Without disturbing the crossfeed, set the collar at zero.

Run the carriage to the right until the bit is off the workpiece. Turn the crossfeed in by the amount indicated by our earlier measurements and calculations. Now, again — very, very slowly — run the carriage toward the workpiece until an almost invisible chip is formed when the work is rotated by hand. A handy thing to determine this is a headband binocular magnifier. Rotate the work by hand until the full circle is made. Microscopically, one side of this scratch is square with the face and the other at an angle. When using a sharp divider in this groove, the error will be very small, plenty good for a bolt circle.

If you have an indexing headstock, it will be easy to scribe the centers of the holes. In case you do not have an indexing spindle, it will be necessary to pace off the desired number of spaces. One simple fact that helps is: the radius of any circle will pace off exactly six equal spaces on *that* circle. This enables you to lay out either three or six accurate spaces.

Also, once you have the six spaces, you can scribe a line through two opposite marks and obtain an accurate line through the center of the work. With some simple geometry and a pair of dividers, four or eight spaces are easy to get from this centerline. Outside of two, three, four, six and eight, the spacing will have to be trial and error with dividers. Handbooks giving chordal distances for various numbers of holes will help in getting an initial divider setting.

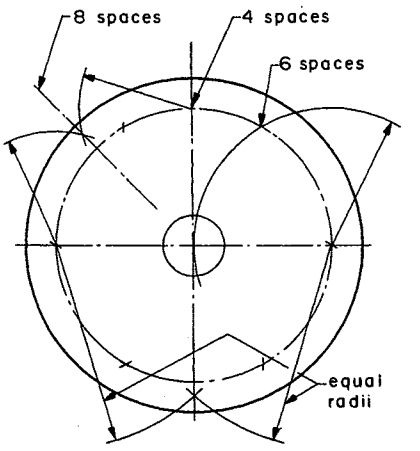
Finish your bolt circle by prick-punching, then center-punching and drilling.



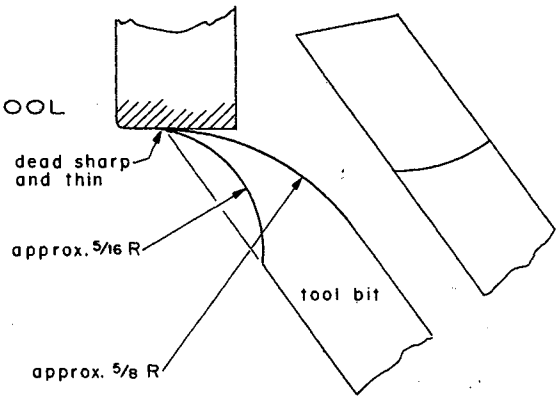
EXAMPLE

outside dia	4.008
bolt circle	-3.250
	.758
divide	÷2
feed in	.379

SETTING SCRIBING TOOL



BOLT CIRCLE LAYOUT



TOOL FORM

Parallel Clamp Vise

There isn't anything new or sensational about these vises, but they have proven quite handy around my shop. They are the result of a need for holding thin material such as bronze spring stock when making electro-mechanical parts by hand in the model shop.

The standard vise is too coarse for making tiny parts requiring fine filing and shaping. These clamp vises provide solid working conditions and fair knuckle clearance when using needle files, etc. The clearances in these vises are small, so there is good jaw alignment and yet allowance for a bit of taper in the stock. The large wheels make it easy to tighten the jaws. A grip as small as 1/32" can be made on narrow stock. The work is a few inches nearer eye level, making work more comfortable and they should be handy when making eccentric straps, etc., from thin, flat stock. They are fine companion pieces to a finger-plate vise and have been used many times in that combination. All five of the vises shown in this article have been made and all seemed to adapt to some job or another.

No fine details are given since you will, no doubt, adapt material from your own stock . . . and you may have some ideas of your own to incorporate.

STYLE A is probably the best all-around for general purposes in a model shop.

STYLE B can take irregular pieces with bends and projections. It is limited to thin material only. It also takes the most pressure to tighten. Holes were added to the knob so a pin could be used for added leverage.

The two jaws were clamped tightly together, well aligned, and drilled 7/64" for the 1/8" pin.

STYLE C is obviously for tiny parts or parts with very little flat surface to grip.

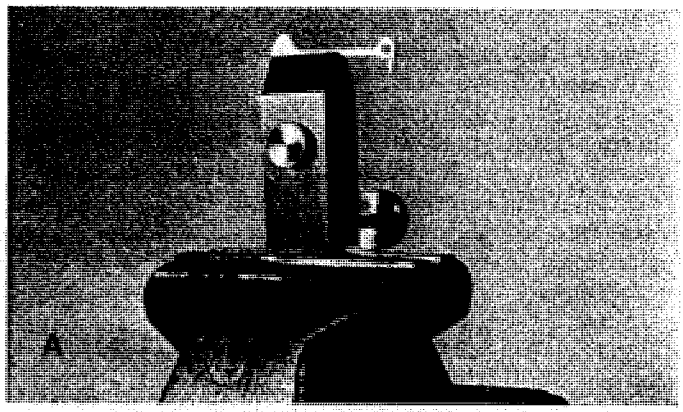
STYLE D is husky and will work well for larger pieces and for bending thin stock.

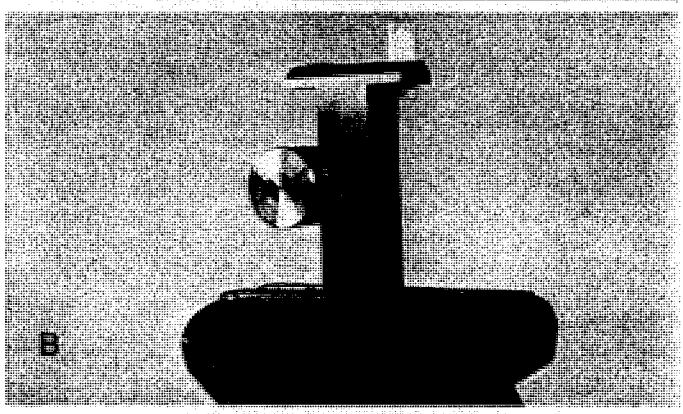
STYLE E holds a limber piece on two sides while shaping a center opening. It is, perhaps, a bit more limited and justified only if you see a future use for it.

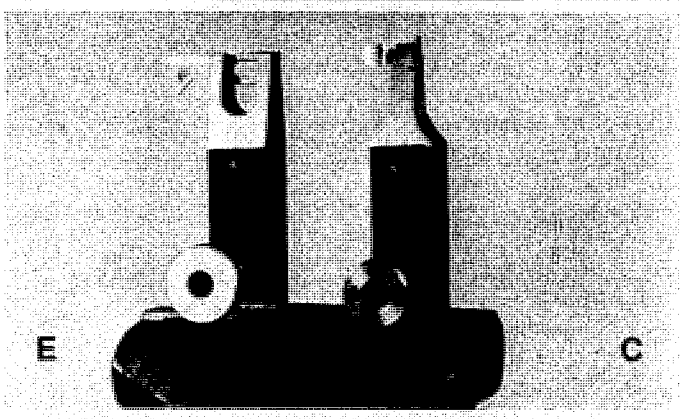
Note that **A**, **C**, **D** and **E** all have the tapped holes in the short member. The screws are just a close free fit in the long pieces. A reasonably close fit keeps the jaws in alignment. All the springs are salvage fromthe odds-and-ends department.

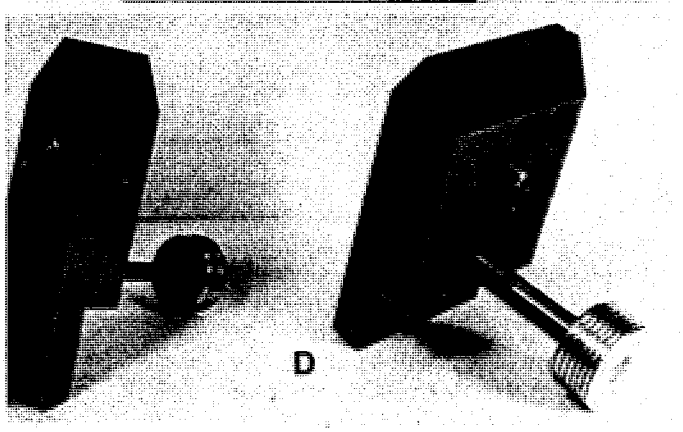
C and **E** are hex socket-head screws: the knob is bored for a drive fit on the screw head.

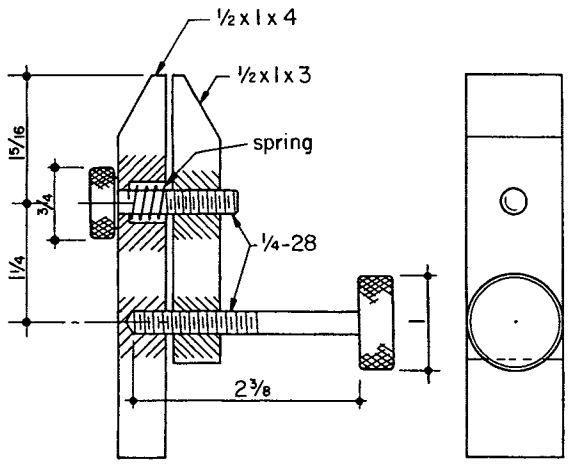
Here are some simple tools that will make your shop work easier. Each vise in this group of five has a specific use and performs well in that task. Make a set of these clamps for your shop and enjoy the convenience that adequate tooling can provide for you.



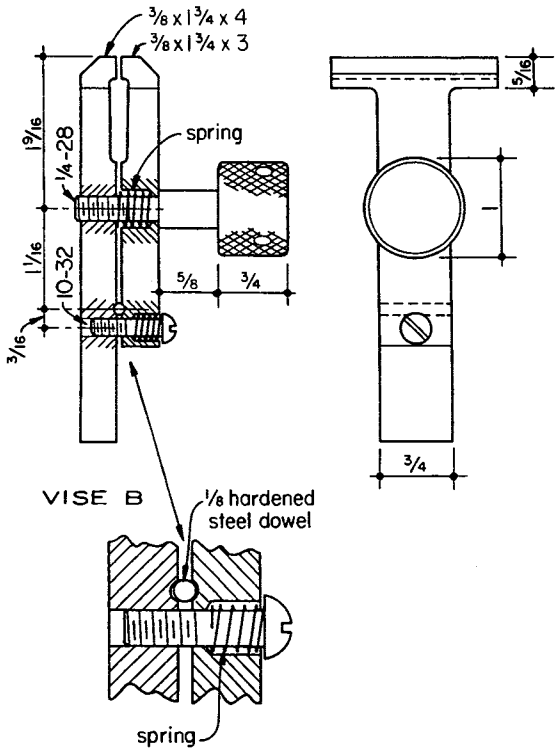




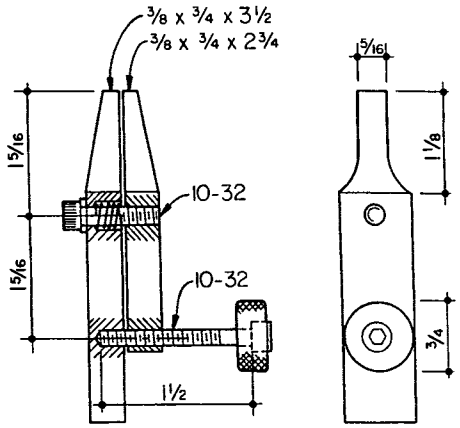




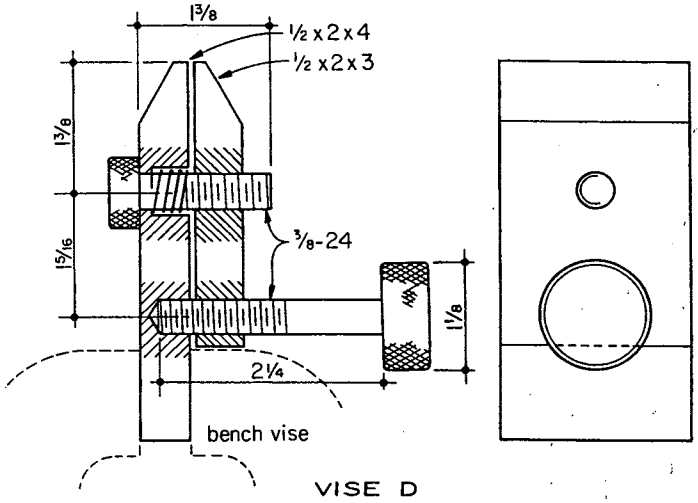
VISE A



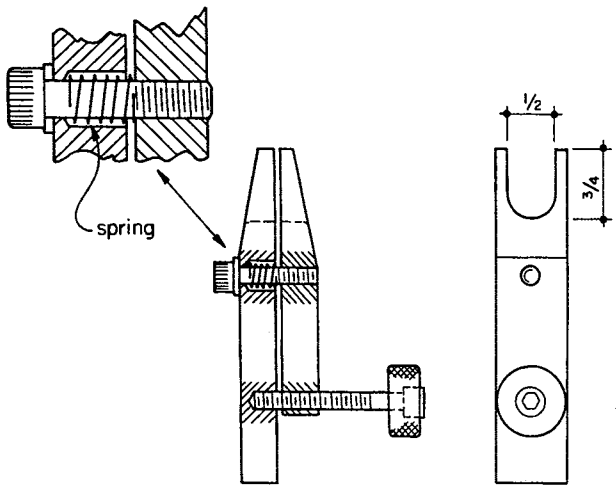
VISE B



VISE C



VISE D



VISE E

PARALLEL CLAMP VISE

Offset Tailstock Center

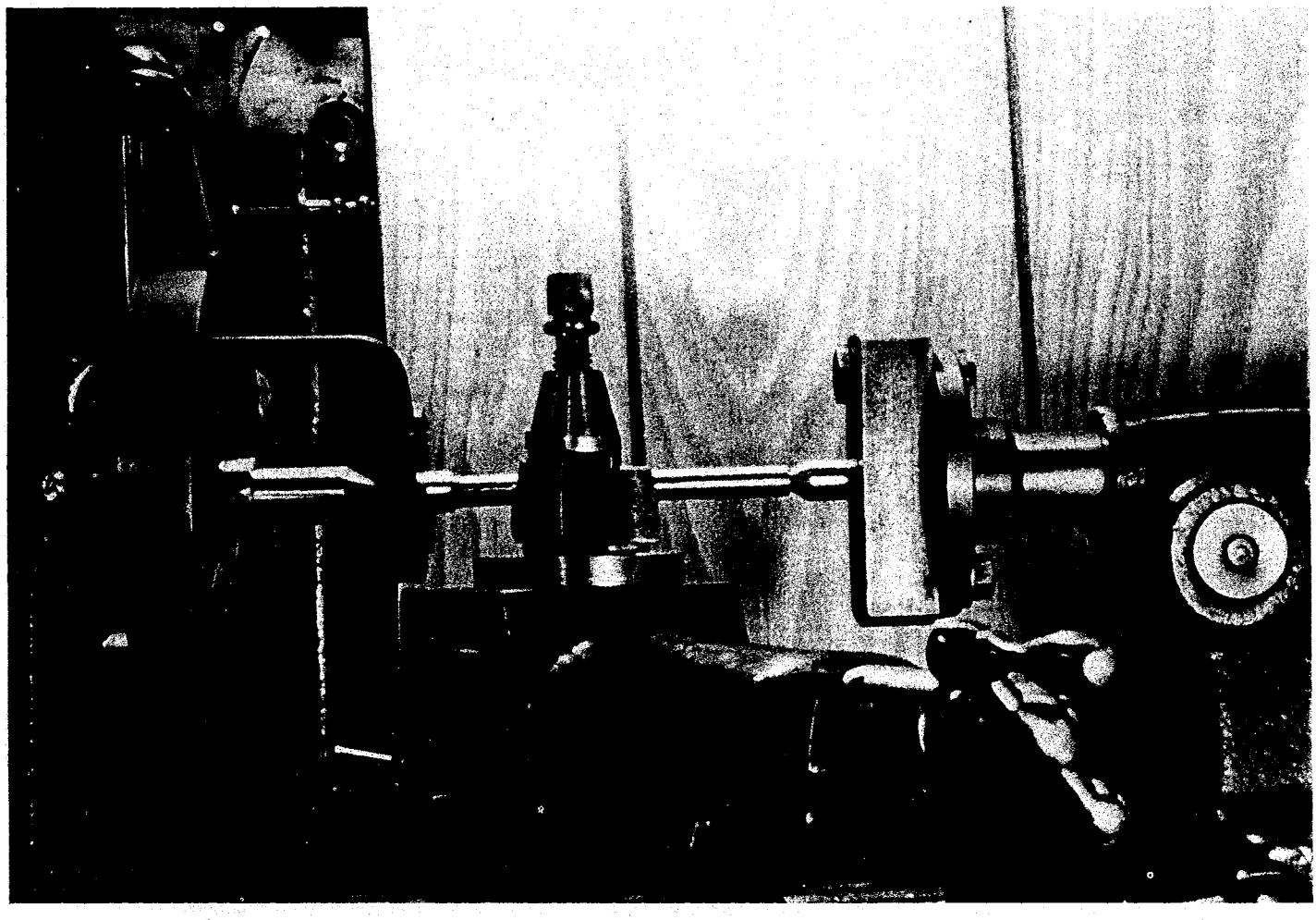
Taper turning in the lathe is best done with a regular taper attachment. If you don't have one, the tailstock is offset to produce a taper. I agree with Charles Darling when he described a new milling machine he was trying out. The machine had a swivel head and the job of getting it square with the table after being tilted was a bit of a problem. He said, "I got it perfectly square and I believe I'll leave it that way." That is the way I feel about offsetting the tailstock of my lathe. Anyone who disturbs that tailstock is going to be sent to Siberia!

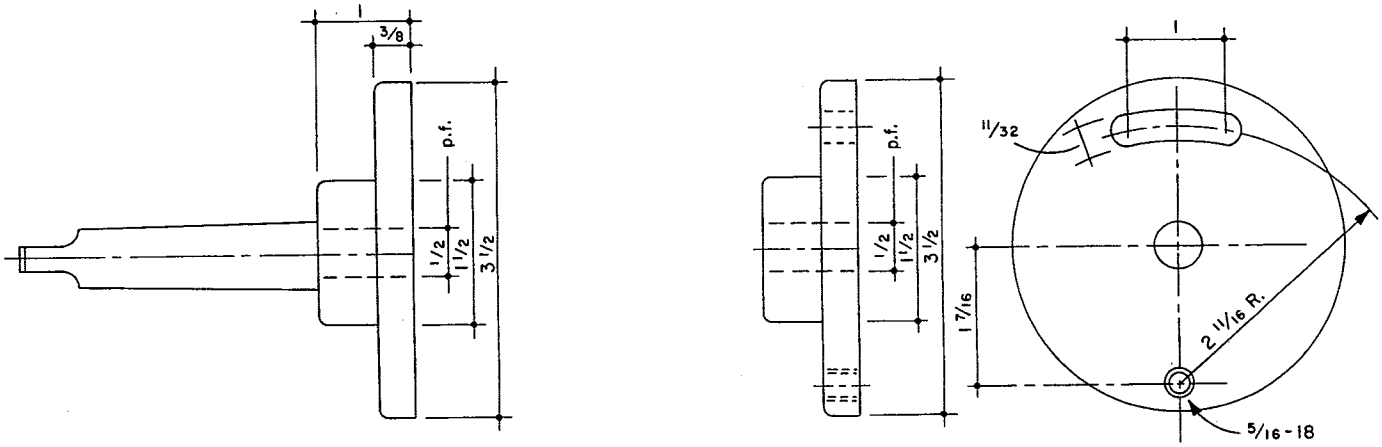
This simple center is an attachment for the drill pad. It involves common machine shop practice and only a few important details will be mentioned. The 60° **CENTER** must be tool steel, hardened. Make the **BOLT A** a close fit in the **BAR**. the Exaggerated sketch **B** shows the relation of the Center to the center hole. As you see, there is only line contact on a steep taper. The slower the taper, the better the condition at the center. So take it easy and keep the center well coated with high-pressure grease. Keep the Offset Center at the same height as the Live Center and not too much pressure on the work piece.

Setting up the Center is a bit of a chore since there are no dials to read. You must calculate the amount to move the Center. Bring it up to the Live Center and measure across for a starter. Say you want 1/8" taper in 6" on a connecting rod. One-half of the taper is 1/16". Since, in the example shown, there is 1" added to each end, then the offset must be 1/3" greater than 1/16".

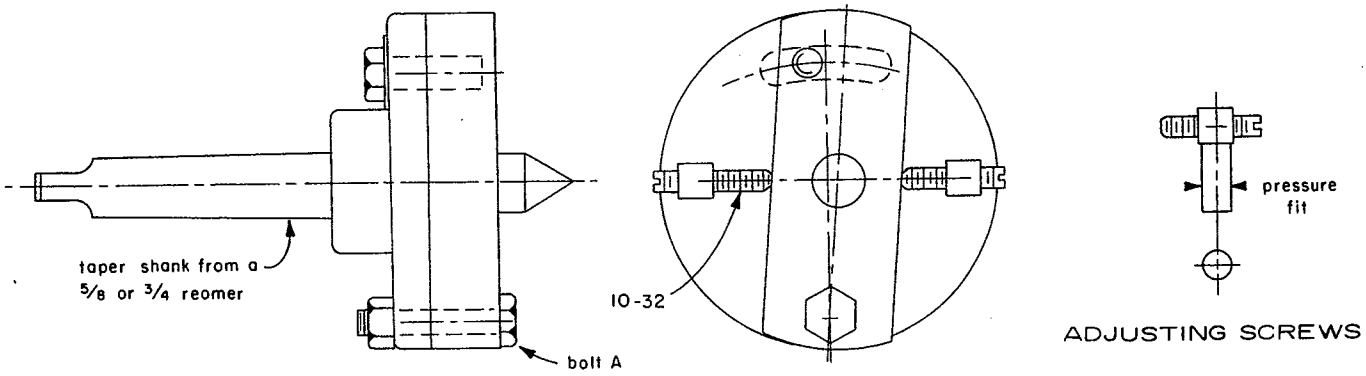
Start out with an offset a bit more than required and make a trial cut. The taper will run out before reaching the 6" distance. Tunk the bar over a bit and repeat, keeping track of the small diameter each time so you won't go undersize.

Adding the two 10-32 screws will help make fine adjustments. One turn of a 10-32 screw moves the Center 1/32". One-half turn moves 1/64" and one-fourth turn moves .008", so you can have an idea of how much you move it. Use this general layout and make one to suit your lathe and use your own ideas for such a tool.

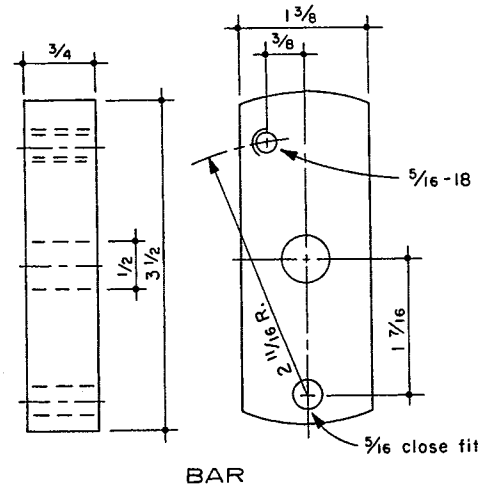




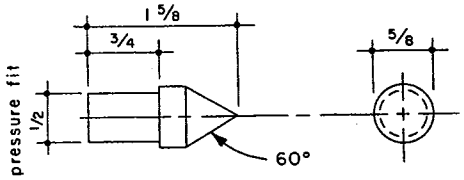
TAILSTOCK DRILL PAD



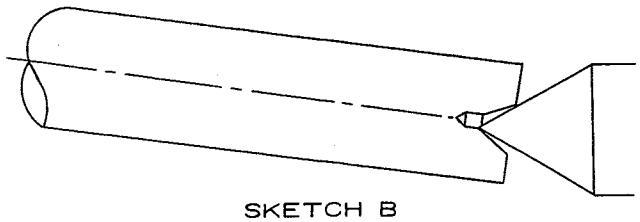
ADJUSTING SCREWS



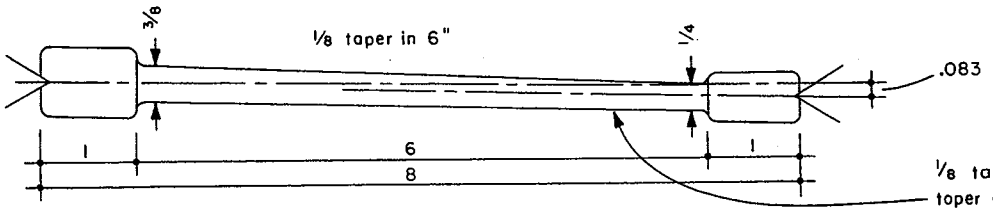
BAR



CENTER
Tool Steel, Harden



SKETCH B



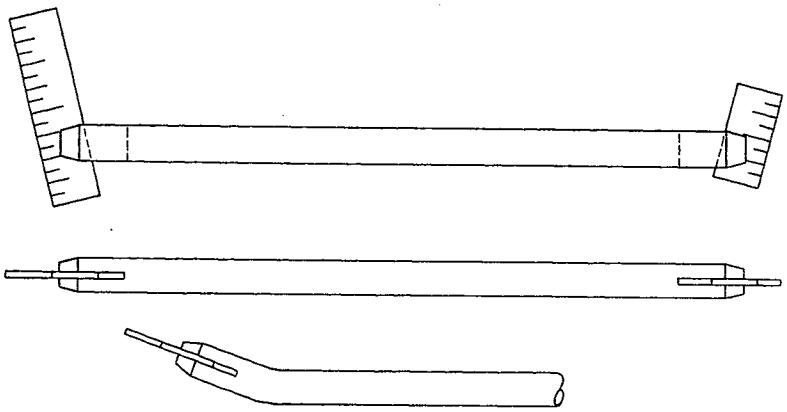
EXAMPLE

1/8 taper in 6" = 1/16 offset
taper at 8" = 8/6 or 1 1/3 x 1/16
.062 x 1.333 = .083 offset

OFFSET TAILSTOCK CENTER

EV/rbo

Handy Scale



If you have a narrow scale, badly worn or broken, cut (as accurately as you can) a one-inch and a half-inch piece on the 1" and the 1/2" marks respectively.

Check these pieces with a good scale, making sure that the marks coincide when the ends are held against a flat surface.

Mill slots in the ends of a 4" piece of 3/16" round stock, just a shade over the thickness of the pieces of the scale.

Slightly pinch these ends together so the scale pieces have to be forced into the slots.

You now have a scale to reach in where a regular scale cannot go.

Make a second tool. Repeat the steps except bend the 3/16" rod at a slight angle. On some jobs, this makes the scale easier to read.

This is just the beginning!

While this may be the end of the book, it is really just the beginning of years of enjoyment in your shop. If the ideas presented here result in the enjoyment to be achieved in actually building a working object, this book has served a good purpose. If, however, it provides food for thought that helps you analyse a problem and arrive at a satisfactory solution, then you have received the full value of this work.

Keep in mind, though, that the Author and the publisher cannot be responsible for the accuracy of the plans, drawings, technical data or information contained in this book, and that the reader makes use of such at his own risk. None of the statements made or information contained herein shall create any warranty, expressed or implied, nor that any of the various devices, plans, drawings, mechanical systems or data shall be fit or useful for any particular purpose. The statements contained are informational only and not made or given as a warranty of the data in any way. The reader shall be solely responsible for determining the accuracy and adequacy of the data for any and all uses to which the reader shall apply the data.

Please keep the safety suggestions throughout this book foremost in your mind as you work with your machine and hand tools. Overconfidence in working with machinery can create a dangerous situation.

Work carefully and thoughtfully and your hobby activity can be most enjoyable and rewarding for years to come.

Index

A

Adapting 270
Appendix 252

B

Baldy 67
Ball Turning Tool 271
Basic Cylinder
  Type F 255
  Type M 254
Beam Compass 267
Beam Engine (Metal) 101
Beam Engines
  Beam Engine (Metal) 101
  Wood Beam Engine 1
Boat Engines
  Educational Model 235
  Model Boat Engine 222
Boiler
  Live Steam Boiler & Engine . . 107
Bolt Circles
  Scribing Bolt Circles 276
Box Base for Modelmaker's Lathe . 260

C

Carriage Stop 274
Catalogs
  Suppliers' Catalogs 260
China Pencil 259
Clamp Vise
  Parallel Clamp Vise 277
Clean Shop 260
Close Tolerance Holes 273
Comber Rotary Engine 217
Compass
  Beam Compass 267
Compound Engines
  Single Cylinder Compound . . .212
Create Your Own Designs 253
Cross-Slide Milling Attachment . . 275
Cross Twin Engine 147
Cutting a Tapered Keyway 261
Cutting Compound 259
Cutting Oil Brush 259
Cylinder
  Basic — Type F 255
  Basic — Type M 254

D

Depth Gauge
  Modelmaker's Depth Gauge . . 263
Donkey Pump
  Vauxhall Donkey Pump 230

E

Eccentric MF8 257
Educational Model 235
Engine Showcase 133

F

Factory Engine 193
Fancy 65
Fancy II 80
Flywheel MF11 257
Four Cylinder Engines
  Four Square 14
  H Quad Engine 116
  V4 Wobbler 111
Four Square 14

G

Gauge
  Modelmaker's Depth Gauge . . 263
  Modelmaker's Thickness Gauge . . .264
Geared Steam Engine 17
Generator 189
Grasshopper Engines
  Grasshopper Engine (Metal) . . 165
  Wooden Grasshopper 33
Grease Pencil 259

H

H Quad Engine 116
H Twin 31
Handy Scale 281
Hardening 270
Head Band Magnifier 258
Heads
  Inboard Head MF6 256
  Outboard Head MF7 256
Horizontal Mill Engine 203

I

Inboard Head 256

J

Just The Beginning 281

K

Keyway
  Cutting a Tapered Keyway . . . 261

Kimble Engine 87
Kimble Engine Rotary Valve 95
Kimble Story 89

L

Layout Hint 259
Live Steam Boiler & Engine 107

M

Magnifier
  Head Band Magnifier 258
Marking Pencil 259
Measuring 258
Mill Engine 141
Milling Attachment
  Cross-Slide Milling Attachment . 275
Mine Engine 123
Model Boat Engine 222
Modelmaker's Depth Gauge 263
Modelmaker's Lathe
  Box Base for Modelmaker's Lathe . . 260
Modelmaker's Thickness Gauge . 264

O

Odds & Ends for Beginners
  Cutting Compound 259
  Cutting oil Brush 259
  Head Band Magnifier 258
  Layout Hint 259
  Measuring 258
  Pipe Cleaners 258
  Pre-Jigging 258
  Simple Storage System 258
Offset Tailstock Center 279
One-Cylinder Engines
  Baldy 67
  Beam Engine (Metal) 101
  Comber Rotary Engine 217
  Educational Model 235
  Factory Engine 193
  Fancy 65
  Fancy II 80
  Geared Steam Engine 17
  Grasshopper Engine (Metal) . . .165
  Horizontal Mill Engine 203
  Live Steam Boiler & Engine . . . 107
  Mill Engine 141

One Cylinder Engines (Continued)
Mine Engine 123
Open Column with Reverse 11
Oscillating Cylinder Engine . . . 198
Scotty 29
Single Cylinder Compound . . . 212
Slider 24
Square 27
Standby 85
Steam Pump 155
Tall Vertical Open Column 135
Tiny 99
Una-Flow Engine 225
Vauxhall Donkey Pump 230
Vertical Reversing Wobbler . . . 160
VR75 171
Wobble Plate Engine 60
Wobbler 105
Wood Beam Engine 1
Wooden Grasshopper 33
Open Column with Reverse 11
Open Column Twin 207
Open Column Twin with Poppet Valves. . . 53
Opposed Piston Steam Engine . . .129
Oscillating-Cylinder Engine 198
Outboard Head MF7 256

P

Pack Nut MF9 257
Pack Nut MF10 257
Parallel Clamp Vise 277
Pipe Cleaners 258
Pistonless Engines
Kimble Engine 87
Poppet Valves
Open Column Twin with
Poppet Valves 53
Pre-Jigging 258
Pumps
Pumping Engine 69
Steam Pump 155
Turbine and Centrifugal Pump . . 49
Vauxhall Donkey Pump 230
Pumping Engine 69
Punch
Sheet Metal Punch 265

R

Radial Engine 44
Reversible Vertical Twin Wobbler . 247
Rocking Chair 259
Rods
Source for Round Rods 259
Rope Drive 179
Rotary Engines
Comber Rotary Engine 217
Rotary Valve
Kimble Engine Rotary Valve 95

S

Scale
Handy Scale 281
Scotch Yoke 29
Scotty 29
Scribing Bolt Circles 276
Sheet Metal Punch 265
Showcase 133
Simple Storage System 258
Simple Turning and Machining Hints . . 269
Single Cylinder Compound 212
Sketching
Starting a Job 259
Slider 24
Source for Round Rods 259
Source for Springs 260
Springs
Source for Springs 260
Square 27
Standby 85
Starting a Job 259
Steam Chest MF1 255
Steam Chest Cover MF2 255
Steam Pump 155
Steel
Tin Plated Steel 259
Storage
Simple Storage System 258
Suppliers' Catalogs 260
Symbols 253

T

Tailstock Center
Offset Tailstock Center 279
Tall Vertical Open Column 135
Tapered Keyway
Cutting a Tapered Keyway . . . 261
Thickness Gauge
Modelmaker's Thickness Gauge . . 264
This Is Just The Beginning 281
Three-Cylinder Engines
Radial Engine 44
V3R 242
Tin Plated Steel 259
Tiny 99
Turbine and Centrifugal Pump 49
Twin Vertical Wobbler 9
Two-Cylinder Engines
Cross Twin Engine 147
H Twin 31
Open Column Twin 207
Open Column Twin with
Poppet Valves 53
Opposed Piston Steam Engine .129
Reversible Vertical Twin Wobbler . . 247
Rope Drive 179
Twin Vertical Wobbler 9
V Twin 97

U

Una-Flow Engine 225

V

Valve MF4 256
Valve Nut MF5 256
Valve Plate MF3 256
Vauxhall Donkey Pump 230
Vertical Reversing Wobbler 160
Vise
Parallel Clamp Vise 277
V3R 242
V4 Wobbler 111
VR75 171
V Twin 97

W

Wobble Plate Engine 60
Wobbler 105
Wobbler Engines
Four Square 14
H Quad Engine 116
Oscillating Cylinder Engine . . . 198
Live Steam Boiler & Engine . . . 107
Reversible Vertical Twin Wobbler . . 247
Tiny 99
Twin Vertical Wobbler 9
Vertical Reversing Wobbler . . . 160
V3R 242
V4 Wobbler 111
V Twin 97
Wobbler 105
Wood Beam Engine 1
Wooden Grasshopper. 33

DRAWING CREDITS

William C. Fitt — Pages 9, 10, 266
Connie Lovell — Pages 11, 12, 13, 19, 20, 21, 22, 45, 46, 47, 91, 92, 93, 94, 96, 108, 109, 110. 112, 113, 114, 124, 124, 125 126, 127, 128, 136, 137, 138, 139, 142, 143, 144, 145, 161, 162, 163, 180, 181, 182, 183, 184, 185, 186, 187, 190, 191, 194, 195, 196, 197, 261, 262, 271, 272
R. Bruce Owens — Pages 35, 36, 37, 38, 39, 40, 41, 42, 43, 60, 62, 63, 71, 72, 73, 74, 75, 76, 77, 78, 80, 81, 82, 117, 118, 119, 120, 121, 149, 150, 151, 152 166167, 168, 169, 170, 172, 173, 174, 175, 176, 274, 280
Elmer Verburg — Pages 3, 4, 5, 6,7, 8, 15, 16, 25, 26, 28, 30, 32, 51, 52, 66, 68, 86, 98, 100, 102, 103, 104, 106, 131, 132, 133, 198, 199, 200, 201, 203, 204, 205, 206, 208, 209, 210, 213, 214, 215, 216, 219, 220, 223, 224, 226, 227, 228, 230, 231, 232, 233, 236, 237, 238, 239, 240, 243, 244, 245, 248, 249, 250, 251, 254, 255, 256, 257, 259, 263, 264, 276, 281
Jerry Williams — Pages 55, 56, 57, 58, 156, 157, 158, 159, 267, 268, 269, 270, 278

PHOTO CREDITS

William C. Fitt — Pages i, xi, 1, 2, 4, 9, 11, 13, 14, 17, 23 center, 24, 27, 29, 31, 33, 34, 41 top, 44, 49, 50, 53, 54, 59, 61, 65, 67, 69, 70, 79, 83, 85, 87, 89, 90, 97, 98, 99, 101, 104, 105, 107, 111, 114 116, 122 bottom, 123, 129, 130, 134, 135, 140, 141, 147, 148, 154 top, 157, 160, 193, 201, 202, 204, 207, 212, 217, 218, 220, 222, 233, 234, 235, 241, 246, 250, 263, 264
Kim House — Pages 18, 23 top bottom, 165, 170, 177, 179, 187, 189 bottom, 192 bottom,
Elmer Verburg — Pages 39, 40, 41 bottom, 43, 48, 64, 84, 88, 95, 115, 118, 122 top, 153, 154 bottom, 164, 171, 178, 188, 189 top, 192 top, 225, 229, 242, 246, 262, 265, 267, 269, 270, 273, 274, 275, 277, 279