

SC1A

SLIDE CRANK
"SCOTCH YOKE"
ENGINE KIT
1/2" BORE x 5/8" STROKE

INSTRUCTION MANUAL

SAFETY PRECAUTIONS

General safety precautions used in machine shops must be used in the machining operations necessary for the finishing of this kit.

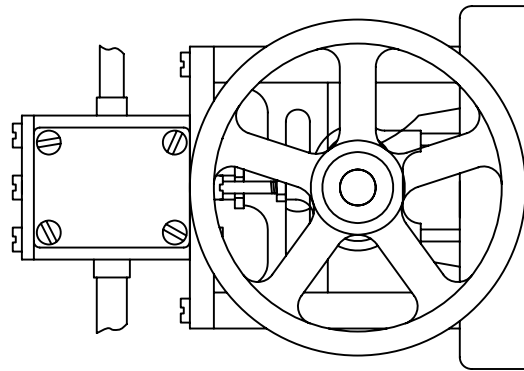
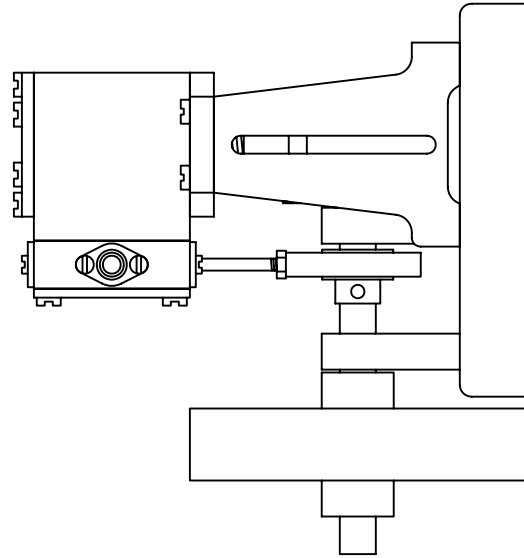
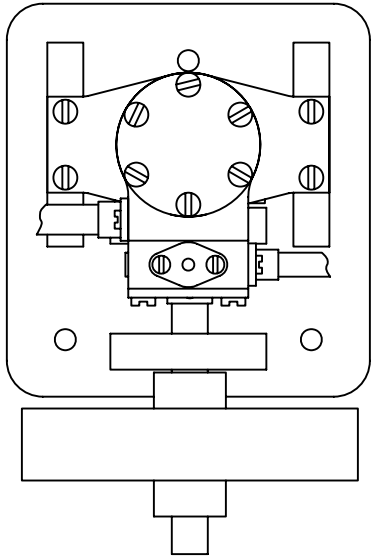
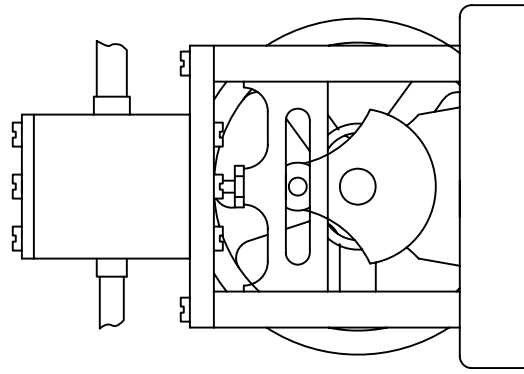
USE PROTECTIVE EYE WEAR AT ALL TIMES.
USE ADEQUATE VENTILATION WHEN USING CUTTING FLUIDS.
AVOID SKIN CONTACT WITH CUTTING FLUIDS AND OTHER CHEMICALS.

Some of the chemicals and materials recommended for cleaning, part retention and cutting fluids may be toxic if not used in accordance with the instructions provided by the manufacturer of the materials. Some of the recommended chemicals or materials may be flammable and should not be used around open flame or other possible sources of ignition.

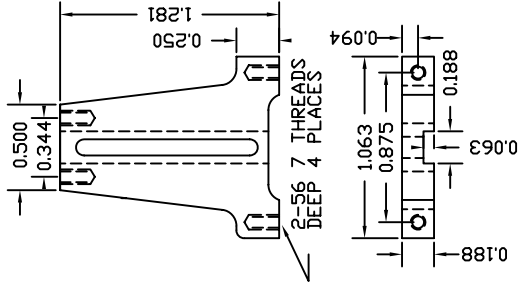
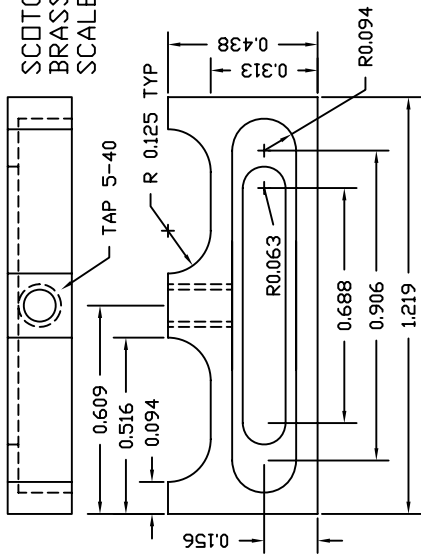
This engine is designed to run at pressures up to 30 PSI. At this pressure, the no load engine speed can be expected to be 5000 to 6000 RPM. If the kit is machined, assembled and operated in accordance with these instructions, no problems should be experienced. Pressures greater than 30 PSI may cause mechanical failure in the engine. If the engine is run on steam, the steam supply boiler **MUST** have a safety release valve set to no higher than 35 PSI.

LIMITED WARRANTY

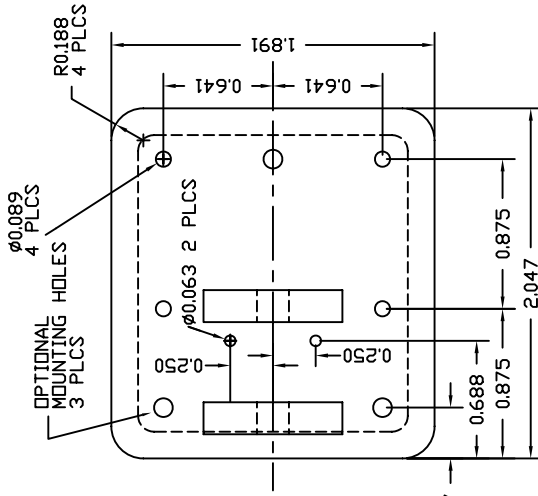
Graham Industries warrants that the materials supplied in this kit are free from defects for a period of 60 days from the date of purchase. If defects are discovered in the supplied materials, the defective material will be replaced upon notification to us in writing. Graham Industries reserves the right to require defective material to be returned to us. This warranty does not apply to materials that have been damaged by machining or assembly.



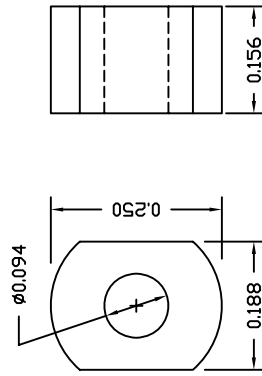
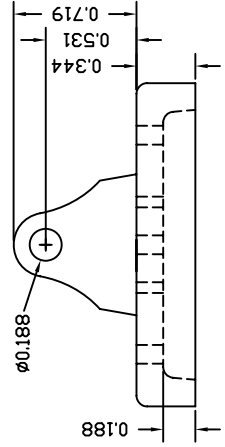
SCOTCH YOKE GUIDE
BRASS
SCALE 2:1



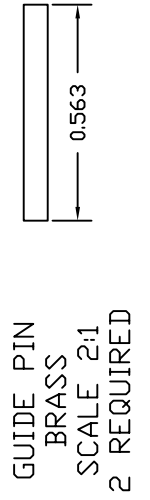
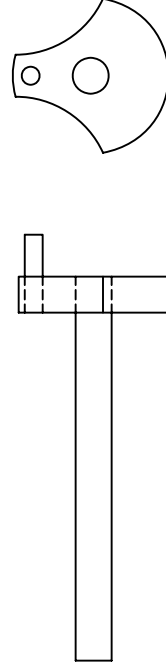
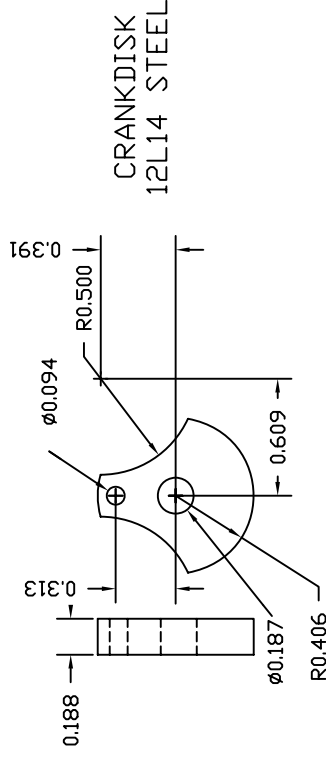
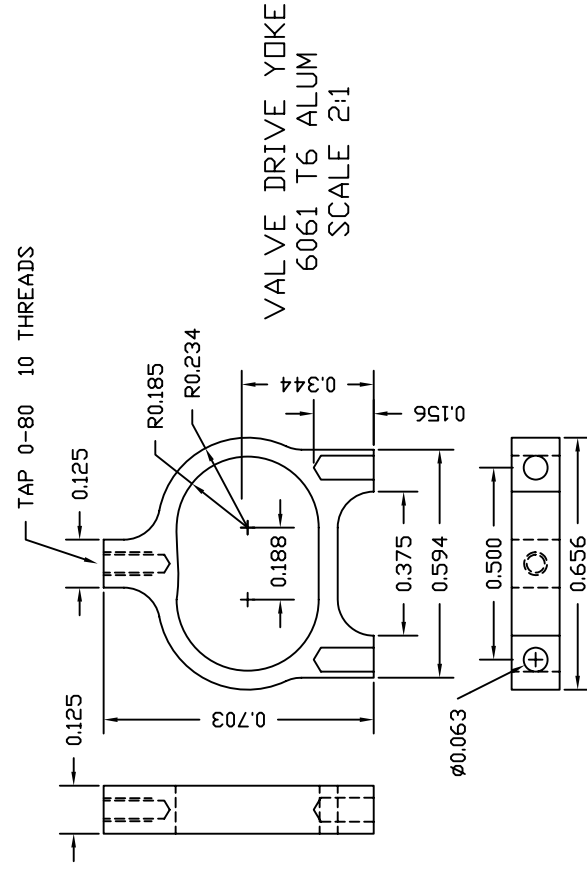
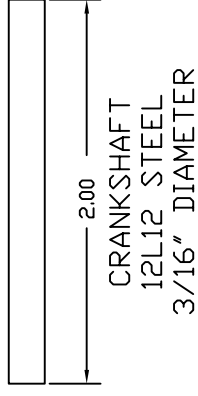
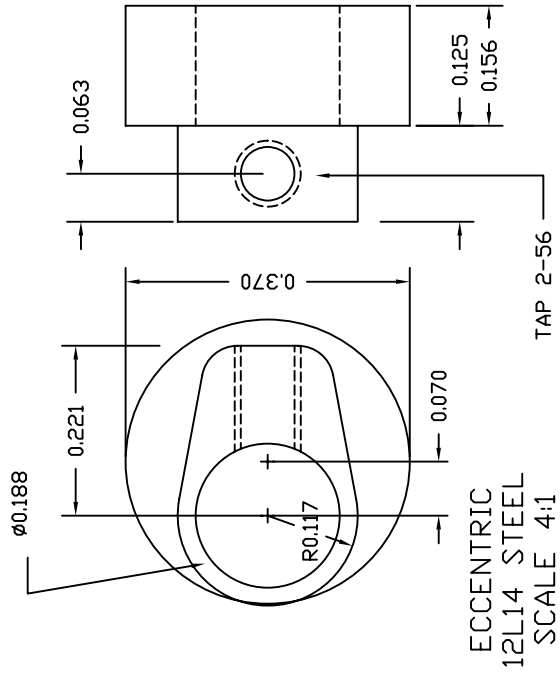
STANDARD 2 REQD
6061 T6 ALUM



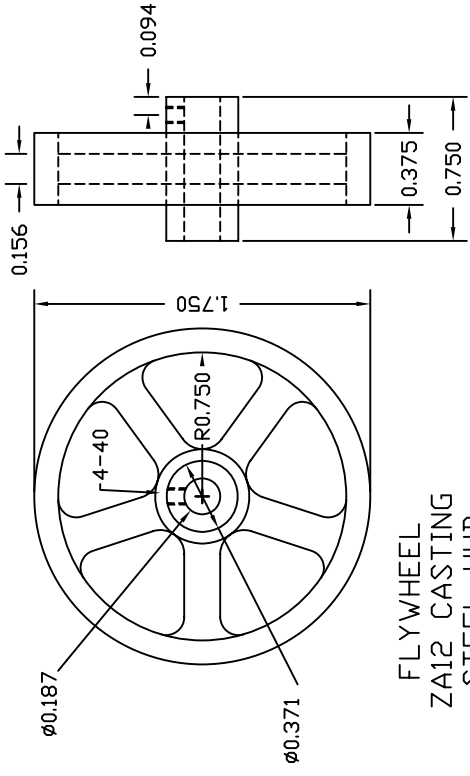
BASE
ZA-12 CASTING



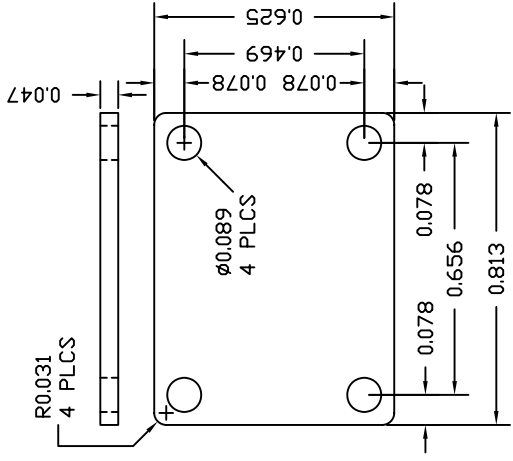
SCOTCH YOKE SLIDE
12L14 STEEL
SCALE 4:1



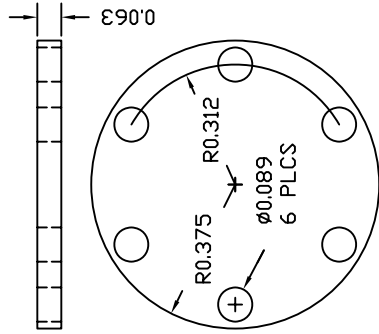
2 REQUIRED



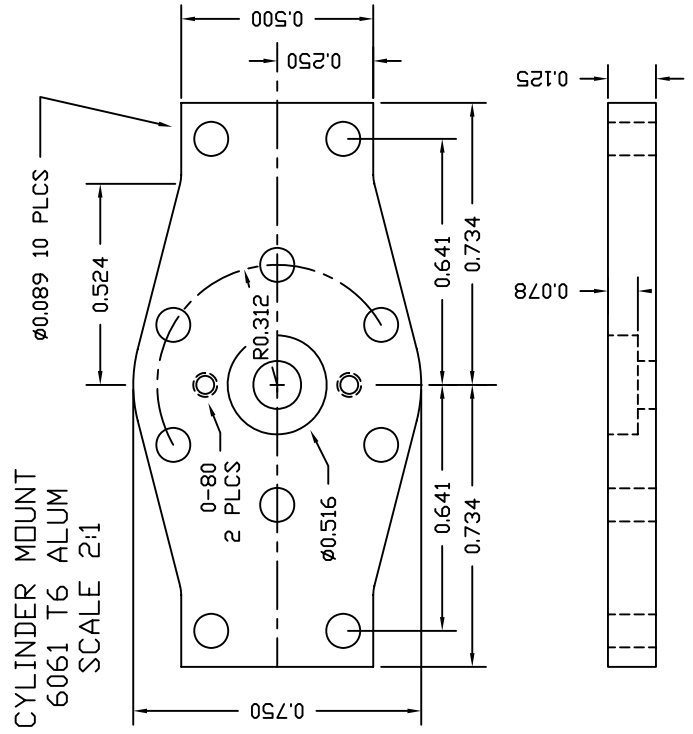
FLYWHEEL
ZA12 CASTING
STEEL HUB
FULL SCALE



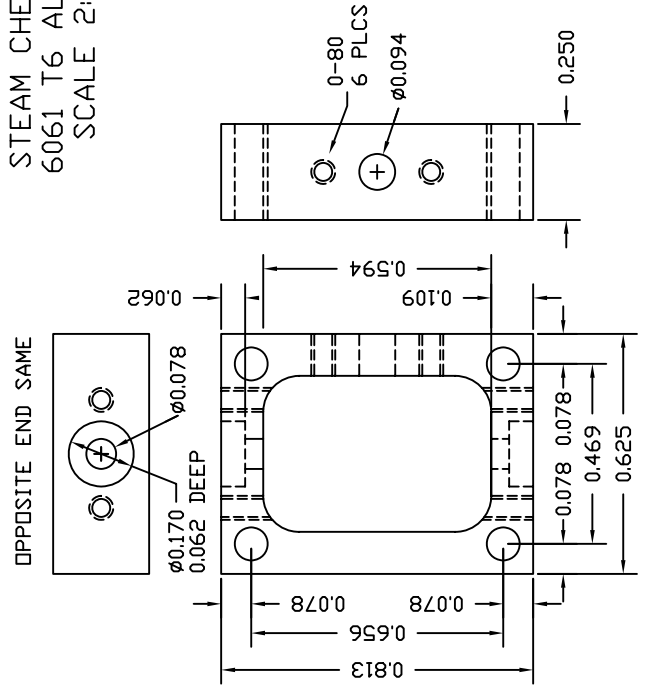
STEAM CHEST COVER
6061 T6 ALUM
SCALE 2:1



CYLINDER COVER
6061 T6 ALUM
SCALE 2:1

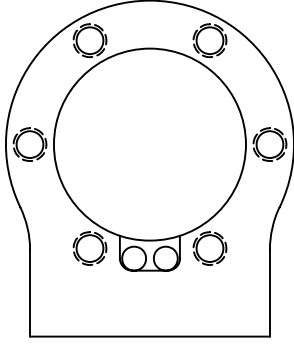


CYLINDER MOUNT
6061 T6 ALUM
SCALE 2:1

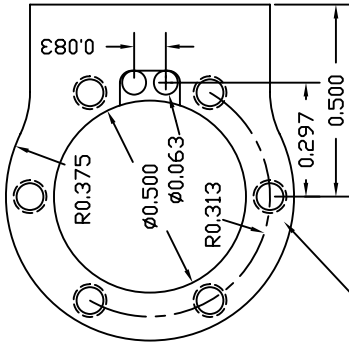
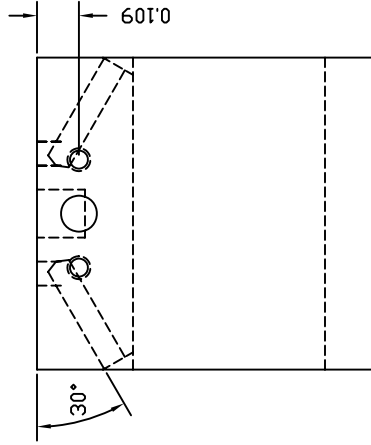
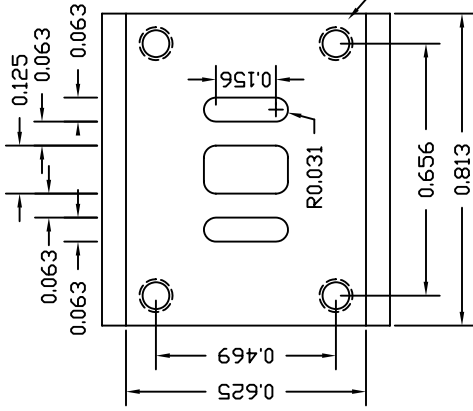
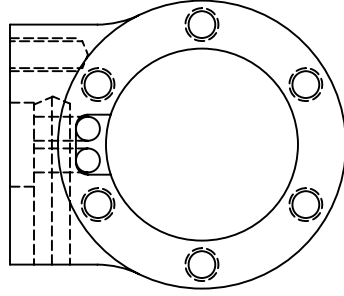


STEAM CHEST
6061 T6 ALUM
SCALE 2:1

CYLINDER
BRASS
SCALE 2:1

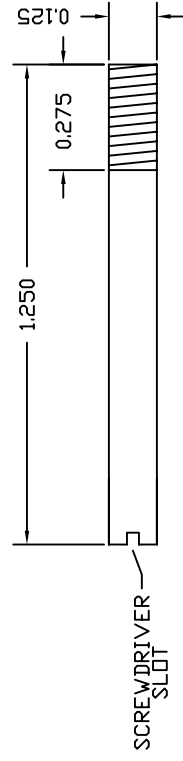


2-56 5/32 DEEP
4 PLACES



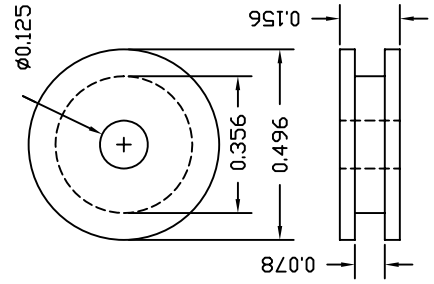
2-56 3/16 DEEP
12 PLACES

PISTON ROD
1/8 DIA BRASS ROD
SCALE 2:1



PISTON
BRASS
SCALE 2:1

USE AS568-012
"O" RING
3/8 X 1/2



INTRODUCTION

The GAGE SC1 is a compact double-acting steam engine of 1/2" bore with a 5/8" stroke. A slide valve is used to control the steam. The compact size is possible by using a "Scotch yoke" drive between the piston and crankshaft. An eccentric driven yoke operates the valve. Using yoke drives eliminates the length of the connecting rod and crosshead commonly used in steam engines.

The "Scotch yoke" has greater frictional losses than a conventional crosshead-connecting rod arrangement, however, unless operating a heavy load, the difference is small. This engine is non-reversing as shown in the plans. If you want to make this engine reversing, there is enough room between the crankshaft bearings for a slip eccentric.

Modern production techniques, using computer controlled machine tools, have made practical replacing traditional castings with parts pre-machined from solid materials. In general, these parts are not completely finished, however, there is always the fitting, filing and polishing necessary to make a showpiece model.

PARTS LIST

Part #	Qty	Description
A2027	1	Base, Machined
53032	1	Flywheel, 1 3/4" 5 Spoke, Brass
BAG "A" - Hardware		
10000	1	Nut, 0-80, 3/32" AF
10408	10	Machine Screw, 0-80 x 1/8" Fillister Slot
12216	4	Machine Screw, 2-56 x 1/4" Pan Slot
12228	4	Machine Screw, 2-56 x 7/16" Pan Slot
12412	16	Machine Screw, 2-56 x 3/16" Fillister Slot
12608	1	Set Screw, 2-56 x 1/8", .035" Hex Drive
14608	1	Set Screw, 4-40 x 1/8", .050" Hex Drive
40003	2	O-Ring, 1/16" ID x 3/16" OD AS568-003
40006	1	O-Ring, 1/8" ID x 1/4" OD AS568-006
40012	1	O-Ring, 3/8" ID x 1/2" OD AS568-012
40030	1	Wrench, Hex, .035" AF
40031	1	Wrench, Hex, .050" AF
51006	1	Washer, Thrust, 3/16" ID, 5/16" OD
53023	1	Nut, Special, 5-40, .047" Thick
BAG "B" - Large Parts		
A2001	1	Piston Assembly
A2002	1	Crankshaft Assembly
53004	1	Cylinder, Finished
53007	1	Steam Chest, 12x58
53009	1	Cylinder Mount
53011	1	Scotch Yoke Guide
53029	2	Standard
BAG "C" - Assemblies, Small Parts		
A1001	1	Steam Pipe Assembly, Inlet
A1002	1	Steam Pipe Assembly, Exhaust
A2003	1	Valve Drive Yoke Assembly
A2004	1	Valve Spindle Assembly
51004	1	Cylinder Cover
51005	1	Steam Chest Cover
51007	2	Seal Retainer, 1/16"
51008	1	Seal Retainer, 1/8"
53008	1	Slide Valve
53012	1	Scotch Yoke Slide
53015	1	Eccentric

SPECIFICATIONS

Bore:	1/2 inch
Stroke:	5/8 inch
Valve travel:	.070 inch
Flywheel Diameter:	1 3/4 inch
Weight:	8 ounces
Size: (WxDxH)	1.8" x 2.5" x 2.7"

ASSEMBLY

Now it all comes together. The rest of the parts in the kit are useable as they are supplied, but you may want to clean them up with a file and/or abrasive paper for appearance.

As parts are assembled, put a light coat of oil on all the working surfaces. Use a good grade of light sewing machine or instrument oil. Some household oils contain more solvent than oil and can not be recommended. Automotive oil is too thick even in the lighter weights. I use Starrett Tool and Instrument oil. It is available from many machinist supply companies.

Paper gaskets may be used if desired on all the sealing joints, but they are not necessary if the parts are well finished. If you do use gaskets, use typing paper with oil applied to it.

Check the crankshaft assembly for any solder or retaining compound at the two joints and clean if necessary. Make sure the crankpin and crankshaft do not protrude beyond the crankdisk where they are supposed to be flush. File if necessary.

Remove any burrs from the 5/16" x 3/16" thrust washer and slide it on the crankshaft. Check the crankshaft fit in the bearing holes in the base. If the base was painted, there may be a little bit of paint in the bearings. Remove the crankshaft assembly.

Slide the valve drive yoke into the 1/16" holes in the base. This needs to be a free sliding fit. Again, check for paint. Enlarge the holes a little if necessary or bend the guide pins a little bit if there is binding at the ends of the pins only.

Insert a 2-56 x 3/32" setscrew in the eccentric. Insert the eccentric in the valve drive yoke with the setscrew ends towards the flywheel end. Slide the crankshaft with thrust washer through the inside bearing, the eccentric and the outside bearing.

Install a 4-40 x 3/32" setscrew in the flywheel hub. Slide the flywheel on the crankshaft. Place a piece of paper or shim stock about .003" to .008" thick between the flywheel and front bearing. Apply pressure between the flywheel and the crankdisk and tighten the setscrew in the flywheel. Remove the spacer. Leave the eccentric loose on the shaft for now. Rotate the flywheel gently. There should be no binding.

Place one of the standards on the base with the groove facing inside. Secure to the base with two 2-56 x 1/4" pan head screws. Do not tighten. Place the scotch yoke slide on the crank pin and place the scotch guide on the slide. Engage the end of the guide in the slot in the standard with the 5-40 hole away from the base. Place the other standard on the base while engaging the guide in the slot of the standard. Secure the standard to the base with two 2-56 x 1/4" pan head screws.

Cut two strips of thin paper 3/16" wide and slide them between each standard and the scotch yoke guide in the slots. Position the crankshaft to place the guide nearest the base. Press the two standards together with your fingers. Apply the pressure over the guide locations. Tighten the four screws attaching the standards to the base. Remove the spacer papers.

Rotate the crankshaft to move the guide away from the base. Place the cylinder mount on the standards and secure with four 2-56 x 3/16" fillister head screws. Try rotating the crankshaft. If the guide binds, loosen the screws on the cylinder mount and spread the top of the standards apart slightly. Tighten the screws. If binding still occurs, locate the problem and correct it before continuing. Sometimes the standards will tilt slightly toward each other because of shrinkage in the base casting. If this is the case, it may be necessary to remove the standards one at a time and file a VERY SLIGHT bevel on the bottom of the standard to compensate. This is normally not necessary.

Now that the bottom part of the engine is operating smoothly, remove the cylinder mount.

Install a 3/8" ID x 1/2" OD "O" ring on the piston. Be sure to put a little bit of oil on the "O" ring. Check that the piston rod "O" ring retainer is an easy fit on the piston rod. If it is tight, enlarge the 1/8" hole with a needle file or a #31 drill bit. Make sure there are no burrs. Remove the "O" ring retainer.

Slide the piston rod through the cylinder mount from the side of the mount opposite the recess for the piston rod seal. Put some oil on the 1/8" ID x 1/4" OD "O" ring and slide it on the piston rod. Be gentle sliding over the threaded portion of the piston rod so the "O" ring is not damaged. Press the "O" ring retainer on the piston rod and secure to the cylinder mount with two 0-80 x 1/8" long screws. Thread the 5-40 jam nut on the piston rod.

Decision time: The steam inlet and exhaust should be on opposite sides of the cylinder (but this is not required). The cylinder is completely symmetrical so the exhaust can be on either side of the engine. If you have a preference as to which side of the engine the exhaust is on, place it on that side during the following step.

Oil the bore of the cylinder. Slide the cylinder onto the piston and seat it on the cylinder mount. Rotate the cylinder so the port face is to one side of the cylinder mount and secure the cylinder to the cylinder mount with six 2-56 x 3/16" fillister head screws.

Check that there are no burrs inside the steam chest. Insert the valve rod assembly threaded end through the hole in either end of the chest from the INSIDE of the chest. Slide it all the way in. The valve driver will barely fit past the opposite end of the chest. Slide the rod back through the hole in the opposite end of the chest.

Slide an oiled 1/16" ID "O" ring on each end of the valve rod. Press them into the recess on each end of the valve chest. Check the "O" ring retainers for an easy fit on the valve rod. Open them up with a #52 or #51 drill bit if necessary. Remove any burrs. Slide a retainer on each end of the rod and secure them to the steam chest with 0-80 x 1/8" fillister head machine screws. Slide the rod to make sure there are no binds. Thread the 0-80 nut on the end of the rod.

Lightly oil the port face of the cylinder. Set the valve on the port face with the valve recess next to the cylinder. Orient the steam chest so the steam inlet is on the opposite side of the cylinder steam exhaust and the long end of the valve rod extends beyond the cylinder mount. Place the steam chest cover over the port face with the valve driver engaging the valve in the wide slot and the valve rod passing through the narrow slot. Temporarily secure the steam chest to the cylinder with two 2-56 x 7/16" pan head machine screws. These screws may not seat as the chest cover is not installed yet.

Place the cylinder assembly on top of the standards and secure with four 2-56 x 3/16" pan head machine screws. Adjust the standards as before to make sure the scotch yoke guide is free. Tighten the mounting screws. Position the crankshaft to move the scotch yoke guide nearest the base.

Use a small screwdriver to push the piston down to engage the piston rod thread in the guide. Turn the piston using the screwdriver in the slot in the piston rod to thread the rod into the guide. Thread the rod into the guide until you feel the piston touch the cylinder mount. Make sure the guide is at the bottom of the stroke nearest the base. Rotate the piston in the opposite direction about 5/8 of a turn. Rotate the crankshaft to place the piston at the top end of the cylinder. There should be about 1/64" (.015") between the piston top and the top of the cylinder. Tighten the piston rod jam nut against the guide while keeping the piston from turning with the screwdriver.

This engine can't be reversed in operation, but it can be adjusted to run in either direction by the setting of the eccentric. Decide which direction you want the engine to run.

Rotate the crankshaft so the piston is at the top of the cylinder. Rotate the eccentric so the setscrew faces the side of the engine that you want the top of the flywheel to rotate toward. Center the face of the eccentric in the valve drive yoke and tighten the setscrew. Rotate the crankshaft so the eccentric setscrew is up. Check that the position of the scotch yoke guide is in the middle of it's travel.

With the eccentric setscrew facing up, press the valve rod down to engage the 0-80 threads. Thread the valve rod into the valve drive yoke. If a small drill chuck is available, use it to grip the portion of the valve rod that protrudes above the steam chest. Otherwise, use smooth jaw needle nose pliers to turn the rod.

After the rod is started in the yoke, remove the drill chuck (if used) and rotate the crankshaft. Adjust the valve rod so the steam ports in the cylinder are uncovered an equal amount at the ends of the valve travel. Tighten the 0-80 nut on the valve rod against the yoke. Check the setting of the valve once again.

Remove the two screws holding the steam chest in place. Using these two screws and two more, install the steam chest cover on the steam chest. Align the chest cover and the chest to the cylinder edges and tighten the screws.

Rotate the crankshaft several times to check for binding. Install the cylinder cover on the cylinder on the cylinder using six 2-56 x 3/16" fillister head screws. Check for any binding again.

Attach the steam fittings with pipes to the cylinder and steam chest with 0-80 x 1/8" fillister head screws. The 1/8" pipe is the steam inlet and attaches to the steam chest. The 5/32" pipe is the exhaust pipe and attaches to the cylinder block.

TEST RUNNING

For test running the engine, a supply of regulated air adjustable from 0 to 30 PSI is recommended.

Clamp the base of the engine in a drill press vise. If the base is painted, use strips of paper to prevent chipping the paint. Oil all the bearings, the sides of the scotch yoke guide, the slider and the eccentric. Place a few drops of oil in the steam inlet pipe.

Connect the air supply to the steam inlet pipe. If no additional fittings have been installed on the steam inlet, slide a piece of 1/8" ID plastic tubing over the inlet pipe to make the connection.

Set the air pressure to 10 PSI and rotate the flywheel in the direction you have selected during the eccentric adjustment. The engine should start running. If it tries, but does not keep running, increase the pressure to a maximum of 20 PSI. If the engine will not run at 20 PSI, something is binding or out of adjustment. If no binding is present, check the eccentric setting. It must be at 90 degrees to the crankshaft.

After the engine starts, let it run for a few minutes. Then reduce the pressure until it stops. This will probably be about 7 or 8 PSI. Increase the pressure a few pounds and restart the engine. Let the engine run for an hour or two at this speed. About every 20 minutes, disconnect the air and add a few drops of oil in the steam inlet. This extra oil is necessary to carry away metal particles from the face of the valve as it wears in. You will probably notice that the oil coming from the exhaust will be darkened from these particles.

After the engine has run in at low speeds, the speed can be increased by increasing the air pressure. **DO NOT EXCEED 30 PSI.** As the engine continues to run in, the low speed operation will improve. The prototypes all ran on about 3 PSI after they had several hours of running time on them.

STEAM OPERATION

Operation on steam requires some form of lubrication system for the steam. Unlike air operation, the wet steam washes away the oil on the valve and in the cylinder.

A displacement lubricator attached to the engine at the inlet pipe is the easiest, but other types can be used.

While steam cylinder oil is the best, other types can be used if the engine is not being used with steam pressures higher than 25 PSI and the steam is not superheated.