HEX-2

BY

Jerry James

Made with Cox .049 Cylinder assemblies Simple machining using smaller machine tools

The HEX-2 was designed to investigate alternate induction methods for a 2-cycle engine and to create an easy-to-build engine for the inexperienced Model Engineer. The use of Cox .049 cylinder assemblies allows the builder to avoid the more difficult aspects of engine construction but supplies the experience necessary for the next phase in engine construction.

Machining Instructions

Crankshaft Holding Fixture

Cut a 0.550" length off of the 7/8" hex bar and mount that piece in a 3-jaw chuck on your lathe. Center-drill, drill and bore 0.625" through. Face off both ends to reduce it to 0.500". Finally cut a slot the length of the cut off part using a hack saw as shown below. This will be used to hold the Crankshaft when you machine it.

Crankshaft Holding Fixture

Rear Plate

Hex Rod in the Lathe

Mount the 7/8" hex bar in lathe and face the end square. Turn a 0.620" diameter shoulder 0.340" deep in from the end. Then locate and mark holes for the screws or use the X-Y table located at the end of this article to position the hex bar for drilling in the mill. Drill with a #43 drill to a depth of 0.650". Then part the Backplate off at a 0.390" length. Now enlarge the 6 screw holes for

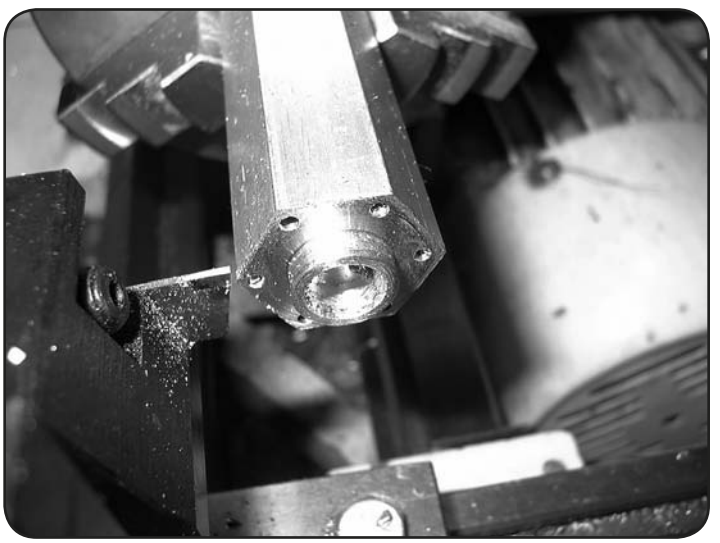
Drilling screw holes in Backplate

Milling clearance for Piston

screw clearance to 0.125". Finally, mill the clearance for the rear piston but do not cut it beyond depth.

Front Plate

Mount the 7/8" hex bar in the lathe, ensuring the screw holes to mount the Backplate face away from the tail stock of the lathe. Face the end of the bar square and turn a 0.500" diameter shoulder 0.150" deep. Smooth the front of the shoulder with fine abrasive paper. Center drill then drill a 0.375" hole 0.300" deep. Then locate and mark the front plate screw holes and with a #43 drill, make each 0.625" deep. Now part off the Front Plate at 0.200" length. Finally, enlarge the screw holes in the Front Plate to 0.125".



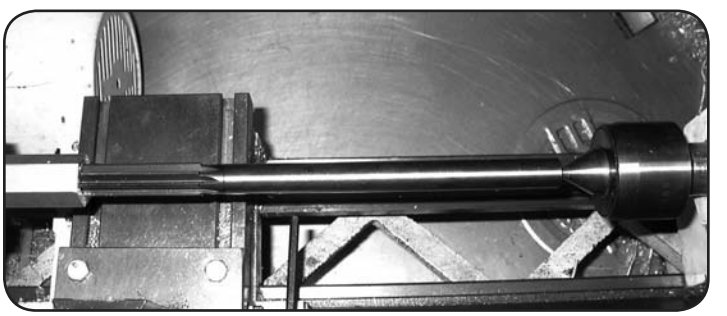
Parting the Front Plate to Length

Crankcase

Face off the end of the hex bar, ensuring the facing operation does not remove the hole locations, drill deeper if needed. Then reverse the 7/8" bar in the lathe and face to length. Again insure the #43 holes are deep enough so that they will not be faced off, drilling deeper if necessary. Then drill, bore to 0.620" and ream the bore 0.626" diameter through the Crankcase

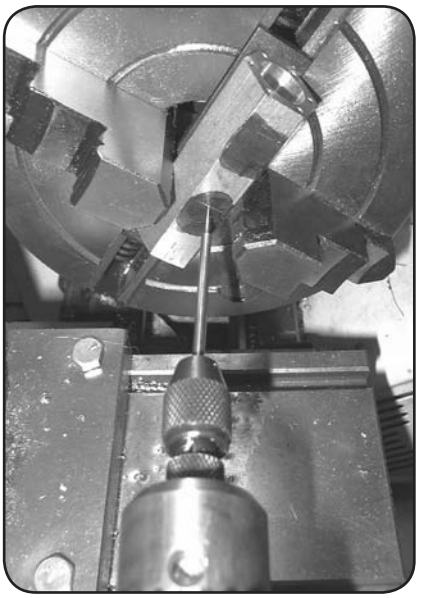
Facing the Crankcase

Boring the Crankcase



Reaming the Crankcase

The reamer may have to be mounted between work piece and tail stock center – GO SLOW. The lathe should be turning at about 950 RPM for reaming this hole. (Reamers should be run at 50% of the proper speed for drilling with a High Speed Steel drill). Use lubricant when reaming and never turn the work backwards with the reamer in the bore.

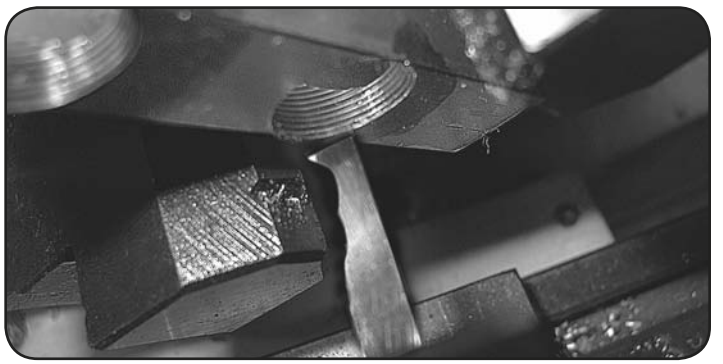


Centering Crankcase

Note: an alternative method is to first bore the Crankcase to 0.524"–0.625" and lap the bore to 0.626" using the techniques described by Ken Croft in his excellent article on Lapping in Issue 2 of *Model Engine Builder*. Use a suitably modified version of his cylinder lap. [Ed.]

Remove from the 3-jaw chuck and locate and mark center of the two cylinder positions. Then mount

Tool ground for cutting internal threads

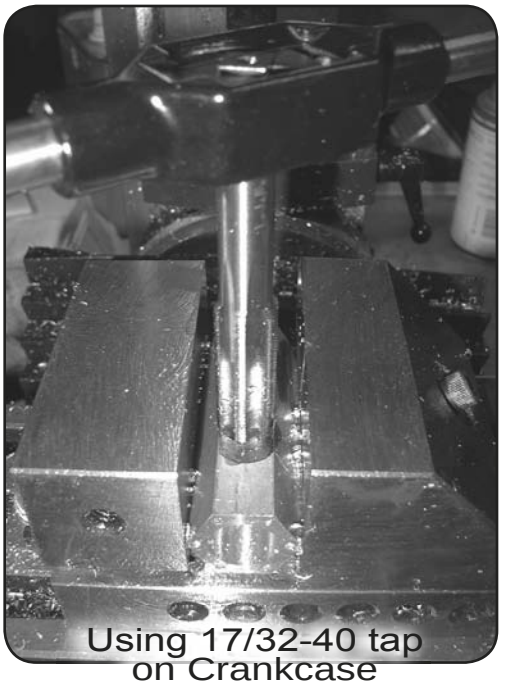


Cutting internal threads

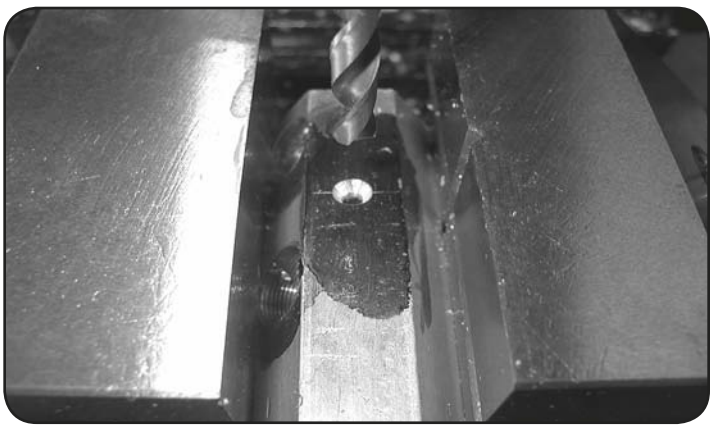
the Crankcase in a 4-jaw chuck and center on front cylinder centerline. Center drill and drill a 0.500" diameter hole through the top half of the Crankcase. Do not allow the drill to contact the far side of the bore for the Crankshaft. Cut the internal threads for cylinder mounting with a 17/32-40 tap or using the lathe to cut the screw threads. Taps can be special ordered or ordered on www.jamesengine.com.

Reposition the Crankcase centered on the Rear Cylinder centerline and repeat the operations as for the for the Front Cylinder.

NOTE: If you have a 17/32-40 Tap then the holes can be created on a milling machine or drill press.



Using 17/32-40 tap on Crankcase



Drilling the Crankcase for the Venturi

Locate and mark the Venturi hole position on the side of the Crankcase and Center drill, drill and tap a 1/4"-28 hole through side of the Crankcase for the Venturi.

Insuring the #43 holes are deep enough on the front and rear of the Crankcase, tap each hole 4-40 by 0.250" deep.

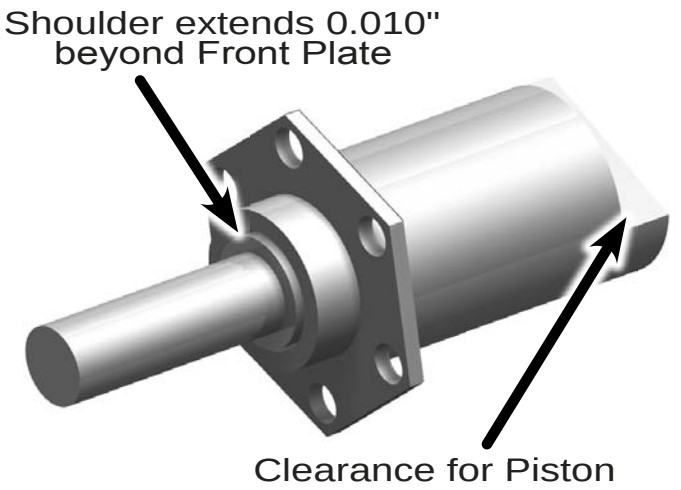
Finally, Run the 0.626" reamer through the Crankcase to remove any burrs caused by the machining operations.

Front Crankshaft

Start by cutting the 0.625" Turned, Ground, and Polished (TGP) shafting to a slightly oversize length. Face-off one end and reverse it in the lathe and face to length. Turn a 0.250" diameter shoulder, 0.740" in length. From that point, turn a 0.350" shoulder to a 0.210" length so that when the Front Plate is slid onto the Crankshaft, the face of the shoulder extends 0.010" beyond the Front Plate.

Cut ¼-20 threads on the 0.250" shoulder back to the 0.350" shoulder then mill or very carefully mark out and file the clearance for the Piston.

NOTE – do not drill hole for the Crank Pin until you are told to do so later in the instructions.



Crankshaft Front
Section with Front Plate

Rear Crankshaft

Cut a length of 0.625" TGP slightly longer than the 1" finished length, insert in lathe and face one end. Reverse and face to 1" total length. Then mill or very carefully mark out and file the Piston Relief on both ends of this Crankshaft section, 180° from each other.

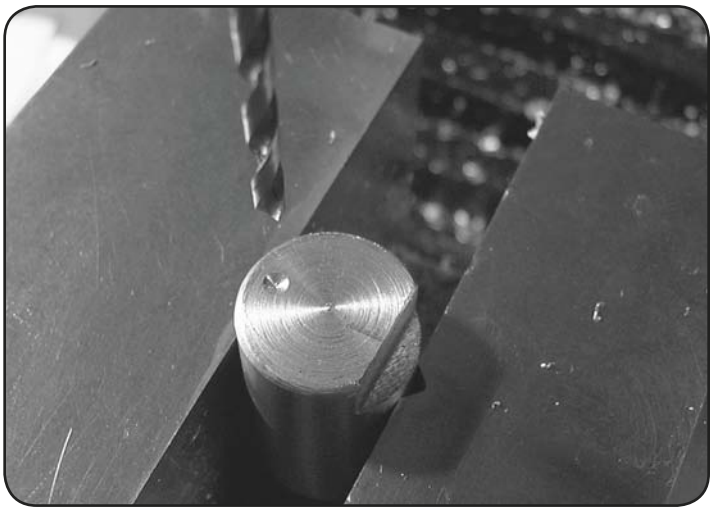
Referring to the drawings, drill the Crank Pin holes with a #41 drill (0.096") 0.250" deep as follows: 1 in the rear of the Front Crankshaft and 2 in the Rear Crankshaft on a centered 0.386" diameter circle. Drill all 3 holes using the same setup to insure that all three holes are as equally spaced from the crankshaft center line as possible. The *critical* dimension is the bolt circle dimension. If this dimension is off by more than a few thousandths, the outer surfaces of the two Crankshaft sections will not align in the Crankcase and the Crankshaft will not turn freely. The 180° separation front to back on the Rear Crankshaft Crank Pin location is not as critical. The 180° dimension insures that the pistons are 180° out of phase but it is not critical for port timing since the port timing is marked using the actual Crank Pin location.

To finish this section of the Crankshaft you will need to mark which end (1) will face to the front and which end (2) will face to the back. Which end you mark as 1 & 2 does not matter. Use a metal letter stamp or something very permanent.

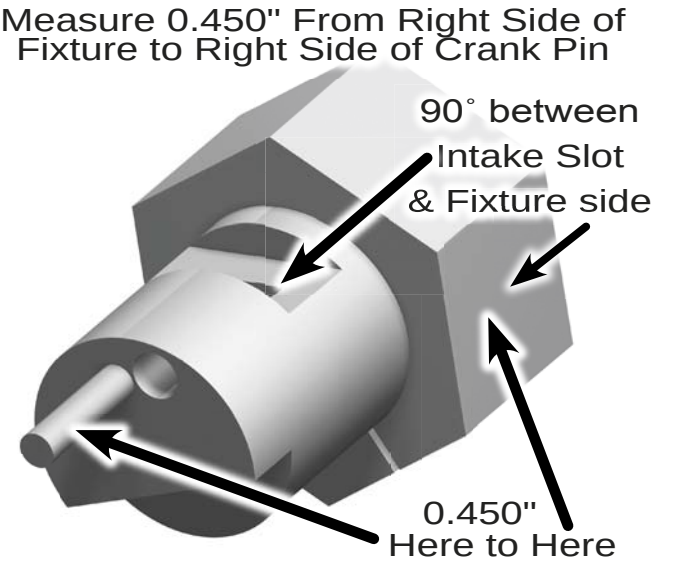
Setup and Machining the Intake Slots

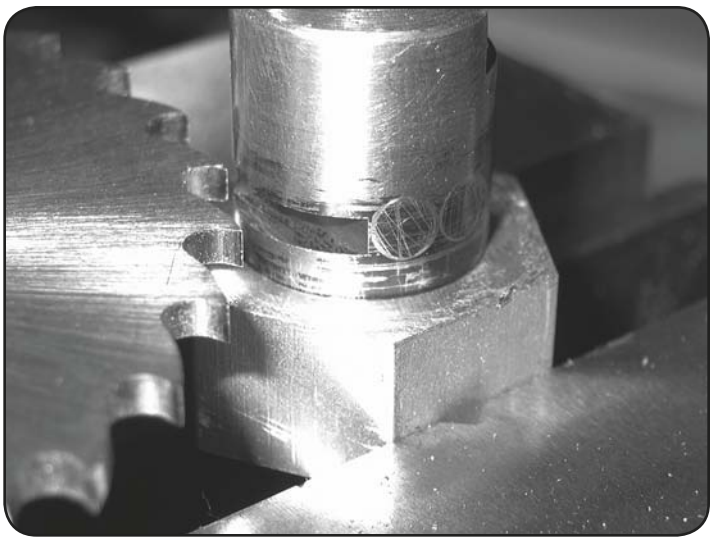
Insert the Crank Pin into End 1 of the Rear Crankshaft and insert the assembly into the Crankshaft Holding Tool 0.225". Measure from the right (this is important because you will measure from the left side to do End 2) side flat of the Crankshaft Holding Tool to the right side of the Crank Pin. The measurement must be 0.450". If you draw a line through the centerline of the Rear Crankshaft and the Crank Pin, that line would now be rotated 18˚ counter–clockwise. Refer to the drawing section Intake Slot Fixture Alignment for more detailed information.

Depending on your preferences, mount the assembly vertically in your milling machine vise and using a saw, mill a 0.250" wide slot 0.090" deep and centered between the two ends of the Rear Crankshaft. If the Crank Pin hole in End 2 was accurately drilled 180˚ from the Crank Pin hole in End 1, you can move the milling table over and cut the intake slot on the opposite side of the Rear Crankshaft.



Drilling hole for connecting rod dowel





Slotting the Rear Crankshaft

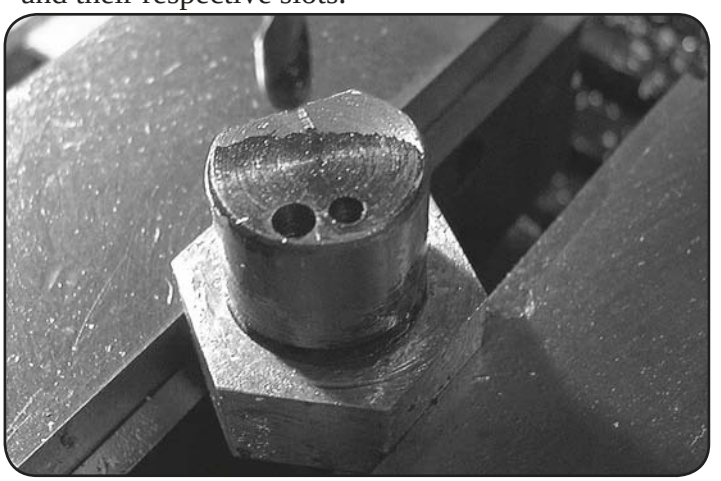
If the End 2 Crank Pin hole is not accurately placed, reverse and re-install the Crankshaft in the Crankshaft Holding Tool as described and measure 0.450" from the *left* side of the holder to the pin. Mill the same sized Intake Slot for End 2 halfway between the ends of the Rear Crankshaft but on the opposite side.

If you wish to use a milling cutter to cut the Intake Slots, the assembly should be placed horizontally in the milling vise and the End 1 Intake Slot cut. Reverse the assembly in the vise and cut End 2 Intake Slot if the End 2 Crank Pin hole is accurately placed 180° from the Crank Pin hole in End 1. Otherwise, re-orient the Rear Crankshaft as discussed before.

You may also cut the Intake Slots with a hacksaw and finish with a file without reducing the performance of the HEX-2.

Drilling Transfer Ports

Drill 1/8" holes between the ends of the Crankshaft and their respective slots.



Drilling passage between face of the Crankshaft and slot

Note: The Transfer Port for End 1 is to the right of the Crank Pin as seen on the 'Aligning Rear Crankshaft to Cut Intake Slot' illustration on the previous page.

Except for their relationship to the Crank Pins, the location of these holes is not critical as long as they provide flow between the proper slot and end of the Crankshaft. Insure the hole does connect to the slot.

Thrust Washer

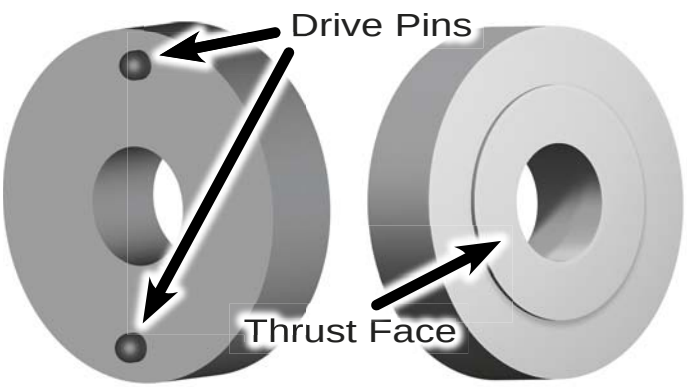
The Thrust Washer serves 2 purposes, it provides a thrust bearing function to keep the Crankshafts in position if rearward thrust attempts to push the Crankshafts back in the Crankcase as might be experienced during engine starting operations. It also provides a drive connection to the propeller.

The drive from the Crankshaft to the Thrust Washer depends on friction between the rear of the Thrust Washer and the front of the 0.350" shoulder on the Front Crankshaft. For this engine, experience has shown that this is adequate. If you wish a more positive drive, you could taper the front of the Front Crankshaft shoulder and machine a matching taper in the rear of the Thrust Washer. Alternately, you could design a pin or square drive between the Thrust Washer and the Crankshaft.

Mild steel is the material of choice for the Thrust Washer. Chuck a 0.750" round bar of steel into your lathe and face off the end. Then center drill and drill to about 0.245" for the Crankshaft nose. Finish with a 0.251" reamer or bore it to size.

Now cut the Thrust Face to a 0.500" inch diameter and leave it about 0.010" high. Use abrasive paper to leave a smooth surface. You will adjust and finish the Thrust Face later if necessary.

Last operation is to drill the holes for the Drive Pins in the front of the Thrust Washer. You can drill these with a 1/16" drill and then Loctite® the pins into place or you can drill under size by 0.005" or so, ream 0.001"



Front & rear of Thrust Washer

under size, then press fit the pins into the holes. I recommend the Loctite approach as easier.

Drive Pin

Drive Pins

Drive Pins are made from 0.0625" diameter steel and are lightly chamfered on the end that will be pressed into the Thrust Washer and rounded on the end that will press into the propeller.

Venturi

Mount the 1/2" aluminum rod in lathe and turn to 0.300" than turn a shoulder 0.250" diameter 0.250" long. Then thread the reduced shaft 1/4”-28. Reverse the die and cut threads to shoulder and reduce the threaded portion to 0.100" long

Center drill and drill #20, 0.161". Part to length and reverse it in the lathe. Now countersink the bore with a 90˚ countersink, 0.057" deep leaving a small lipped edge on top.

Thread the Venturi into the Crankcase and mark the position of the hole for the purchased Needle Valve assembly. The assembly’s axis should lay parallel to the Crankcase long axis. Remove from the Crankcase and drill a #33, 0.116" hole for the Needle Valve assembly through the side of the Venturi.

Needle Valve Assembly

Obtain the Needle Valve assembly from the donor Cox .049 engine.

Note: This assumes you purchased one of the current engines from Cox Hobby Distributors.

Remove the 4 screws holding the plastic assembly to the Crankcase. Remove the Needle Valve and Needle Valve Spring and save. Remove the black plastic Spring Retainer from the end of the Needle Valve Body. Now, using a Drive Pin, drive the Needle Valve Body from the plastic in which it is embedded.

Turn the 0.125" shoulder on the Needle Valve Body down to the same diameter as the knurled portion which is about 0.119".

Press the Needle Valve Body into the Venturi, centering the fuel outlet between the sides of the Venturi bore and pointing down towards the threaded end of the Venturi. Use epoxy if the body is too loose in the bore.

Install the Needle Valve Spring and the Needle Valve. Don’t worry, you have a spare if you ruin the first set.

Starting and running

NOTE: You must continuously check for interference among the engine parts. Some common locations to check are:

1. Pistons and Crankshaft – look for marks where the piston clearance was milled. Small areas can be removed from the front Crankshaft or rear Crankshaft with a file.
2. Cylinders and Crankshaft – insure that when the cylinder is tightened down that it does not press against the CRANKSHAFT. You can remove some of the cylinder bottom on the lathe if this becomes a problem.
3. Piston and Back Plate – look for marks where the piston clearance was milled. Small areas can be remove from the Back Plate with a file.
4. Venturi and Crankshaft– insure the Venturi does not press against the Crankshaft when tightened. Remove some of the threaded end on the Venturi if this is a problem.
5. Front Plate – insure that the Crankshaft end can move slightly in and out of the engine between 0.010" and 0.013" when the propeller or other object is mounted on the front of the engine. The Thrust Washer, pressing against the front of the Front Plate and the front of the Crankshaft, pressing against the rear of the Front Plate, act as thrust bearings.
6. Crank Pin and Back Plate – insure that when you push on the rear Crankshaft that it does not push the Rear Crank Pin into the Back Plate. This should be prevented by the rear surface of the Thrust Washer bearing on the front of the sleeve machined into the Front Plate. The Front Plate acting on the rear side of the Front Plate acts as a thrust bearing to counteract thrust developed by a propeller.

Assembly

NOTE: Before inserting the Crankshaft pieces into the Crankcase, it is important to insure that all burrs have been removed. Use 600 grit abrasive paper (or finer) on all edges. If the crankshaft does not turn freely in the Crankcase, remove and continue to deburr using sandpaper or small file. Layout fluid may be used to find interfering areas. If the Crankshaft does not turn freely, the engine will not work

1. Assemble Crankcase, Crankshafts, Back Plate and Crank Pins. The distance between the two Crankshaft segments, the space for the connecting rod, is 0.130" with a minimum of 0.120". The Crank Pin can be ground shorter until the 0.130" separation is reached. If the distance is less than 0.120", a short segment of another steel pin can be Loctited in the holes. The distance between the Rear Crankshaft and the Rear Plate, the space for the Rear Cylinder Connecting Rod, is also 0.130". The Crank Pin for the Rear Cylinder will have to be ground down to clear the Rear Plate.
2. Insure that the 0.625" diameter of the Front Crankshaft does not extend past the front of the Crankcase. If it does, grind down the Crank Pin(s).

3. Attach the Front Plate and insure the Crankshaft turns freely. Place some oil into the Crankcase and using your model engine starter or suitable substitute, turn the Crankshaft in a counter-clockwise direction for several minutes. This will break in the Crankshaft and insure smooth operation.
4. Disassemble engine.
5. Re-assemble the engine without Venturi and Cylinder Heads. The Connecting rods are slid onto the Crank Pins as the Crankshaft is slid into place. Lightly oil all parts as you assemble them.
6. Insure the Crankshaft turns freely. Place a small amount of oil on the top of the cylinders. Turn the engine over by hand to insure it turns without an internal obstruction. Then, using your model engine starter or suitable substitute, turn the Crankshaft in a counter-clockwise direction for several minutes.
7. Remove any excess oil from the top of the Piston.
8. Install the Glow Plug/Heads, Venturi and Needle Valve, connect Fuel Line and Battery.
9. Using the starter, start the engine and adjust the needle valve for best performance.

NOTE – if the engine does not run, check the following:

- Does the engine turn freely?
- Do the glow plug heads glow with battery power? If you are in a bright environment and cannot see the glow, remove them one at a time and hold it inverted. Then pour a slight amount of fuel into the glow plug recess and listen for a sizzle when the power is applied.
- Are the Front and Back Plates properly installed with all bolts? The top two bolts in the Rear Plate must be installed if the threaded holes go through into the lower cylinder volume.
- Is the fuel level of the tank approximately 1" below the Venturi?
- Are you using ½–A fuel?
- Are the cylinders and heads tight?

Note: Without airflow over the cylinders the engine will starve itself and quit and possibly over–heat. You can use an air compressor rather than a prop.

Author

Jerry grew up in Orlando, FL and has an Aerospace Engineering degree. He has spent the last 13 years in the Air Force and specializes in space and missile systems. While stationed in Colorado, he attended some machine shop classes where he built his first two–cycle model engine and his interest in model engine

building has taken hold. He has a Jet 9 x 20 lathe and HF mini-mill along with the usual accessories. Due to his frequent moves in the Air Force, his workbench is on wheels to make moving easier.

About this engine

This engine was designed and built to investigate several aspects of the intake system. It uses Cox cylinder assemblies including the piston and connecting rods to speed development of the engine.

This engine runs reasonably well and can be built with a minimum of tools. There are probably many areas that could be improved but at the cost of additional build time. This design is adequate for the purpose.

If you have ideas for improving the design, please contact jerry@jamesengine.com

Since Cox 0.049 displacement engines can now be purchased from Cox for $6.00 US until they run out of stock (50,000 units the last we checked), the use of the cylinders seems very cost effective.

www.coxmodels.com will get you to their web site or you can contact them at:

Cox Hobby Distributors
Post Office Box 274
Penrose, CO 81240
1-877 269-9235
or
1-800 525-7561
0 01 719 372-9877 facsimile

Engine Dimensions

Length	3.8"
Height	2.1"
Width	1.4"
Weight	175.8 grams, 6.2 ounces
Displacement	0.098 cc, 0.005 in^3