Shay Steam Brake Valve

Nelson Riedel Nelson@NelsonsLocomotive.com

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Update 10/28/2003: The day after I published this page Mike Green from up in Ontario emailed and pointed out that I had the steam and air brake controls on Cass 5 backwards. I've corrected the following to reflect Mike's input.

Cass 5 Brake Valves: This photo shows the two brake valves on Cass No 5. The valve on the right controls the locomotive steam brakes and the valve on the left controls the train air brakes.

Note that the air brake valve is located under the throttle handle and beside the reversing lever.

This is another view of the Cass 5 air brake valve. One thing is sure, there is clutter everywhere.

This shows the bases of the two brake valves on Cass 10.   Note the pipes below the air brake valve.   It's not clear if the valve is supported by the pipes or if there is some sort of support bracket.

Mike Green also was able to shed light on the air brake mounting bracket. The photo on right taken by Gordon Carlson shows the mounting bracket on Shay #3345, the last narrow gauge shay built by Lima and the one that Mike is modeling.

A closer view of the air brake base.

The November/December 2003 issue of Live Steam has a neat brake valve design for a three-truck Climax. The design by Bob Reedy is really two valves, a locomotive steam brake valve and a smaller train air brake valve. The locomotive brake uses O ring seals whereas the train brake uses a Teflon plug. I decided to use a physical appearance similar to Reedy's locomotive brake but try a Teflon sleeve similar to the design used for the cylinder cocks. ***Recall that I had the steam and air valves reversed so I modeled the air brake valve thinking it was the steam brake.***

Test Model: The first thing was to make the model shown on the right. The plug has two holes at a 90 degree rotation of the plug that go half way through. The body has three holes at 90 degree rotations. The plug has three positions ---- in the first position the plug holes line up with the steam supply and brake cylinder holes --- this is the brakes applied position. Rotating the plug 45 degree counterclockwise puts the plug holes between the body holes ---- brake hold position. Rotating a further 45 degrees lines the plug holes up with the brake cylinder and exhaust holes --- the brake release position.

The model worked and made a pretty good seal. Next, a model was made using a 3/4" sleeve OD and a 7/16" plug OD. The valve worked pretty well, leaked slightly at room temperature with 125 psi air applied and leaked only a little in boiling water. The handle was a little hard to turn. Tried another sleeve with a smaller ID to put more pressure on the sleeve and body ---- no difference in force or small leak. Tried yet again with similar results.

Many years of engineering experience have taught that there is a time to leave the lab and do a bit if thinking about the engineering principles ---- and that time had arrived for the brake valve. Some thought yielded the following:

1. **Teflon is pliant:** Teflon is a very tough material, hard to tear and slippery which are properties that make it good for sealing. Another property is that it is pliant which is also necessary for a good seal. However, the pliability means that as pressure is applied on the sleeve between the body and plug, the Teflon tends to ooze out the ends of the body. That is why no improved sealing was achieved by forcing the plug into a smaller ID sleeve --- the extra Teflon oozed out the ends of the body. The maximum pressure is related to the sleeve thickness ----- the thinner the sleeve, the greater the maximum pressure. The cylinder cocks sealed pretty well with a 1/32" sleeve thickness. Several different brake valve sleeve thicknesses were tried. A thickness of 1/64" worked but was touchy; sometimes the sleeve tore. A thickness of 1/16" didn't seal very well at 125 psi. Conclusion --- 1/32" is a good workable choice. (A different approach would be to seal the ends of the body so that the Teflon couldn't ooze out. That was not used because there was no obvious way to accommodate sleeve swelling under higher temperatures.)

2. **Pressure maintains the seal:** The seal is maintained by pressure, not force. That's sort of obvious --- the steam pressure is tending to compress the Teflon and the resilience of the Teflon is pushing back. The area of the seal is less important except that a larger area will reduce leaks due to small imperfections.

3. **Plug Rotating Force is Proportional to Plug Surface Area:** The same sealing pressure is required to maintain a seal independent of the plug size. The friction force between the plug and the sleeve is proportional to the pressure on the surface multiplied by the surface area. The plug surface area and hence the friction force is proportional to the plug radius (and diameter).

4. **Torque:** The plug is rotated by a lever so the force of interest is a rotating force or torque. The torque required for a given force on the sleeve-plug interface is proportion to the plug radius (also diameter). Hence when 3 & 4 are combined, the torque to rotate the plug is proportional to the square of the plug diameter.

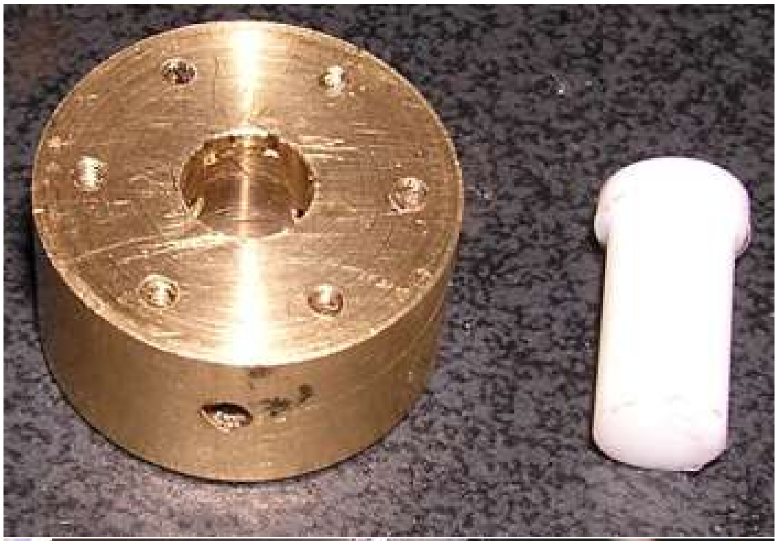
5. **Pressure Between Sleeve and Body:** The total force (pressure X surface area) between the plug and sleeve is the same as between the sleeve and the body. On one model with a 3/4" OD sleeve and 3/8" there was a leak between the sleeve and body. After trying several sleeves a little thought revealed that the sleeve OD area was nearly twice the ID area hence the sealing pressure on the OD was roughly half the sealing pressure on the ID. No wonder the the sleeve-body interface was the most likely to leak.

After thinking about the above points, , the following dimensions were selected:

- 1/4" plug diameter (smaller is better but limited by hole diameter)
- 5/16" hole in body (this is sleeve OD which gives a 1/32" sleeve thickness)

- 1/2" long plug working surface (this size looks good)
- 5/64" holes in plug and sleeve
- holes in body and plug at 120 degrees instead of the 90 degrees of first model
- 1" body OD.

Plug: The plug was made from 1/4" diameter 303 stainless steel. The stem is 3/16" diameter and the end is 0.133" partially threaded 6-32. The holes are 5/64". The body was initially made with a 1/4" hole and the plug put in the body and the holes in the plug partially drilled using two of the holes in the body as a guide. After the holes were drilled to the plug center, the surface around the holes was smoothed with a fine file and then the plug was polished with 400 Emory cloth.



The three holes in the body that access the plug were drilled 3/32" and threaded 1/8" MTP and plugged with pipe plugs. The three ports are in the bottom and drilled up to meet the three horizontal holes. The input and exhaust ports are 3/16" MTP and the exhaust port is 1/8" MTP. The holes for attaching the top are 2-56.

The body ID was bored to ~ 0.305" and an old 5/16" reamer driven in the hole ~ 1/8" to score the hole to keep the sleeve from rotating. The sleeve was turned from 3/8" Teflon rod to a diameter of ~ 0.320" leaving a head on one end. The sleeve was then driven into the body with a hammer.

A 3/16" hole was drilled in the sleeve and then 5/64 access holes drilled through the 3/32" holes in the body.

The body was then bored to 0.010" less then the plug OD. (The pug was 0.249" so the sleeve ID was 0.239") A handle was attached to the plug and the plug forced into the sleeve (by hand) while the body was rotating very slowly. After the initial insertion, the plug was removed and the ends of the sleeve trimmed flush using a utility knife. The plug was then inserted again (easy the second time).

This is the body with sleeve. Note the 1/8" plug in the side hole. The input port below is fitted with a 3/16" MTP nipple and a 1/4" to 3/16" bushing. This was used to test the seal.

The top was also turned from 1" brass and is about 1/2" high. The 6 holes were drilled in the top first and then the top was used as a guide to drill the mating holes in the body. The upper part of the hole for the plug shaft is 3/16" The lower part is drilled 1/64" larger to minimize binding.

The top was later notched to allow rotation of the handle while providing stops to limit rotation.

The (air brake) valve on Cass 5 is mounted at about the height of the top of the rear engine cylinder which scales to about 4" above the cab floor. That height was tried and looked awkward so the valve was lowered to about 2" off the floor as shown on the right.

A brass rod screwed into the input port is the support bracket. The tee was silver soldered on the rod and the top part of the rod was drilled and outside threaded 3/16" MTP. As a result, the top part of the rod is actually a pipe while the bottom part is a fake pipe serving as the mounting bracket. The lower end of the rod is tapped 4-40 and held by a flat head screw on the under side of the floor. The copper pipe pointing into the camera is the input pipe that will connect to the steam turret.

The vertical copper pipe to the right of the input pipe is from the cylinder port. The pipe goes through the floor and connects to a pipe running across under the frame I beams to the cylinder.

This view is from the left side of the back of the valve. The valve handle is in the **BRAKES ON** position.

The smaller copper pipe on the rear side is from the exhaust port. The pipe goes through the floor and has an open end.

The valve and cylinder were temporarily connected with 3/16" plastic hose and the system tested using compressed air. Everything worked as expected.

OK, now that I've learned I had the two brake valves mixed up what a I going to do? I have a valve that can be used to control the steam brakes but is in the air brake position. Of course, it can control an injector for train vacuum brakes. I think I'll make another valve ---- at least another valve mounting arrangement in the more correct position for the steam brake. But there is more to it than just the valve location. The following is part of the note that Mike Green sent describing the steam brake operation:

Just opened up your site today and noticed that you have added the Brake Valve installment. Having ridden on #5 in the past I think that you have the two brake valves reversed in your captions for the first pictures. The valve with the long stem directly in front of the Engineer is the loco steam brake. The larger valve unit under the throttle lever is the Westinghouse valve for the train air brake control. I didn't follow the three pipes descending from the steam valve but one applies the brakes, while another feeds the back side of the cylinders to keep the brakes off, the third one is the exhaust. The Engineer was constantly moving the valve probably because of a disc leak at that time and the application side was showing some pressure. The horizontal pipe would be the steam supply leading up to the stop valve on the main manifold. The reason I was told for the extended valve spindle was to keep the heat of the hot valve from getting into the handle and allow a machinist to be able to re-pack the top gland without dismantling the whole thing, with the gloves of today, the hot handle wouldn't be too much of a concern.

I haven't seen any models that use steam release (backoff) of the brakes. My brakes hang up a bit on release and was thinking of using heavier return springs. However, the thought of using steam release is really intriguing........

Mike also sent a copy of Lima Instruction Sheet No 10 that describes the operation of the Lima Steam Brake. Turns out that I also had a copy. Both our copies came from a booklet of Lima Instruction Sheets published by Kyle Neighbors of Cass WV. The following is a scan of the two page Instruction Sheet No 10.

LIMA LOCOMOTIVE WORKS, Incorporated

Lima, Ohio

GENERAL SALES OFFICE
17 East 42nd Street
New York

SERVICE DEPARTMENT
Lima, Ohio

LIMA STEAM BRAKE

The Lima steam brake equipment for Shay locomotives consists of the following parts:

(1) *Steam Brake Valve*—Same on all size engines.

(2) *Brake Cylinder*—On two truck engines both ends the same size; on three truck engines, one piston and cylinder larger, which is to take care of the additional truck.

(3) *Pipe Connections*—Same for all size engines.

(4) *Brake Rigging*—Built to suit class of engine on which used.

General Arrangement—Steam is piped from the main turret to the steam brake valve. In this line a lubricator pipe is cut in just ahead of the steam brake valve. Three pipes lead out of the brake valve.

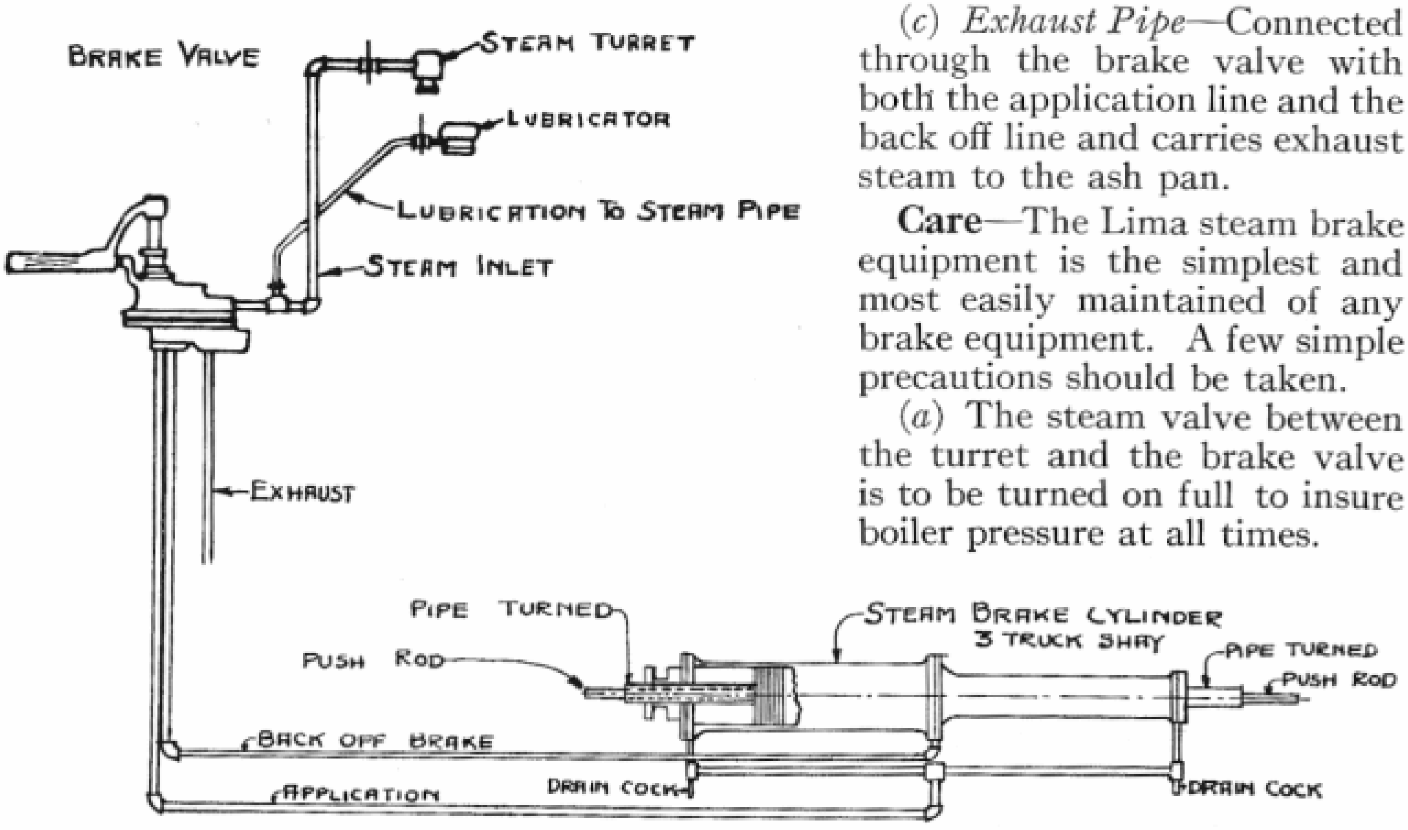
(*a*) *Application Pipe*—Carrying steam to a tee through which the steam is carried to each end of the brake cylinder at each end of which is applied a drain cock.

(*b*) *Back Off Pipe*—Carrying steam to the center of the brake cylinder which introduces steam between the pistons to back off the brakes.

(*c*) *Exhaust Pipe*—Connected through the brake valve with both the application line and the back off line and carries exhaust steam to the ash pan.

Care—The Lima steam brake equipment is the simplest and most easily maintained of any brake equipment. A few simple precautions should be taken.

(*a*) The steam valve between the turret and the brake valve is to be turned on full to insure boiler pressure at all times.



(*b*) Give the lubricator feed to the brake valve enough valve oil so it will work easily and does not stick.

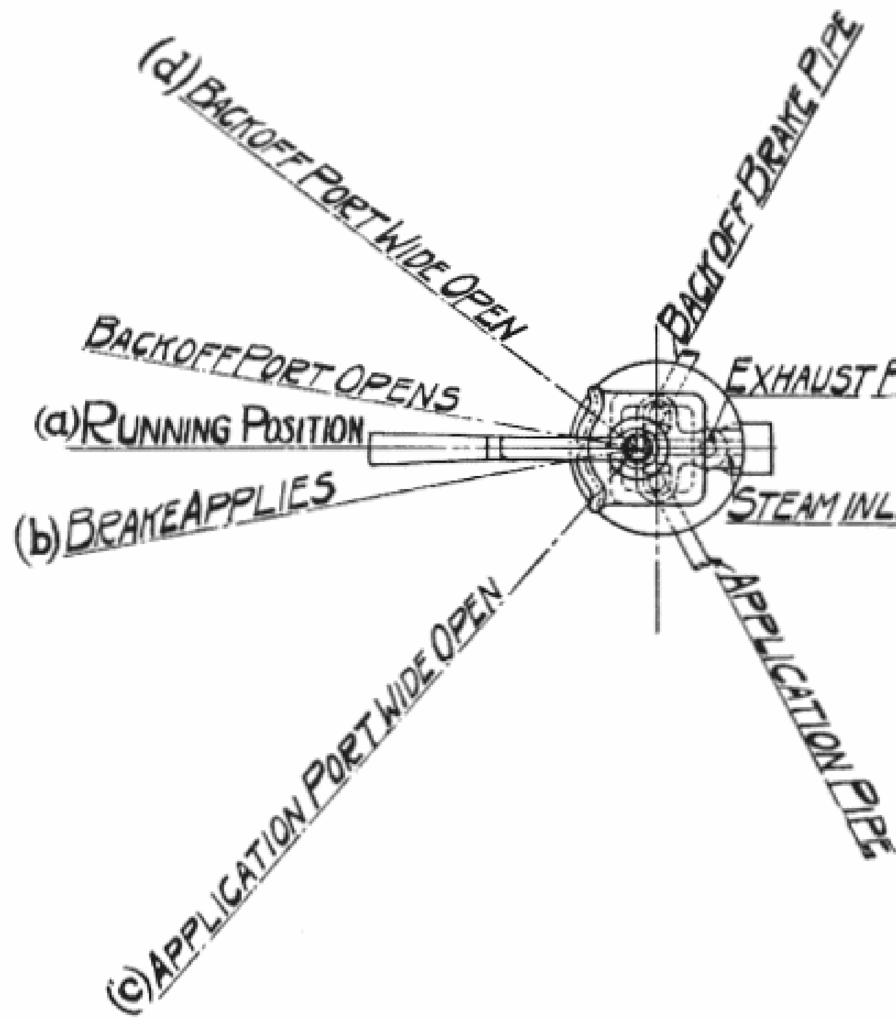
(*c*) See that drain cocks are working—these will take care of condensation.

(*d*) In winter keep steam turned on to prevent freezing.

Operation—On the Lima steam brake live steam is used both to apply and release the brakes. The operation of the brake valve is as follows:

(*a*) *Running Position*—In running position the brake handle is in central position.

(*b*) *Service Application of Brakes*—Move the handle to the extreme left. This will blow the condensation out of the pipes and cylinder. Then back to the right to service application and keep working the handle about half way between running position and emergency application.

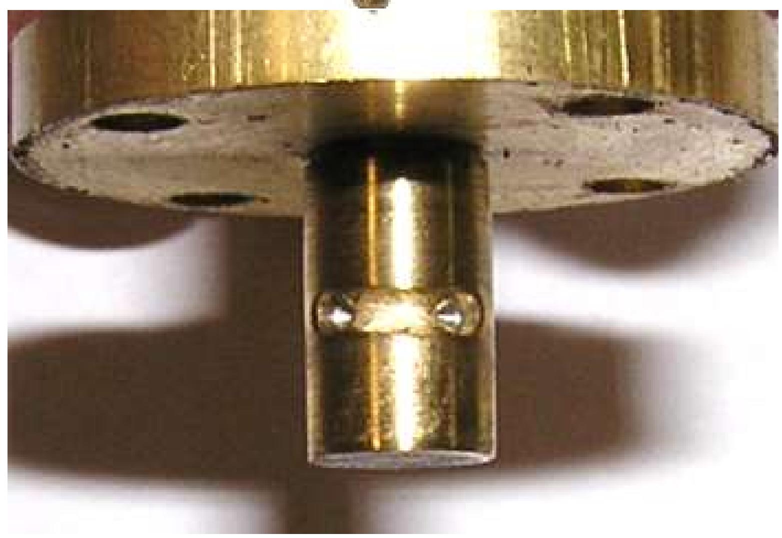


(*c*) *Emergency Application of Brakes*—Move the handles as in service application and then bring around slowly to the extreme right position and work handle between full application and service application.

(*d*) *To Release Brakes*—Move handle to the left as far as it will go on full release then back to central or running position.

Update (12/12/03): I fabricated a steam brake valve along the lines of the valve describe above shortly after Mike pointed out my errors on the first try. I delayed updating this page until the valve was installed and operating the cylinder. The boiler arrived in the mean time so I was off working on getting it installed and plumbing the water and steam. The locomotive is about ready for the first run at the track and assuming that it actually gets moving, brakes might be a nice feature to help stop it. So, hooked up the brakes.

Correct Steam Brake Valve: The photo on right shows the partially disassembled more correct steam brake valve. The stem is longer like on the prototype. The base has a Teflon insert and four ports equally spaced around the base (90 degree angles)



Holes were drilled through each port about 1/32" deep into the plug. The plug was then removed from the body and the slots made between adjacent holes on each side of the plug using a Mototool with cutoff disk and then smoothing with small files. The photo shows one of the slots. There is an identical slot on the other side.

The plug is a brass tube silver soldered to a stainless steel shaft; much less effort than turning one piece from steel.

A top view of the valve. The top pipe is the steam supply and the bottom pipe is the exhaust. The left pipe goes to the outside

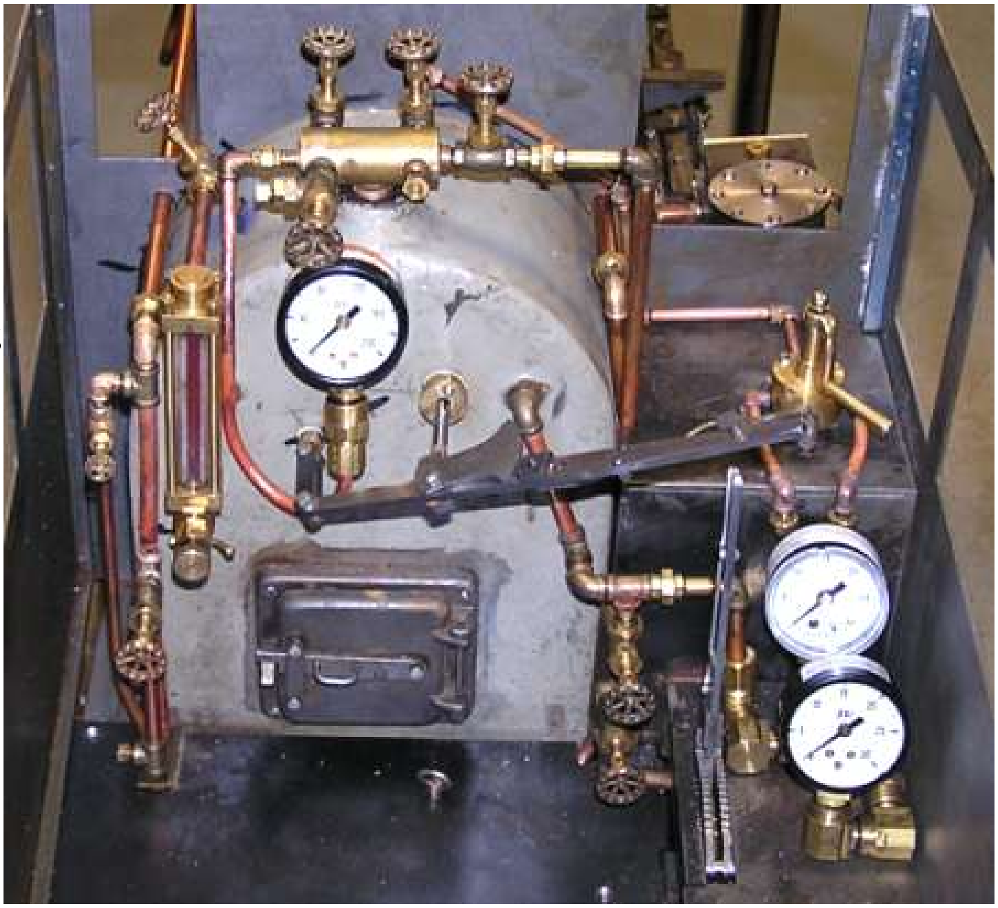
ends of the brake cylinder (apply brakes) and the right pipe goes to the center of the brake cylinder (backoff or release brakes). The handle is in the brakes "full on" position. In this position one plug slot connects the top and left pipes (steam to outside ends of the cylinder) and other slot connects the bottom and right pipes (exhaust the center part of the cylinder). When the handle is in the left most or other extreme position steam is applied to the right pipe (backoff) and exhaust is connect to the left pipe (exhaust outside ends of the cylinder). When the handle is centered, the plug slots are centered on the upper and lower pipes and there is no connect between any of the pipes.

This photo shows the valve mounted on the shelf. The valve is off center to the right side of the shelf to minimize interference with the reverse and throttle levers. The plan is to also mount the whistle valve on the shelf --- to the left of the brake valve.

Brake Pipe Routing: The pipes run from the valve on the top of the shelf down the shelf front, through notches in the platform top and then bend and go under the frame just behind the firebox to the brake cylinder on the left side. The pipes are identified on the photo on right.

The photo below of the left side shows the cylinder and the other end of the pipes. The pipe to the cylinder center is 3/16" The other pipe is 3/16" to the tee at the big end where it converts to two 1/8" pipes. There is a drain cock at the end of the small cylinder. The union in the upper pipe appears to be oversize and in fact is a 1/4" union. I had run out of 3/16" unions so the 1/4" union is a temporary substitute.

This photo shows the cab interior with the installed brake valve.



The valve works great! The return springs on the brakes were removed. (The return spring on the park brake lever was left in place.) It takes about two seconds for the brake pistons to move after the brakes are applied. The speed is controlled by the pipe and valve size. This speed is probably good; we weren't designing a steam catapult. On the test stand it's possible to control the braking force by moving the valve on and off. It'll be interesting to see how the brakes work on an engine and string of cars with a little momentum.

Thanks to Mike Green for steering me to this neat design.

Update 1/30/2004: The valve worked OK on compressed air but sometimes would not pass steam, especially under lower pressure such as less than 50 psi. I modified the the valve by drilling the passages larger. This fixed the blockage problem but the clearances were reduced with the larger passages and the valve developed a small leak. One solution would be to make a new valve designed with larger passages. A valve with 3/32" passages would be satisfactory and this size passage could probably be achieved reliably with a 3/8" valve plug. Another solution would have been to ignore the leak. Instead, I tried a different design using O-Rings that worked pretty well. That valve is described in webpage titled Another Shay Brake Valve.

Shay Home
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