Shay Fire - Burner Tests & Modifications.

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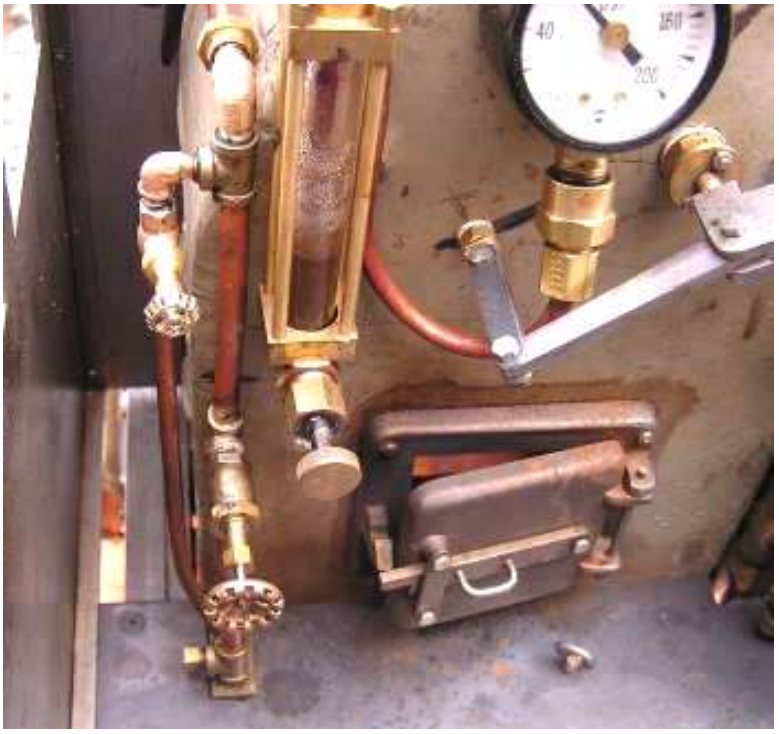
After the initial streaming test on December 3, 2003 many deficiencies were corrected and then additional tests were conducted in December and January that revealed several additional problems described here. More corrections were made when everything was disassembled for painting. Then additional tests were conducted in April which revealed a few more problems that were quickly repaired. Finally, on April 21st the burner was test again and seemed to run great ---- this thing is ready for the track.

Note that I've described the winding path I've taken to get this burner working properly for several reasons. One reason is encourage folks to keep at it when building a live steam locomotive ---- things often don't work perfectly the first time. A second reason is that maybe you all can develop a feel for how the burner should run from my experience. While writing this summary, I realized that I didn't know how a proper burner should operate since I'd never operated one ---- sort of like a hunting elephants when you've never seen an elephant. I've summarized the operation of the burner at the end to tie everything together.



Dec 16 Test: The photo above shows the setup for a test on December 16th. Note the snow on the grown. It was about freezing at the time of the test.

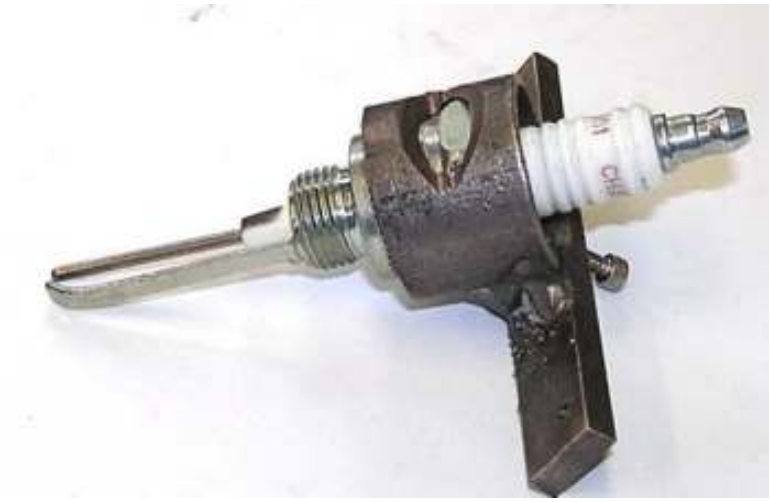
The burner didn't seem to run very well-- it went out often. I then opened the fire box door slightly as shown on the right and everything worked great --- burner was very stable. That indicated a little more more air was needed at the back of the fire pan. Chester Peterson had vents at the back of the fire pan in his design so decided to make that modification.

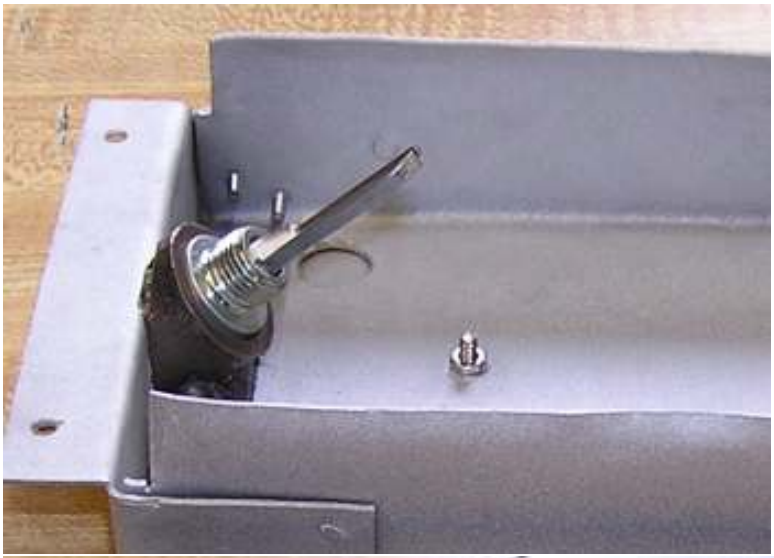
January 29th Test: Between December 16th and this test on January 29th the cab roof, whistle and steam powered pump were fabricated and installed. The snow was deeper on the 29th as seen in the photo above and it was pretty cold ---- about 15 degrees. Mark Mihalyi had come over from near Pittsburgh and we both froze.

Two 5/8" vent holes had been added to the rear of the fire pan and that seem to fix the burner --- it was very reliable. The pump and the modified brakes with both steam powered application and release all worked great. The whistle however didn't work very well ---- too cold --- the steam condensed and it spit more than it whistled. Hopefully it'll work better in warmer weather. The only other problem noticed was that the blower seemed to be less effective than on previous tests. Several of the blower holes were found to be plugged when it was later disassembled for painting. The engine had been run quite a bit on compressed air and the lubricator was supplying too much oil, much of which ended up on the blower It was probably this excess oil that plugged the blower holes.

This test was cut short after about an hour when one of the water pipes froze. Were were glad to get inside and warm up.

Sparker: Last fall I had observed Dave Johnson using a spark arrangement to relight his oil burner. More recently we exchanged a number of emails in which he described the sparker he used. He suggested a a kerosene heater plug (more than $10) screwed in the bottom of the fire pan about 3/4 of the way toward the back. The plug takes a 14 mm tap. I figured I'd save some $$$$ and buy a lawn mower plug. The local hardware store carried the heater plug and once I saw one (photo on right) it was clear why Dave likes them ---- look at the length of those electrodes.

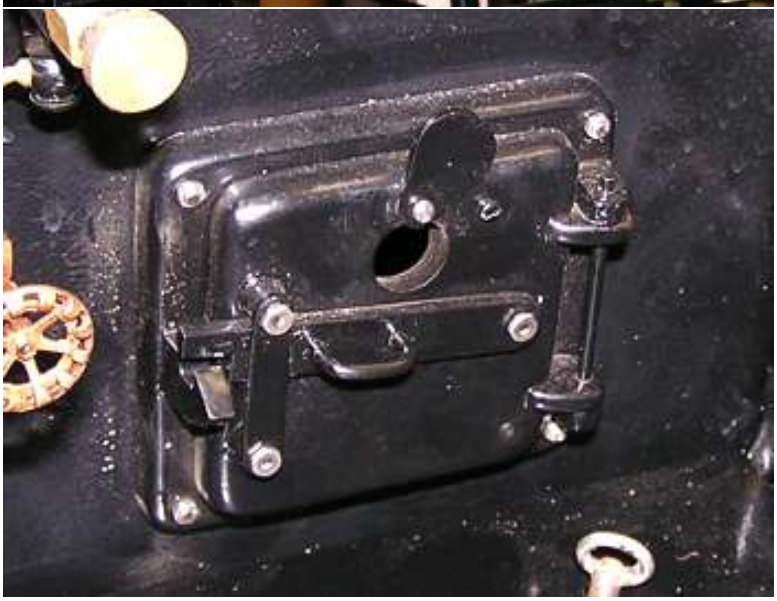




The plug is threaded 14mm with 1.25 mm pitch and my 14 mm tap had a larger pitch. The fire pan is too low on the shay to have the plug sticking out the bottom of the fire pan so the holder in above photo was fabricated. The plug is a very loose fit it the holder (so it hopefully won't rust in place) and is retained by the screw. It is a tight fit after the screw is tightened. The plug is at a 45 degree angle. Note that the fire pan had been powder coated with a high temperature powder made for auto exhaust manifolds.

Damper: This photo shows the bottom of the fire pan with the plug in position. Dave has an adjustable damper on his burner so I added the hinged flap damper. The cleat on the end holds the damper in position. The two vent holes mentioned earlier are visible under the flap. That seemed to be enough air on the previous test so no need for more holes. There is some leakage around the plug holder so it may be necessary to close the damper more than shown n the photo.

This photo shows the fire pan in position under the boiler. Bob Reedy had used studs into the boiler with nuts to secure his fire pan. I tried studs but had great difficulty getting the nuts started on the studs. I found that socket head cap screws worked better for me. The edges of the holes in the boiler were opened slightly with a countersink to make it easier to get the screws started.



Observation Port: Last fall I noticed that most the guys with oil burners have a small observation port in the firebox door to view the fire. I added the the little hole with teardrop cover that is similar to one that Dave Johnson uses.

April 15 test: April 15 is a day I normally dread as I wait to mail my income tax payment while grumbling about it all day. This year I was due a refund so it was mailed in early February. The refund arrived weeks ago and has already been used to stimulate the economy. The day was bright and sunny so I spent all morning and most the afternoon cleaning up limbs and other debris from her lawn. It'll take another few hours before the lawn is clear enough to run the mower. (She's already fertilized it ---- I keep hoping she applies Roundup by mistake.) Anyway, by about 4 pm I was exhausted, sore and not in a good mood ---- like a normal April 15th.

Wheeled the shay out on the walkway, put some diesel in the fuel tank and filled the tender. Connected the compressed and used the steam powered pump to fill the boiler. Just when I got it to the correct level, the pump quit. Drats!

I tried to light the burner with the igniter --- not luck. It lit easily with the propane torch. After it ran for a few minutes, I shut off the atomizer air valve to extinguish the flame and then turned it back on. The igniter easily relit the burner. At least that part worked slick. Through that test I used the igniter several dozen times and it worked every time. The igniter can be labeled finished!

Tested a number of variations of throttle opening and fuel, atomizer and blower settings. The atomizer seemed to run fine at 8 to 10 psi. The burner seemed to produce the best heat with 25 psi or greater blower when engine is not running.. When running, the exhaust creates a draft so the blower can be cut back. It looks like leaving the blower on about 10 psi when running will keep the burner running if the throttle is closed.

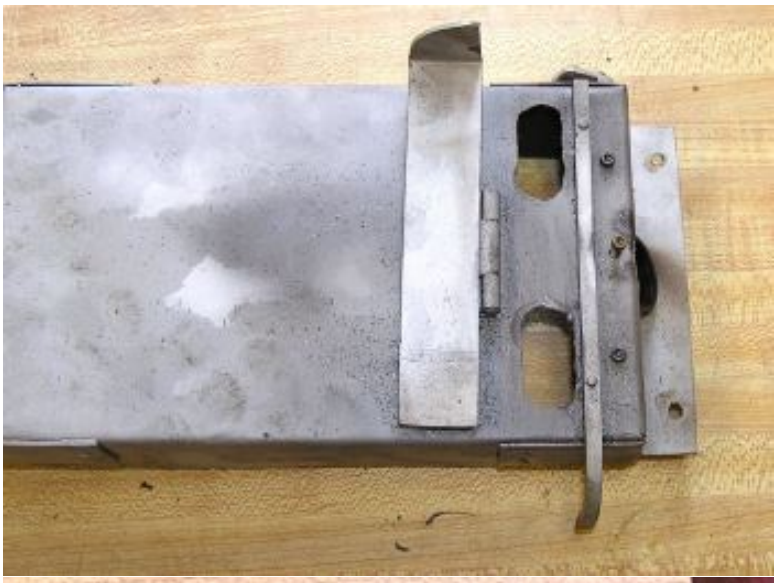
There were several problems uncovered:

- The burner seemed to be relatively insensitive to the fuel valve setting and it was impossible to make it rich enough to produce white smoke.
- The burner would go out at full throttle unless the door was cracked indicating more air was required.
- The most serious problem was that some of the fire came out around the spark plug hole and burned the insulation on the plug wire. This had been a problem from the first test ---- to much heat coming out around the back of the fire pan. Bob Reedy and Chest Peterson angled their nozzles up slightly --- maybe to fix this problem.
- After everything was shut down I checked the smoke stack to see if the change in the lubricator piston size had reduced

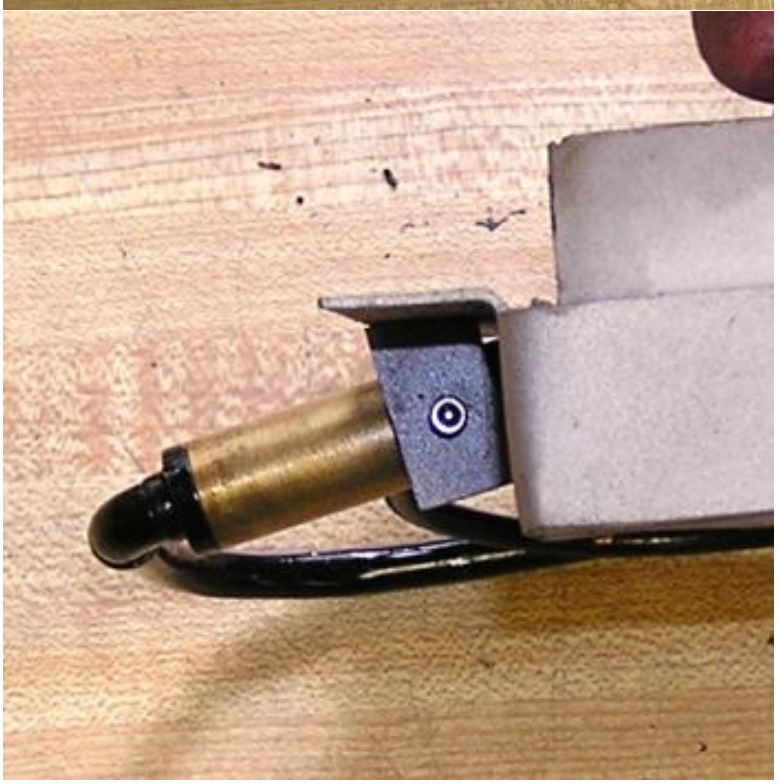
the amount of oil dripping down the side of the stack. There was no dripping --- good. However, there was a big puddle under the lubricator. Bad! (It was really bad when she noticed it on her cedar walkway.) I then noticed oil bubbles coming out the lubricator vent hole (there was still some boiler pressure) indicating the ball check in the lubricator output wasn't checking very well.

At that point I was sore, tired, dirty and discouraged. The next day I went out to Mill Creek Central and helped Dick McCloy move a few things around his track. That lifted my sprits. That evening I went to work on the lubricator and pump. The lubricator problem was that the output pipe protruded into the side of the output chamber and pushed against the side of the ball check keeping it from seating. This was probably done after painting when I tightened all the connections. It was fixed by cutting off the end of the pipe. The problem with the steam powered water pump was that the lower end of the pilot valve stem had come unscrewed --- must have not tighten it sufficiently when reassembled after painting. Two problems fixed already and my spirits were really up.

Bigger Vent: The fire pan was removed and the front vent holes about tripled in size.



Nozzle Angle: The top of the brass block that holds the nozzle was milled at about a 12 degree angle so the nozzle points at a spot about an inch above the bottom of the fire box.



Fuel Flow: The nozzle was checked and verified to be clear. Next, the flow at the output of the filter was checked. The flow didn't increase after the valve was opened about 1/2 turn. There was only about 1 inch of fuel left in the tank. I filled up the tank and opened the valve again. There was much greater flow when the valve was opened. This indicated there may be a problem with very low fuel level.

April 17th Test: Fired it up again on April 17th. The good news was that the burner worked much better --- greatly reduced heat around the back of the boiler (I was beginning to wonder if I really wanted foot pegs ---- it looked too hot down there). The larger rear fire pan vent worked better, could keep the fire going at full throttle with door closed. Also noticed better fuel control and could make it smoke a little with a rich flame. Also noticed a relationship between the amount of blower, smoke and fuel setting ---- i.e., increased fuel caused white smoke, increased blower leaned it out and it stopped smoking. This was all as I initially expected. Another piece of good news --- the lubricator wasn't bubbling oil.

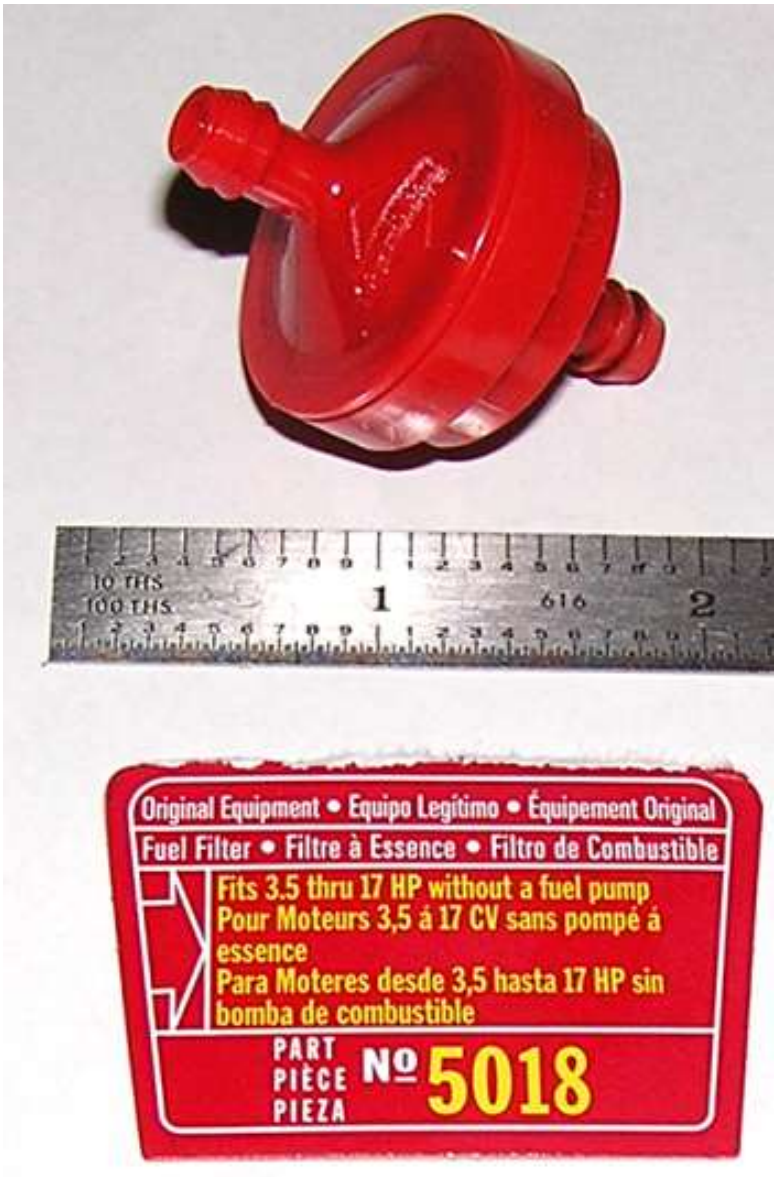
This test was for about an hour. Whistle worked great --- recall that it just spit in freezing weather. There were a few small steam leaks but I'm getting used to them --- that might be easier than actually stopping the leaks. The Teflon packing in the engine rod and valve stem glands worked really great. I did notice that the rod bearing on the rear cylinder is a little loose. Maybe I can mill the joint between the two halves slightly and then ream it again. After I shut everything down again I noticed bubbles on the lubricator vent again. Even so, it was a good day.

The Lubricator Again: This time I cleaned the lubricator up before working on it. What a mess!!!! The steam that backed up through the lubricator tank turned the steam oil into a thick sticky grease --- it must have washed out the tallow. I couldn't see anything wrong with the ball check valve but did see some small pieces of copper from the end of the output pipe I cut off last time. That might have been holding the ball off the seat. Also, maybe it was just the grease left from the last time steam got into the tank ---- I didn't clean it out that time. I did drill out the seat slightly to (hopefully) make a better sealing seat. I later tested it running the engine on compressed air. First, the output was left open at the union next to the steam input header to verify that it pumped oil to that point. The union was then connected and engine run for about 20 minutes; no bubbling from the lubricator. (Note: I had further trouble with the lubricator and later changed the design to use a poppet check valve. This change is documented on the Lubricator page.

New Fuel Filter: I discussed my concern about the fuel filter and low fuel level with Dave Johnson and he said that it sounded like I wasn't getting enough fuel. He uses a fine screen and pointed out that the nozzle fuel opening is really pretty big and not much of a filter is required. He suggested that a screen or filter designed for engines without fuel pumps was appropriate.

I then did an Internet search for small engine fuel filter and found a number of references to filter of sizes as small as 10 microns to the Briggs & Stratton #298090 that is 150 microns. Took that number and went to the local TSC (Tractor Supply Center) where I found a Briggs & Stratton No 5018 shown on the right. On the back of the package it says its the same as #298090.

Before disconnecting the old auto type filter I measured the time required to fill a small bottle with the valve wide open. I then did the same test with this red filter and found that it took about 1/3 the time.



April 21 Test: The locomotive was fired up again on the test stand to check the operation with the new filter. The operation finally seemed correct. Some of the key points were:

- It was possible to increase the fuel feed to the point that the fire smoked.
- It was possible to reduce the smoke by increasing the blower or opening the throttle.
- If the fuel was adjusted for no smoke at low blower or throttle, the fire went out when the blower was open to maximum or the throttle opened to max. This makes sense, the blower and exhaust supply more air and lean the mixture.
- The minimum burner setting generated enough heat to get to and maintain over 100 psi pressure so if the locomotive is stopped for a while with the burner on, the safety valve will be operating constantly --- distracting.
- One way to minimize the safety valve going off when stopped was to add water; this lowers the temperature and stores the energy from the heat in the form of more hot water.
- Good operation was achieved with the damper at the rear of the fire pan about half open. This will need further checking under load.
- A noticeable soot collected on the inside of the smokestack and some collected in the tubes. Clearly, a smoky fire generates soot. Baring any new data, will run fuel adjustment just to the leaner side of where it smokes to minimize soot buildup.
- Soot buildup will require cleaning the tubes periodically.
- The lubricator used some oil and none leaked out the bottom of the lubricator. Also, there was none deposited on the smokestack so the oil feed amount is probably about right.

The locomotive is ready for a test at the track.

April 28: Took it to the track today and it ran pretty for about 90 minutes and then a few problems developed. This first operation will be discussed in the operation section. The burner modifications described here seemed to work well.

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