Model Horizontal Single Compressed Air Engine
By Chuck Fellows
How the valves work

This engine uses a unique slave exhaust valve. It is a spring loaded, sliding piston which is activated by the pressure of incoming compressed air when the inlet valve is opened by the cam operated push rod. This design lends itself to compressed air engines of any number of cycles. It’s particularly useful on hit n miss operated engines, since the exhaust valve will remain open as long as the inlet valve is closed. This allows the engine to turn over multiple times with no back pressure due to compression.

Here, the inlet valve is closed. The spring keeps the slave exhaust valve pushed to the left, exposing the cylinder to the exhaust port. This allows the free passage of air into and out of the cylinder with no back pressure.

As the inlet valve begins to open, high pressure air enters the head and begins pushing the slave exhaust valve to the right. This opens the input port and lets the high pressure air into the cylinder. The exhaust port is still partially open, which allows some of the high pressure air to go directly to the exhaust, giving the engine its distinctive pop when it “fires”.

As the inlet valve continues to open, the slave exhaust valve is pushed all the way to the right, completely closing off the exhaust port and forcing all the high pressure air into the cylinder. This is the power stroke and will continue to push the piston down until the inlet valve is closed. At that time, the spring again pushes the slave exhaust valve to the left, letting the high pressure air in the cylinder exhaust to the outside.
Engine Frame

This is the engine frame, minus the base. All pieces are ¼” thick cold rolled steel. I welded my frame together, but silver solder or screws would work equally well or better. The welds are on the inside of the frame and I used a ball end mill to make the welds look a lot less offensive.

Dimensions are all pretty close to my finished engine, but they can be varied as long as careful attention is paid to getting the crank mounted on the centerline of the cylinder and, of course, the length is such that the piston doesn’t come out of the cylinder at the bottom of the stroke or hit the head at the top of the stroke.
Crankshaft Bearing Caps

The crankshaft bearing caps were made to accommodate a ball bearing race ½" OD x ¼" ID. The bearings I used were flanged with the flange on the inside of the engine frame.

To drill the hole for the bearing, start with a 9/32" hole through the bearing cap. Enlarge the inner part of the hole to the OD of the bearing, not counting the diameter of the flange. The enlarged hole should only be deep enough to accommodate the bearing and not all the way through.

If I were building the engine over again, I wouldn’t use ball bearings. Instead, I would use brass or cast iron for the caps and just drill ¼” holes in the bearing block to accommodate the crankshaft. This would allow the screws to be moved in some and provide more room for the cam gear shaft.

This is the timing gear bearing cap. It has an extension on the front to allow for the large (driven) timing gear. The spacing between the Crankshaft and the large timing gear axle hole will be determined by the size and pitch of timing gears you use. On my engine, I used 48 Pitch gears, but 32 pitch might be more practical. Use whatever size and aesthetics allow, remembering that the primary gear has to have ½ as many teeth as the secondary, driven timing gear.
Cylinder – Steel, Cast Iron, or Brass

Not much to say about the cylinder. I made mine out of brass, but steel or iron would work as well. You could also use aluminum if you used a harder cylinder liner.

I started with a 1.25" diameter brass rod, bored it out to .75", then shouldered down one end to 0.25" long by 0.90" diameter. The cylinder is fastened to the engine frame with 4 socket head cap screws.
Nothing special about the crankshaft. These are the dimensions of mine, yours may vary.

The overall width of the two webs and connecting rod journal is less than the .750" distance allowed in the frame because I used flanged ball bearing races which extend inside the frame a bit.

Also, I made the connecting rod journal a little wide to allow clearance for a .250" thick connecting rod.

My crankshaft was machined from a solid bar of cold rolled steel 1" wide by .375" thick. If you are new to making crankshafts from solid, you need to make hacksaw or bandsaw cuts parallel to the long sides, about 3/8" in from the edge, most of the way from each end to the webs to relieve stress before laying out the centers of the crankshaft ends and the connecting rod journal ends.
Connecting Rod & Piston, Aluminum

Procedure for making connecting rod:
1. Cut ¼” thick aluminum to overall dimensions shown.
2. Drill & tap 2-56 holes in connecting rod big end.
3. Mark and cut rod cap away from rod.
4. Screw the rod cap tightly to the rod end.
5. Mark, drill, and ream 0.25” big end hole.
6. Measure, mark, drill & ream 0.125” small end hole.
7. Shape the rod as shown.

Procedure for making the piston:
1. Ideally, start with a length of rod sufficiently longer and larger in diameter than the finished piston.
2. Turn the OD down to 0.75” or sliding fit in cylinder. I recommend you make the cylinder first and fit the piston to the cylinder.
3. Bore the inside of the piston 0.625” ID to a depth of 0.219” (7/32”).
4. Clamp the piston vertically in the milling vise using two v-blocks, one on either side against the jaws. Use a 0.25” end mil to cut the slot for the connecting rod. The finished slot should be a few thousandths over ¼”. Mill the clot to within about 1/8” of the piston face.
5. Drill and ream the 0.125” wrist pin hole in the piston perpendicular to the milled slot. Drill and tap a hole inside the piston for a setscrew to hold the wrist pin.
The cylinder head was machined from a piece of steel 1.75" x 1.25" x 0.375".

All the holes were laid out and drilled before any of the outside shaping was done.

- First I drilled the 0.375" hole that accepts the valve assembly.

- Then, I chucked the rectangular piece of steel in the 4 jaw chuck, with the .375" x 1.25" end facing the tailstock, and centered it carefully with a DTI. I center drilled the end, then drilled a #29 hole straight through the center, drilling slowly, and backing out the bit frequently to clear the chips. This helps ensure a straight and parallel hole all the way through. I used a #29 drill because the other end of the hole will be tapped 8-40.

- Next, while the piece is still mounted in the chuck, I enlarged the hole to 0.25" to a depth of 1".

- Finally, removing the piece from the lathe, I drilled the two 0.125" ports that lead to the cylinder in the bottom of the head.

To shape the head, first made hacksaw cuts as shown below. I then used a belt grinder to grind up to the lines of the inscribed circles.

I mounted the head on a rotary table and used a 3/8" end mill to shape concave parts on the small end.
I made my valve assembly out of brass, but most any metal would do. The housing is made up of two pieces. The bottom part houses the poppet valve and is seated in the head by the 3/8" shank. The 1/8" hole in the side of the shank aligns with the hole into the head, opposite the set screw which holds the valve assembly in place.

The valve is turned from 5/16" drill rod. The angled portion of the valve and the valve seat are both 45 degrees. The valve is positioned inside the lower part of the valve housing and the stem extends out through the bottom. I cut a small groove near the bottom of the valve stem and use an e-clip to hold the spring and spring washer in place. A small cotter pin would work as well but requires a mighty small hole thru the valve stem.

The top of the valve housing is secured to the bottom part with 4, 2-56 socket head cap screws.

Here is an assembled view of the valve group to give you an idea of what the finished piece looks like. Note the spring and retaining washer at the bottom. The e-clip isn't shown.