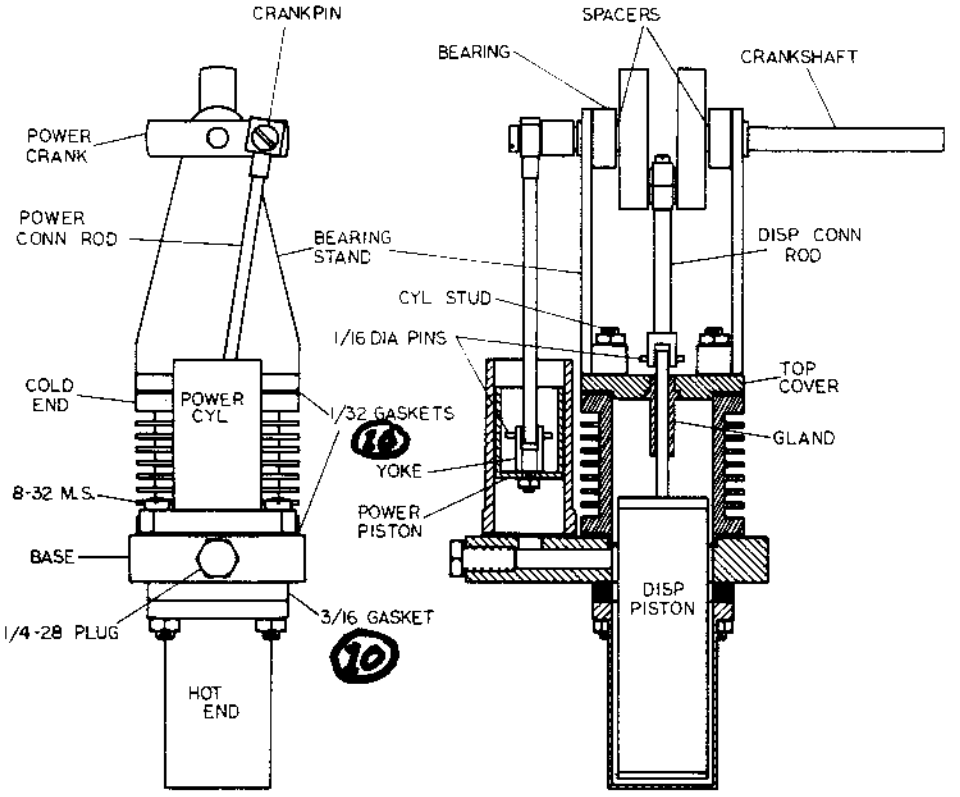
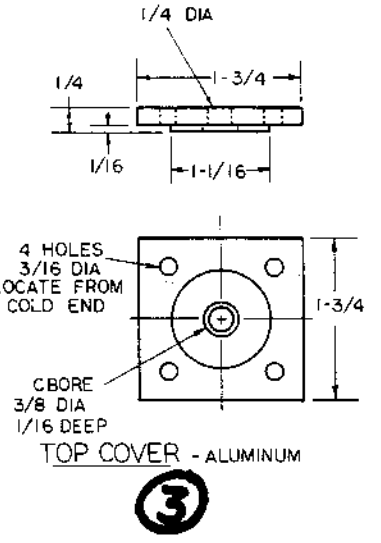
A 10-inch Stirling Engine Powered Fan... Moriya

by Dr. James R. Senft

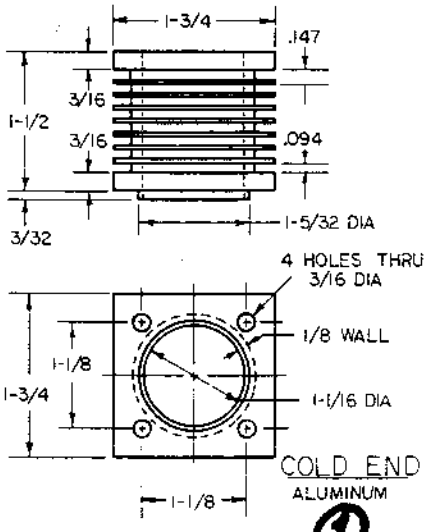
Photos and Drawings by the Author





TOP COVER - ALUMINUM

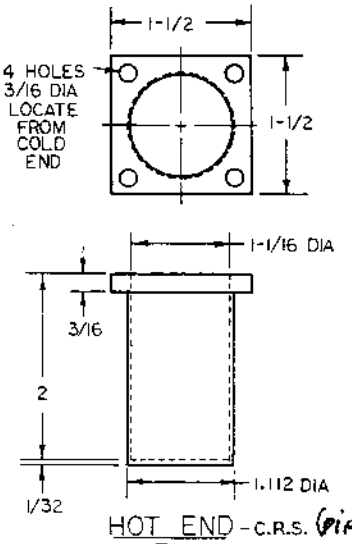
(3)



COLD END

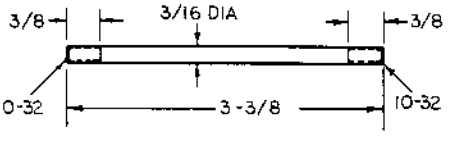
ALUMINUM

(1)



HOT END - C.R.S. (PIPE)

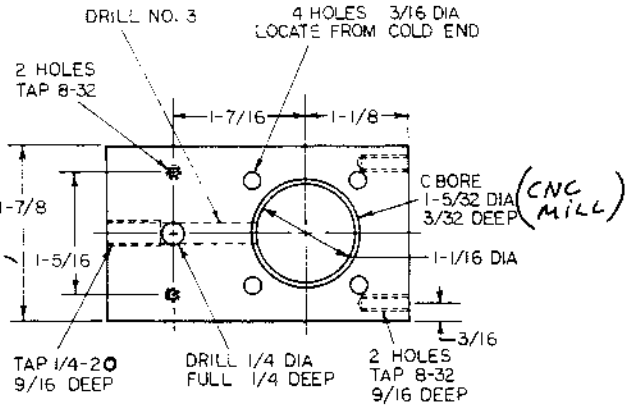
(2) (a, b, c)



CYLINDER STUD - ~~ALUMINUM~~ DRILL ROD

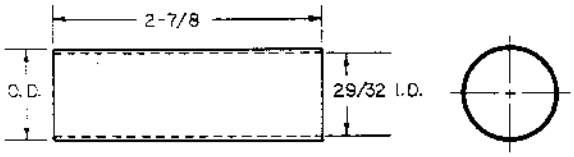
4 REQ

(4)



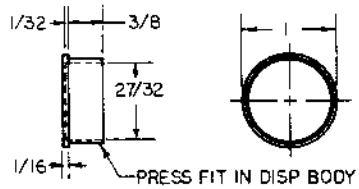
ENGINE BASE - ALUMINUM

(5)



DISPLACER PISTON BODY - ~~ALUMINUM~~ Stainless Steel Tubing

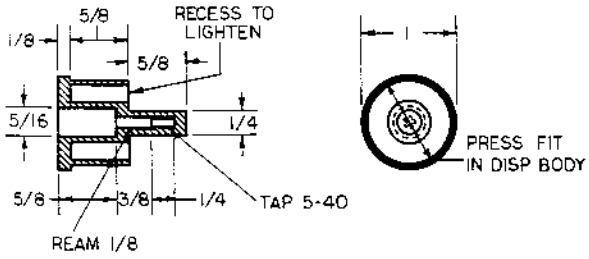
(6)



DISPLACER PISTON CAP

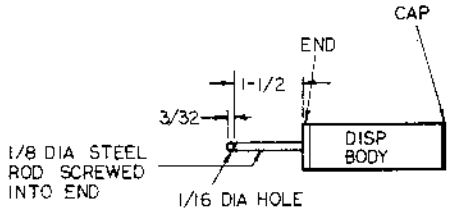
ALUMINUM

(7)



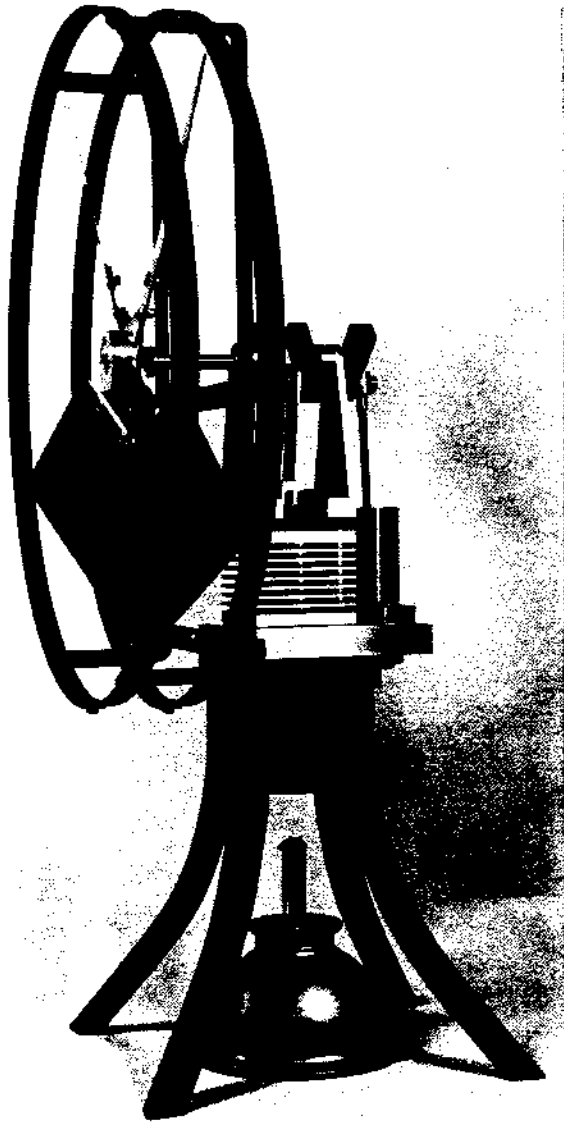
DISPLACER PISTON END - ALUMINUM

(8)



DISPLACER PISTON ASSEMBLY

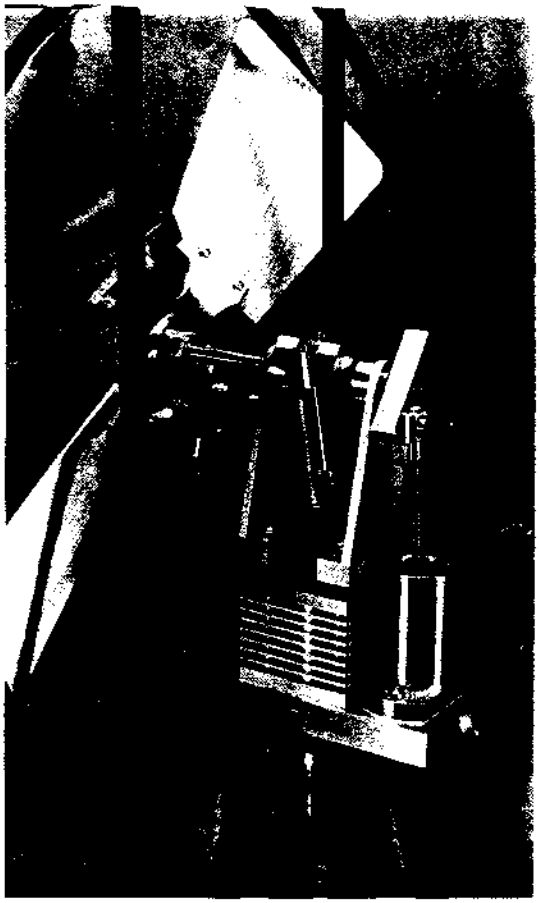
(9)



Moriya is a project that can make you more comfortable. And, because of its novelty, provide perhaps more than the usual measure of satisfaction which accompanies the construction of any precision machine.

Until at least 35 years ago, hot air fans were produced commercially and were to be found in widely scattered parts of the globe. Despite the fact that the power output of the rudimentary stirling cycle engine is extremely low, it was ideally suited to the task of driving these fans because of its quiet, reliable, and maintenance free nature. These fans were very popular among farmers and missionaries in remote torrid regions.

Although hot air powered fans are no match, size for size, for electric fans, Moriya spins its 10 inch fan blade in excess of 500 rpm to provide a gentle



soothing breeze at a distance of two or three feet. Not having an electric table fan, Moriya has on several occasions done faithful and commendable duty alongside my drafting table or atop my desk. The project requires no castings and the machining can easily be handles on a 6 inch lathe.

Begin construction with the COLD END. Although it doesn't have to be a critically accurate job, it would be well to be a bit fussy about it since many parts stack above and below it and their relative alignment is important. The machining is straightforward with the possible exception of cutting the fairly deep fins in square stock. If you have never done it before, it might be well to experiment on a few pieces of scrap first.

Firmly chuck an ample length of 1¾" square aluminum bar to run true in the 4-jaw chuck, face the end, centerdrill, and bring up the tailstock center. Set up a parting tool to cut the fins. Setting the topslide parallel to the lathe axis will allow the use of its micrometer feed to precisely space the cuts. Use a good sharp (and sufficiently long!) 3/32" wide parting tool and set it dead square to the work. Set the topslide to zero, bring the side of the tool against the faced end of the bar, and lock the carriage. Back the tool clear and feed the topslide toward the chuck exactly 3/16" plus the width of the tool for the first cut.

The square shape of the work affords an ideal opportunity for devilish little chips to position themselves across the cut and jam the tool. To minimize the chance of catastrophy, loosen the drive belt as much as possible. Set the machine in lowest backgear and the finest automatic crossfeed rate. It is surprising how little belt tension is required to drive the workpiece in backgear.

Thus prepared, commence the first cut. Use a lubricant! Kerosene is usually recommended, but it might pay to try a fluid especially compounded for aluminum. I have found that lacquer thinner works extremely well, but it cannot really be recommended for machine operations because of the terrific fire hazard involved. Note the cross slide reading at the instant that the cut becomes continuous, and then continue the cut for another .218". Back the tool out, feed the topslide over exactly .147" and make the second cut. Repeat until all eight cuts have been made.

Remove from the chuck and saw off a little long. Chuck the finned block truly in the 4-jaw again with the sawn end out; best lay some flat strips between the jaws and the work to avoid marring those beautiful fins! Face the end to length and turn the 1-5/32" dia. spigot. Now drill and bore through the block to exactly 1-1/16" dia. Out of the chuck, check with a mike to be sure that the two mounting surfaces are exactly parallel; if not, wring the block onto a stub mandrel and take a skim cut across the plain end.

All that remains is the drilling of the four 3/16" dia. stud holes through the entire piece. It is important that these holes be parallel to the bore so use brand new or accurately resharpened drills. The employment of the milling attachment to locate and carry out the drilling would probably be best.

For the TOP COVER, chuck a short length of 1¾" square aluminum, face, and turn the spigot to a close fit in the bore of the cold end. Centerdrill and drill undersize for the gland; finish the stepped bore with a tiny boring tool. Chamfer the step to ensure that the gland will seat squarely when pressed in. Saw or part off a bit long. The top surface of the cover must be parallel to the spigoted surface and must be flat to ensure that the bearing stands will align nicely. Hold the cover against the faceplate with a drawbolt through the spindle or mount on a stub mandrel fitted with a nut. You can now face the top to correct width up to the drawbolt nut; the unfinished portion under the nut will not matter at all so long as it is not high enough to foul the displacer connecting rod at B D C. Use the cold end to spot the four 3/16" dia. holes and move on to the engine base.

Cut a piece of ½" thick aluminum to the outside dimensions shown in the drawing and mark out the location of the cold end. Position in the 4-jaw and bore through 1-1/16" dia.; then form the counterbore to fit the spigot on the cold end. You can now carry the ENGINE BASE over to the drill press for the remaining work. The stud holes are spotted through the cold end.

The HOT END is probably best made from solid 1½" square cold drawn steel bar even though most must be cut away! It could be fabricated from tubing and flat stock by sliver soldering but it would still need some truing on the lathe afterward — about the same amount of work either way. Do the lathe work at a single chucking. Firmly grip the stock in the 4-jaw, face, centerdrill and engage the tailstock center. Turn the outside to shape but about 1/8" oversize with the flange at the tailstock end. Follow by boring the interior to exactly 1-1/16" dia. Support the end with a large center or a stepped centerdrilled plug prepared in advance and turn the outside to size, taking lighter cuts as the wall becomes thinner. Part off to exact length.

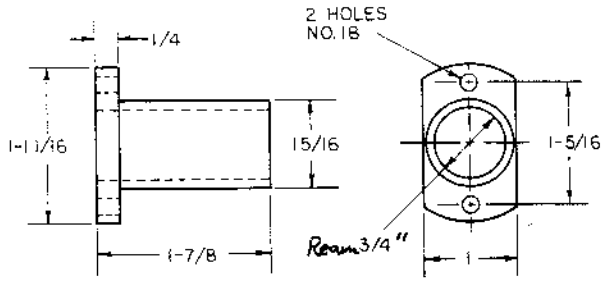
To locate the four holes in the flange, place a length of 1-1/16" dia. bar half in the cold end and half in the hot end and spot through the cold end. Be careful if you clamp the hot end in the drillpress vise not to permanently distort the thin-walled section; best fit a snug-fitting plug or clamp by the flange. If you feel a bit uneasy about the thin wall, it can be made a little thicker but engine efficiency will suffer due to heat loss to the cold end by conduction, although the thick insulating washers will assist matters.

Aluminum is used for the DISPLACER PISTON in the interest of light weight and ease of construction. Thermodynamically, a thin walled stainless steel piston would be much better. With the body cut to length and the ends lightly chamfered, the cap and the end can be made up. The cap is a simple turning, but the end must be a careful job to ensure that the piston rod will be sufficiently concentric with the piston to prevent it from making contact with the cylinder walls. Chuck a length of 1" dia. aluminum bar in the 3-jaw and turn the ¼" dia. portion, the lightening recess, and the stepped portion to a nice press fit in the body. Saw off and chuck truly — using the 4-jaw and dial indicator if necessary — and drill and tap as shown in the drawing. Press fit the pieces together carefully and make up the rod. The hollow piston must be airtight; test by immersing the piston in near boiling water. No bubbles should be seen emerging from the joints.

Now is a good time to make the GASKETS for the displacer cylinder stack. The 3/16" thick compressed asbestos gasket is best made in two or more thinner pieces. The large hole in the two 1/32" thick gaskets can be cut freehand with a penknife; the thick gasket can be treated trepan style by mounting a stout knife blade in the tool holder and tacking the material to a piece of wood secured to the faceplate. Cut the hole a little on the large side since the material will rise at the edge of the hole when cut causing the hole to close in under compression. The holes for the studs can be punched by means of a simple tool taking only a few minutes to make. Chuck a 2" length of 3/16" drill rod truly, face, and centerdrill clear to the edge; harden and temper. Use a light hammer for the punching with hardwood or masonite for backing. Once again the cold end can be used for spacing the holes.

Make the four CYLINDER STUDS to the dimensions in the drawing. If necessary, you can open out the holes a bit, say to .191" dia., in the cold end, top cover, and engine base so that the studs will pass through easily and permit the pieces to bed down properly.

To make the GLAND, chuck a length of 7/16" dia. bronze in the 3-jaw and turn down to ¼" for a distance of 5/8". Saw off a little long and reverse in the chuck, gripping the piece by the ¼" dia. portion. Face to length, drill through and ream 1/8" dia. for a nice close fit around the displacer piston rod. This hole must be concentric with the portion to be turned; since twist drills often wander — especially when they mustn't — it is worthwhile to make up a .120" dia. D-bit and follow with the reamer.

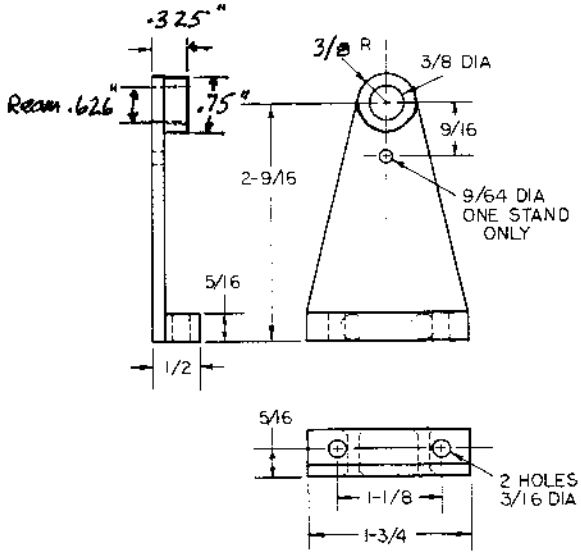


POLISH BORE TO REMOVE TOOL MARKS

POWER CYLINDER

BRONZE — OR BRASS

14

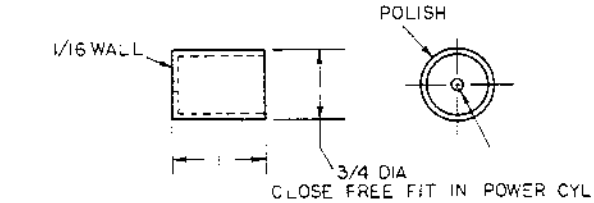


BEARING STAND - ALUMINUM

2 REQ

CNC Mill from ½" Plate

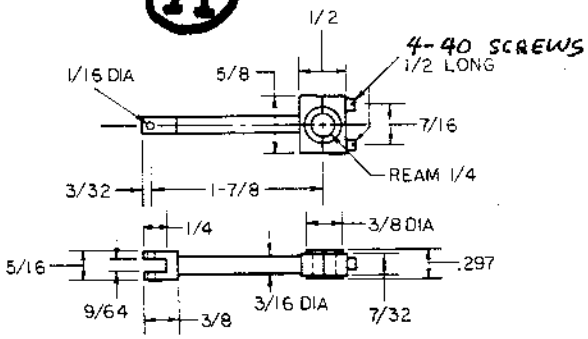
11



POWER PISTON

STEEL - DRILL ROD

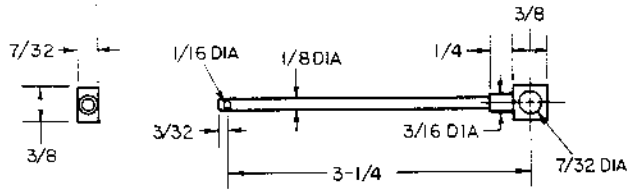
15



DISPLACER CONN ROD

ALUMINUM With SPLIT BRASS BEARING

12

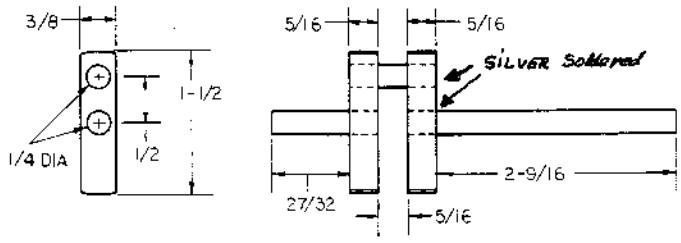


POWER CONN ROD

STEEL ROD - DRILL ROD

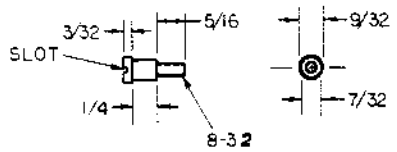
ALUMINUM END - With BRASS Bushing

16



CRANKSHAFT - STEEL SHAFT and BRASS CRANKS

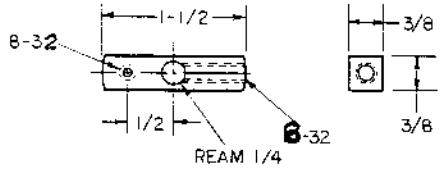
13



CRANKPIN - STEEL - DRILL ROD

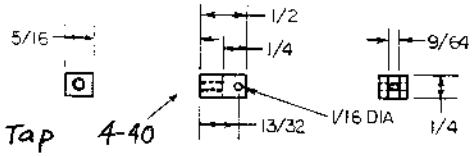
17

Now turn the end to 3/8" dia., a snug fit in the top cover recess. Further reduce the end to ¼" dia. for a length of 3/16"; this portion should be a good press fit in the cover. If your press fit turns out too loose to be fully trusted, you can save the job by using Loctite retaining compound. To check that all is well thus far, assemble the displacer cylinder stack with some spacers on the top cover to fill in for the absent bearing stands. The displacer piston must stay clear of the cylinder walls for its entire stroke.



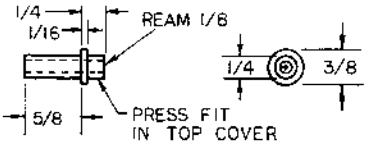
POWER CRANK - ~~STEEL~~ BRASS

(18)



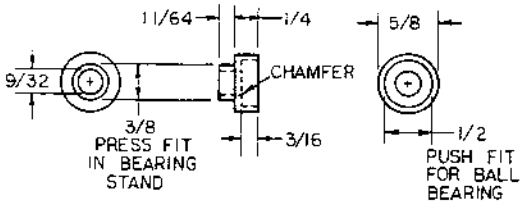
PISTON YOKE - ALUMINUM

(19)



GLAND - BRONZE - BRASS

(20)



BEARING MOUNT - ALUMINUM - 2 REQ

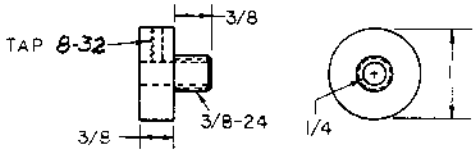
(Part of #11)

The BEARING STANDS are interesting jobs. The requirements are that they both be the same height, that they stand at true right angles to the top cover and that the holes in the base of the stands are correctly positioned for alignment of the bearing holes. Face two pieces of 3/8" square aluminum to a length of exactly 1¾". Drill the two 1/8" dia. rivet holes on ¾" centers equidistant from the ends and 5/32" from one edge and countersink on one side. Drill one of the mating holes in a 3" length of 1/8" thick aluminum plate about 1-7/8" wide and countersink. The wider portion of the square leg should be approximately flush with the edge of the plate which will be cut to final shape after machining. Slip a piece of 1/8" dia. rod through both pieces, rivet over to fill the countersinks, and file flush. Now drill the second hole through the plate and treat likewise.

Clamp a thick wide bar — say ½" by 2" — to the carriage with its edge parallel to the faceplate and its wide top surface square to the faceplate; if you have a milling attachment, hold the bar in the vise. Lay the bearing stand on the bar with the square leg hanging over the edge and, holding the leg against the edge, clamp securely. Use a flycutter to machine the width of the leg to the required 5/16". The result is a perfect right angle leg with a flat mounting surface. By bringing the stands to proper height, you can locate and drill the two 3/16" dia. mounting holes with micrometer precision to mate the holes in the top cover at the same setup. Carefully lay out the position of the 3/8" dia. hole, clamp the two stands back to back, and drill and ream; the holes must be square to the plate surface. Now the outline can be cut and filed as in the drawing. Don't forget the 9/64" dia. hole for holding the fan guard in the front stand.

Turn the BEARING MOUNTS to nicely take the ball bearings. Be sure to chamfer the stepped bore so the inner race of the bearing does not make contact. The mounts should press fit into the stands, but the 3/8" dia. spigot is long enough to permit rivetting over if desired.

The CRANKSHAFT is built up from drill rod and bar stock. Cut the webs a bit longer than finished size from 3/8" square steel bar and reduce one dimension to 5/16" by facing or milling. Clamp the two and drill and ream the two ¼" dia. holes exactly ½" apart. You may as well make the POWER CRANK now also. If desired, the curved ends on the webs can be machined by mounting them on a stub mandrel fitted with a securing nut. Cut a piece of straight ¼" dia. drill rod 4-11/32" long for the main shaft and another piece 15/16" long for the throw. Countersink the holes in the webs slightly, slip the pieces together and soft solder. Then saw out the portion of main shaft between the webs. Cut two spacers from ¼" I.D. thinwall tubing to center the crankshaft between the bearings. The bearing stands with the shaft between can now be bolted atop the displacer cylinder; it must turn absolutely free.



FAN HUB - ALUMINUM

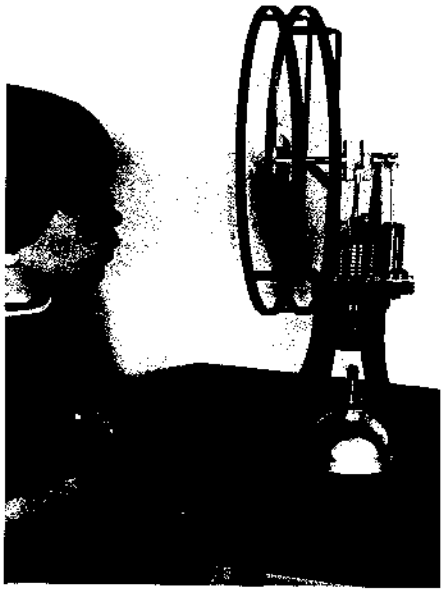
(21) Part of #25

Begin work on the DISPLACER CONNECTING ROD by squaring off the ends of a 5/8" by 5/16" or 3/8" rectangular aluminum bar about 2½" long. Drill and tap one end for the two 3—48 cap screws and, with a slitting saw, saw off a ¼" length. Bolt back together, drill and ream the ¼" dia. hole centered on the split line, and drill the 1/16" dia. hole through the other end; best determine the distance between these holes from your model. Chuck by the big end, centerdrill the other, bring up the tailstock center and turn the rod to shape. Saw the rod to length and file or mill the little end to shape, including the slot. Clamp the big end around a turned stub mandrel for reducing the end to proper width and turning the bosses. You can now add the rod to the engine assembly; test for free working, shimming the cap if necessary. The 1/16" dia. pin through the little end and piston rod should be prevented from turning in the aluminum fork; otherwise, wear would be rapid. The pin ends could be threaded 0—80 and nuts fitted to hold it from rotating. A good lubricant for the big end and the piston rod is graphite or graphite grease.

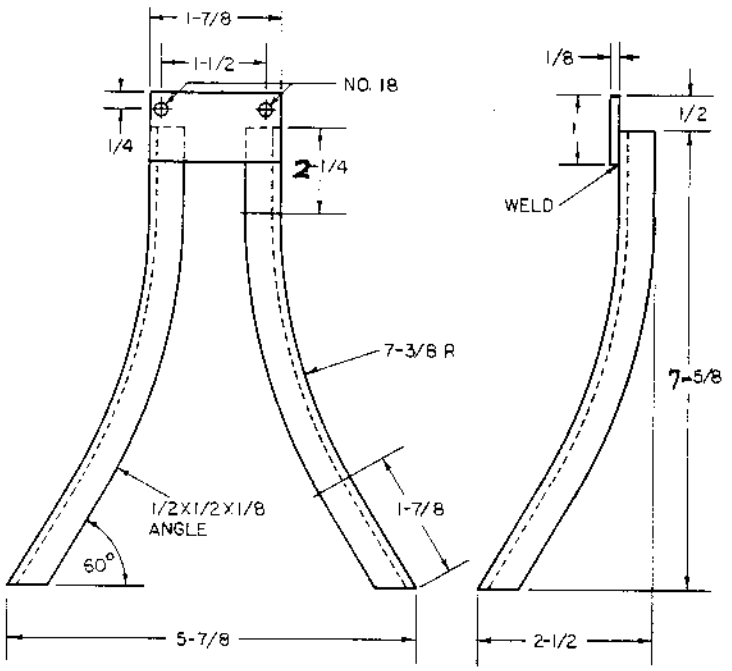
The POWER CYLINDER is an easy turning job, but care should be taken to obtain an accurate bore. A brake cylinder hone does a reasonably good job of removing the tool marks but resist the temptation to overdo it. A bronze cylinder was made for my model with a steel piston, but cast iron for both items would be better yet. Turn the piston and polish away the tool marks to a close but smooth fit in the cylinder. With the piston and cylinder surfaces clean and dry, the piston should fall through the bore when tilted, yet with the cylinder capped at one end and the hole in the piston plugged, the piston should lively snap back when pulled outward or pushed inward. Do your best here.

The POWER CONNECTING ROD is made in two pieces, a steel rod screwed into an aluminum end. If desired, the end can be bushed with bronze or teflon. Make the power CRANKPIN and the PISTON YOKE now. Use a small nut to secure the yoke to the piston — small enough to clear the ¼" hole leading to the passageway in the engine base. Make sure that the yoke seals the piston; apply gasket cement if necessary. Cut a 1/32" thick gasket for the cylinder and mount it on the base with 3/8" long 8—32 machine screws. Lubricate the power cylinder with dry graphite or dry molybdenum disulfide; oil would eventually find its way to the hot end and inhibit heat transfer. Set the cranks at about 90°. Check that the shaft turns absolutely free — no tight spots allowed here! Plug the end of the passage with a ¼—28 bolt and soft washer and make sure the engine is airtight. Moriya's engine is ready to come to life!

Secure a temporary flywheel to the shaft, apply a good size flame to the bottom of the hot end, wait about 30 seconds, and give the shaft an easy spin; the displacer piston leads the power piston 90° in the direction of rotation. Direction can be reversed by turning the power crank 180°.

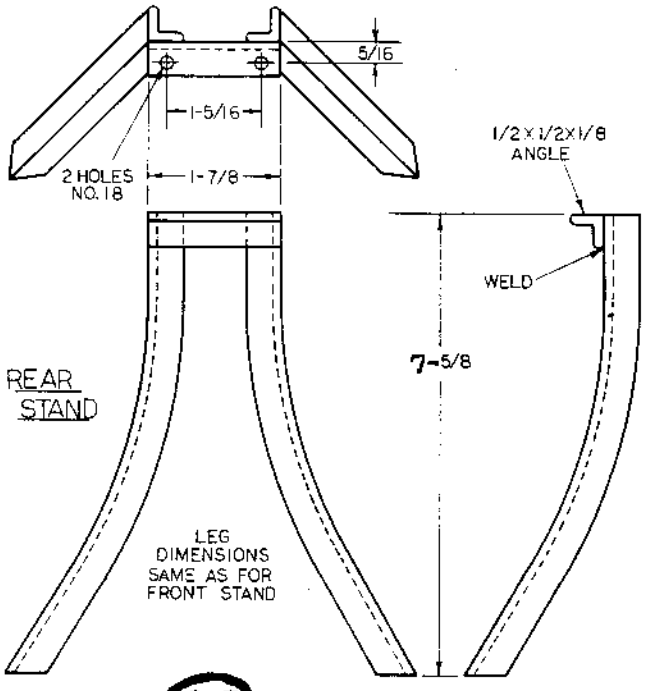


The author's son (above) enjoys Moriya's gentle breeze on a summer day. The "Ky-Ko" hot air fan, depicted in the 1938 advertisement below, was about four feet high and well-known for its trouble-free performance. Reproduction of the ad is by David Swann.



FRONT STAND – STEEL

22



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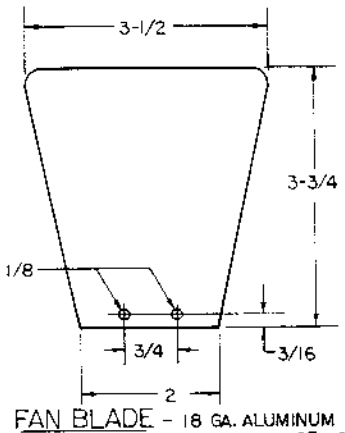
If Moriya is the first hot air engine you have made, it is highly probable that you will be content for some time to leave it as is and simply watch it quietly spin a nicely finished flywheel! But the remaining parts are non-precision jobs and therefore offer a pleasant and relaxing change from the careful engine work — especially from the feverish activity that occurs whenever an engine is nearing completion.

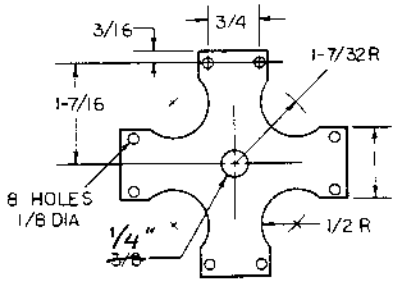
You will probably want to make the FAN BLADES first to "see what she'll do." Simple sheet metal work finished in one evening. I purchased a pop rivet tool to fasten the blades to the web and fell in love with the device. Since then it has been invaluable for restoring broken toys and sad faces! You may wish to experiment with the pitch angle of the blades for maximum breeze, or perhaps even try curving the blades.

The legs for the FRONT STAND and the REAR STAND are bent up from ordinary ½" angle iron. The astute engineer will note that many of the dimensions in the drawings of these items are redundant; the point is, of course, that you can follow those most convenient for your shop. The dimensions need not be critically followed; but the legs should turn out identical for the sake of appearance. To this end, I made a jig by bending a length of angle to the desired shape and reinforced it by welding short lengths of angle to the back. Then four generous lengths of angle were cut, placed in the jig, clamped by one end in the vise, and bent into the jig with the aid of a pipe handle slipped over the free end of the leg.

After bending, the legs can be cut to exact length and welded to the mounting pieces. The rear stand is secured to the engine by 8—32 screws that enter the tapped holes in the engine base below the power cylinder. An alternative would be to use long screws to hold down the

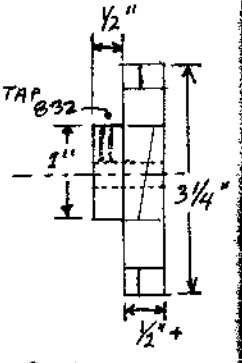


FAN BLADE - 18 GA. ALUMINUM
4 REQ. (24)
OR CARBON FIBER, OR?

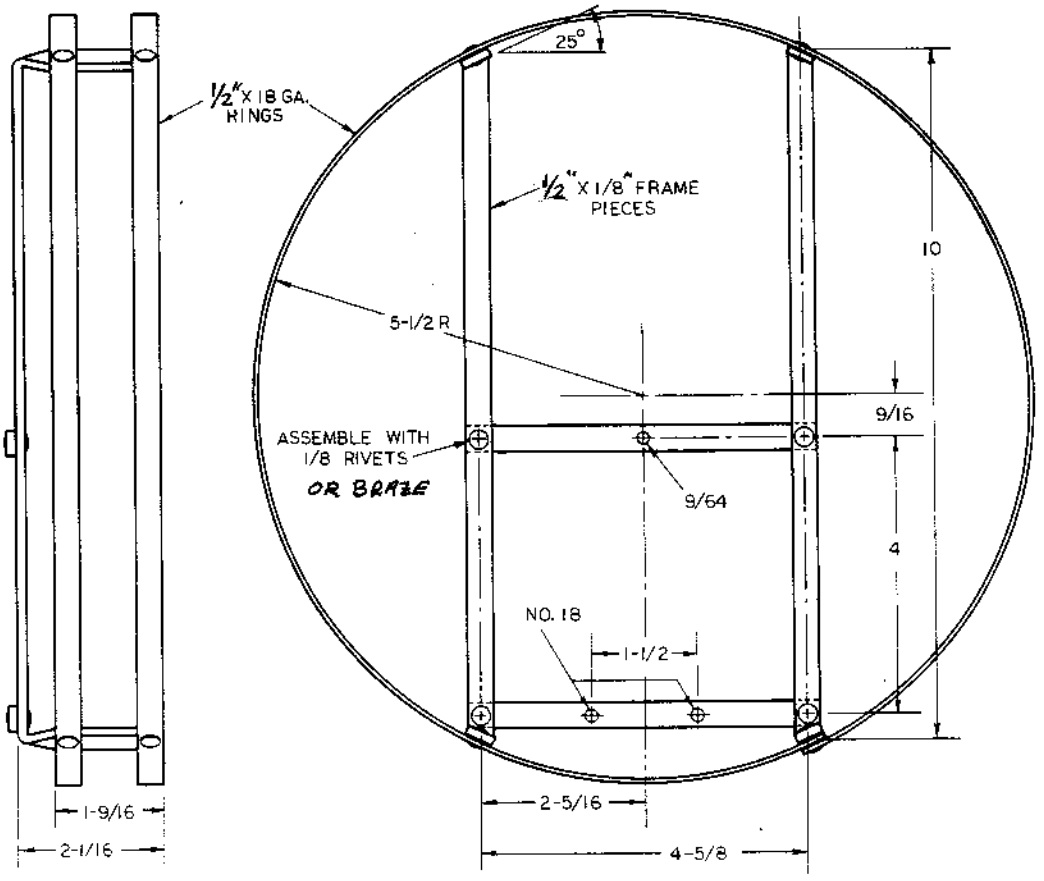


TWIST EACH TAB 20°

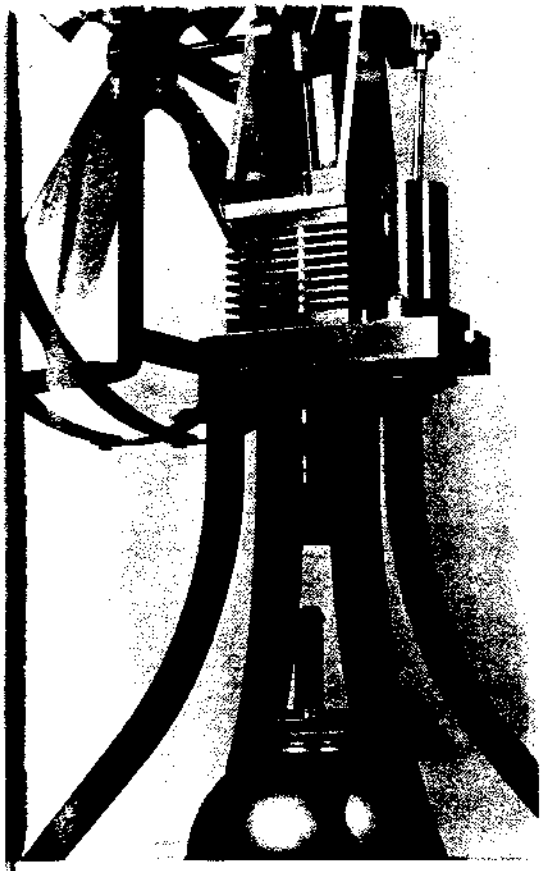
FAN WEB
14 GA. ALUMINUM (25)



Part of #21



FAN GUARD - STEEL (26)



power cylinder and nuts on the underside to capture the rear stand. The front stand is secured by two 8—32 screws to the front of the engine base; these screws also pass through the lower cross bar of the fan guard.

I found the FAN GUARD to be an interesting task — once again the pop rivet tool could be used! Cut out and drill the cross pieces and bend the U-shaped uprights. You may wish to increase the depth of the guard; in fact, if you use a larger pitch angle for the fan blades, the depth must be increased. Simply increase the 2-1/16" dimension the desired amount and increase the 1-9/16" dimension by the same amount. Twist the legs 25° taking care that the legs are truly prependicular so that the rings will line up nicely. Drill the required holes in the uprights and rivet on the cross pieces securely. Turn a 3/8" O.D. by 9/64" I.D. by 3/8" long aluminum bushing and mount the assembly to the engine with the bushing between the upper cross bar and the front bearing stand, a 6—32 bolt passing through the three.

Bend the rings around any convenient round object to produce a diameter of approximately 11". Drill a 1/8" hole near one end of each and temporarily bolt to the frame. Adjust the positions of the rings till they form round identical circles, temporarily clamp in position, and mark off the holes and the exact length. Remove the rings, drill the holes, cut to length, and rivet to the frame. The lap joint should be made at one of the legs as depicted in the drawing for maximum rigidity.

With the stands and guard shaped to your liking, finish these pieces by painting. Flat black was used on my Moriya and contrasts nicely with the bright aluminum engine surfaces. The blades can also be painted if desired; perhaps grey or dark green. All that remains now is the ALCOHOL LAMP.

Jewelry and watch repair supply houses can furnish cute little alcohol burners which may be the right height for the job, but an ordinary oil can is easy to adapt to our purposes. Remove the spout from the filler cap, open out the hole if necessary, and solder a length of thinwall 3/8" O.D. brass tubing in its place. The top of the tube should be about 1" below the bottom of the hot end. Pack in string for a wick, but not too tightly so that the tank can vent itself.

Finally, you may wish to fit a flame shield against the front stand as on the "Ky-Ko" fan in an attempt to prevent the products of combustion from being pulled along with the cooler air. Also, some thick asbestos insulating material placed on the underside of the engine base will help keep the temperature of the cold end lower.

The author and his son, Victor, enjoy firing up Moriya on any occasion, just for the satisfaction of watching it operate.