Air Compressor/Water Pump Part II
Fabricating the Cylinders, Pistons & Water Valve

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Design Decisions: There's snow on the ground so it's too cold to do any more steaming tests of the shay good time to finish up the plumbing and then start painting the trucks, frames and engine ----- and make a compressor that pumps water rather than air. I had a touch of flue just before Christmas (or maybe it wa shock after making my annual visit to the mall) so sat down and sketched out the pump components witl emphasis on how to make the valves for both the steam and water cylinders. This turned out to be an ite process and along the way decided to use EPDM O-Rings for rings and seals on both the steam and wate of the system. The plan is to attempt to follow the Westinghouse pilot and shuttle valve design and to tr make the exterior of the valves resemble the Westinghouse units. Teflon was selected for the slide valve water pump valves will be a duplicate of the valve Kenneth uses on the Shay axel pump. The following summary of these design decisions:

- 2" head diameter
- 1 3/4" cylinder length (both cylinders)
- 1 1/4" steam piston diameter
- 5/8" water piston diameter
- 1 1/4" stroke
- 5/16" piston rod diameter
- 7/16" shuttle valve piston diameter
- EPDM 3/32" cross section piston O-Rings (later changed to Viton for steam cylinder and Buna N for water piston))
- EPDM 1/16" cross section shuttle valve piston O-Rings (later changed to Viton)
- EPDM 1/16" cross section rod seal O-Rings (later changed to Viton)
- Teflon sliding valves.
- 1/4" diameter water input ball checks
- 5/16" diameter water output ball checks
- Brass cylinders, heads and pistons
- Stainless steel piston rods and valve stems.

The tricky parts of the pump are the valves, both water and steam. One approach would be to make the v first and then complete the easy part. Another approach would be to make the cylinders, heads and pist and then use that as motivation to make the valves (and remake as necessary) to finish the project. I toc second approach. If nothing else, I'll have a realistic decoration.

Cylinders: The cylinders are turned from 2" diameter brass rod. The pump cylinder was done first since the

outside could be turned while the stream cylinder was held in the chuck as shown on the right. After the pump cylinder was bored, the two cylinders were sawed apart and then the ends of both cylinders finished and then the steam cylinder bored. I was pretty careful to not screw up this part since the 2" brass costs over $3 an inch.

Heads: The heads were made from pieces of 2" X 1/8" brass flat bar left over from the whistle project. This photo show turning the outside of the squares. The center of the squares were drilled 1/4" and held on a mandrel.

The lathe chuck was transferred to the rotary table and the attachment holes drilled on the four heads using the mill as a drill press. Later I realized that I'd made 6 holes instead of the planned 8 holes Let's see, 60 degrees times 6 is --- yep I should have used 45 degrees. On the other hand, the prototype had 12 holes, so if I get real ambitious I can readily and another 6 holes.

Tie Piece: This is the piece that connects the two cylinders. It is made from 1 3/8" diameter brass with the inside bored to 1 1/8". (I had a piece of 1 3/8" brass left over from the brake cylinder project.) The one end was left closed in the boring operation and the other end was then closed with a plug silver soldered in place. The side was opened using the side of an end mill.

The lower piece in the photo is a partially fabricated pair of simulated packing glands with nuts. The piece is 9/16" hex rod, the ends turned and the 1/8" wide 0.050" deep slots mill down the middle of the flats. Next, the rod was sawed in half and then the hex part turned down to 0.59" diameter and the end finished

This shows the tie piece after the simulated packing gland nuts were finished and the glands silver soldered in place. The packing glands were pinned with 1/16" brass rod to keep them in position when the heads were

later soldered to the tie piece ---- the ends of the pins are visible on the sides. The piece at this point is long enough to extend through the heads. The ends were turned down to 1.325" and slipped over mating holes in the heads.

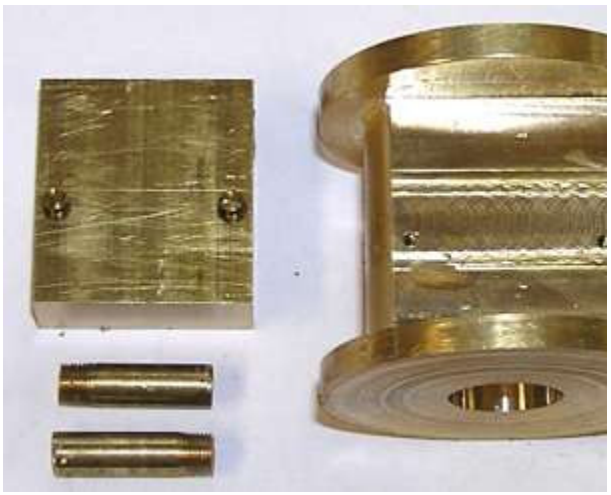
Assembly: This shows the finished tie piece sandwiched between the two cylinders.

Piston Rod Seals: O-rings will be used for the seals on the rods between the two pistons. The O-rings (#011-5/16" ID - 7/16" OD) fit is recesses in the tie piece and are held by stainless steel washers. This photo shows the seal for the bottom of the steam cylinder. A couple holes will be drilled through the washer for #2 screws to retain the washer. There is a 1/16" long 1 1/4" diameter stub on the tie piece that fits into the steam cylinder to align the two pieces.

This shows the water cylinder side piston rod seal cavity. The washer is ~0.730" OD. Recall that the water piston is only 5/8" diameter. On this side, a 1/16" high 7/8" diameter stub was turned on the tie piece. A mating recess was also turned in the pump cylinder. The 5/8" diameter pump cylinder is smaller than the washer OD and hence retains the washer and in turn the seal in position.

The slit in the end of the tie piece is the hole for 1/16" pin that held the pieces together during soldering. The pin fell out when it was cut in half out during the subsequent machining.

Pump Valves: I had planned to do all the valves last but instead decided to do the water valves at this point and see how silver soldering a couple pieces of brass together worked to model castings. It's necessary to add a little material to the back of the cylinder to make room for the check valves. The piece to be added is 1 1/4" X 1 3/8" X 1/2" cut from the same 1 1/4" X 1/2" bar used on the axel pump. The side of the cylinder was milled flat to mate with the flat piece. The nipples were threaded 1/4" MTP and have a 5/32" ID. The unthreaded ends were prick punched on the outer surface to raise dimples so that the nipples were held snug when soldering. Flat strips of silver solder were placed between the block and the cylinder. The block was held in position during the soldering operation by the two 1-73 flat head brass screws.



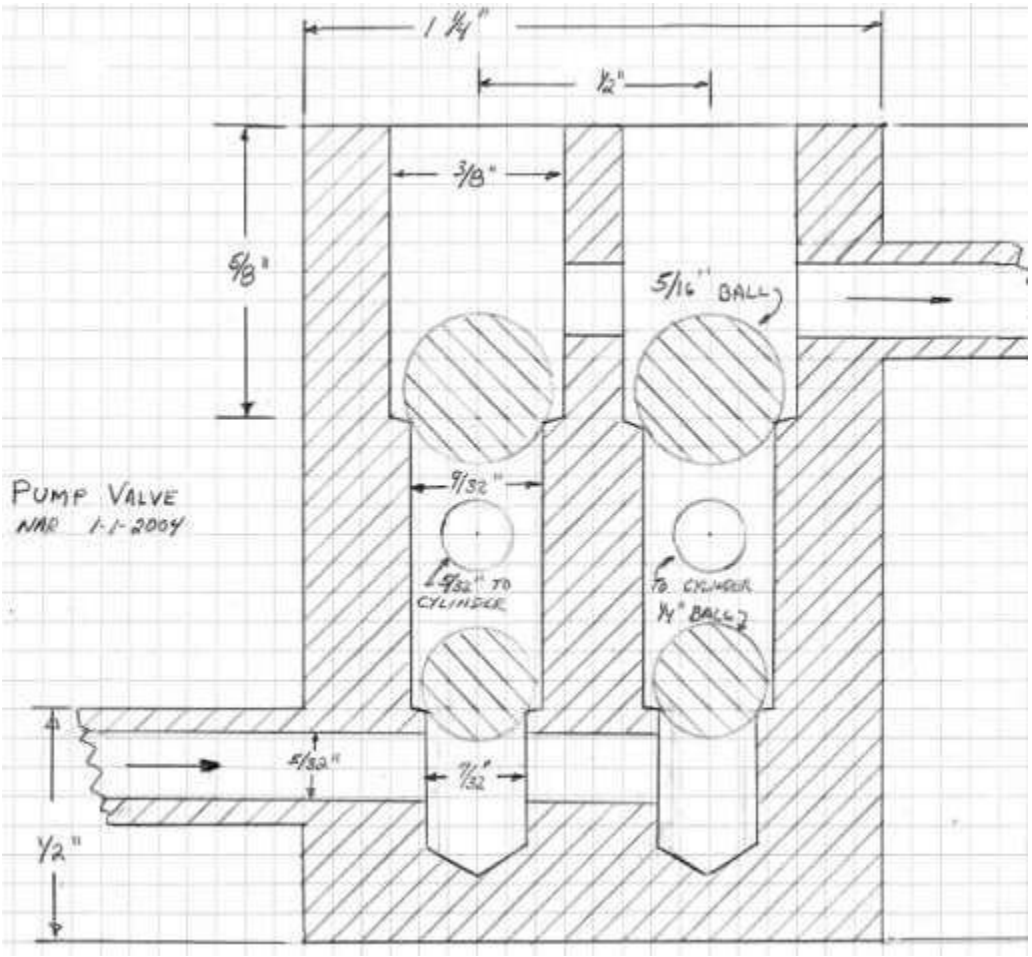
This shows the back of the pump cylinder after the soldering and all machining was finished. There are two sets of input and output checks side by side in the block. The input is via the lower pipe on the left and the output is via the upper pipe on the right. The left set of checks

is in position and the right set is laid out in front of the cylinder. The input (lower) check uses the 1/4" ball. The plug with pin is above the lower ball to limit the vertical motion. The output (upper) check is 5/16" and the plug with the O ring limits the upper motion of the 5/16" ball. Part of the inside of the upper plug is threaded 4-40 to permit easy removal.

This shows the upper end of the pump cylinder with the left check valves in place and the right valves removed. The left valve connects to the upper end of the cylinder via a hole between the balls (behind the plug with the pin) and the vertical hole that is visible between the left valves and the inside of the cylinder. There is a similar passage from the right set of valves to the lower end of the pump cylinder.

The valves were carefully sketched to avoid (or minimize) problems during fabrication. This is the sketch for the pump valves --- a section through the middle of the square containing the valves. The sketch was on 1/4" cross sectioned paper using a compass and straight edge. It was drawn to

X 4 scale so that each square was 1/16" inch. Sorry I can't include a nice CAD generated drawing. I have electronic CAD with simulation software which is enough for any soul to learn in a lifetime.



Pistons: This photo shows the 1/4" thick 1 1/4" diameter steam cylinder piston. The piston is silver soldered to the 5/16" diameter rod. The inside is drilled 0.198" to a depth of 2 .5" The cover plate is secured to the piston with 4-40 screws. The hole in the plate is 0.128" diameter. The EPDM (later changed to Viton) piston O ring is # 121 - 1 1/16" ID and 1 1/4" OD.

This shows the 1/4" thick 5/8" diameter pump cylinder piston. The inside of the piston is 1/4" diameter matching the end of the piston rod. The 1/4-24 stainless steel jamb nut secures the piston. The end of the rod is tapped 8-32 for the set screw plug. The EPDM (later changed to Viton) O-Ring is # 111 - 7/16" ID 5/8" OD . This is the same O-Ring as used on the smaller of the brake cylinders.

This is the assembled pistons with rod.

Note that the smaller piston must be attached after the rod is inserted through the tie piece. The larger piston can be wrapped in a cloth and the grasped in a vise if necessary to loosen the nut.

Update 5/16/04: After some use under steam power the pump started to run really slow. A few drops of silicone brake fluid speeded it up for a few minutes but then it slowed down again. A lubricator seemed real pain. The pump was disassembled and the steam piston was found to be hard to push. A little water easier to push but still pretty tight. The depth of the O-Ring grove was according to specifications from Marco Rubber website--- but that was for a tight seal. For this application a slight leak is tolerable so the depth was increased to give a 0.100 allowance for the O-Ring --- a loose seal for the 0.103" O-Ring cros section. That seemed to fix the problem. The grove on the water piston had been sized to the minimum recommended squeeze on the Marco website and was not changed. **End Update.**

Update 2/23/2006: I replaced the EPDM O-Rings with Viton O-Rings in the steam cylinder and valves a Buna-N O-ring on the water piston. The EPDM O-Rings had softened and become sticky. I also added lubricator as described in Part IV. **End Update.**

The steam valves are next ---- in Part III.

Shay Project

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