Shay Engine

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The following shows the various parts of the engine for the Shay locomotive.

Rough Castings: I started with the set of castings shown on the right that were purchased from Kenneth Schroeder. The gray castings are cast iron and the bronze colored ones are indeed bronze castings. The cylinder castings are at the top with steam chests (the boxes). As you can see, it's a three cylinder engine. The long narrow pieces are the crosshead guides. The little pedestals are the valve stem guides. The three smaller bronze casting are the valves and the six larger thin bronze castings are the eccentric straps that drive the valves. The big casting with the three arches is the crankcase.

Lower Engine: The lower engine parts are shown on the right. The crankcase has been machined. It's dark because it was given an acid bath and then sprayed with WD40 just before the photo was taken. The eight bronze pieces are the split main bearings machined from bronze rod. The four rectangles are caps machined from steel stock that hold the bearings in place. The crankshaft is made from precision ground stainless steel rod and stainless flat bar stock. The webs are pinned in place with stainless taper pins. The stainless disks are the eccentrics that drive the valves.

The next photo shows the bottom of the assembled lower engine with the crankshaft, bearings and bearing caps and eccentrics all in position.

This next photo shows the top view of the lower engine. The aluminum block on the left is a handle to turn the crankshaft. The two larger aluminum blocks hold the engine upright and off the table. These three aluminum blocks are used only for engine assembly and test and will be removed when the engine is mounted to the locomotive frame.

Cylinders & Associated Parts: The parts for one of the three cylinders are shown on the right. Sorry that the photo is a little dark. I tried making the background lighter but the stainless parts then became hard to see.

The machined cylinder is in the upper left with the upper and lower heads and the green head gaskets. The machined crosshead guide is shown below the cylinder.

The two piston rings are shown on the upper right. These are made from cast iron and were purchased completely machined. The piston and piston rod were machined from stainless steel stock. The brass disk near the bottom of the piston rod is a packing gland that is mounted in the lower head to seal around the piston rod by pressing against graphite impregnated yarn.

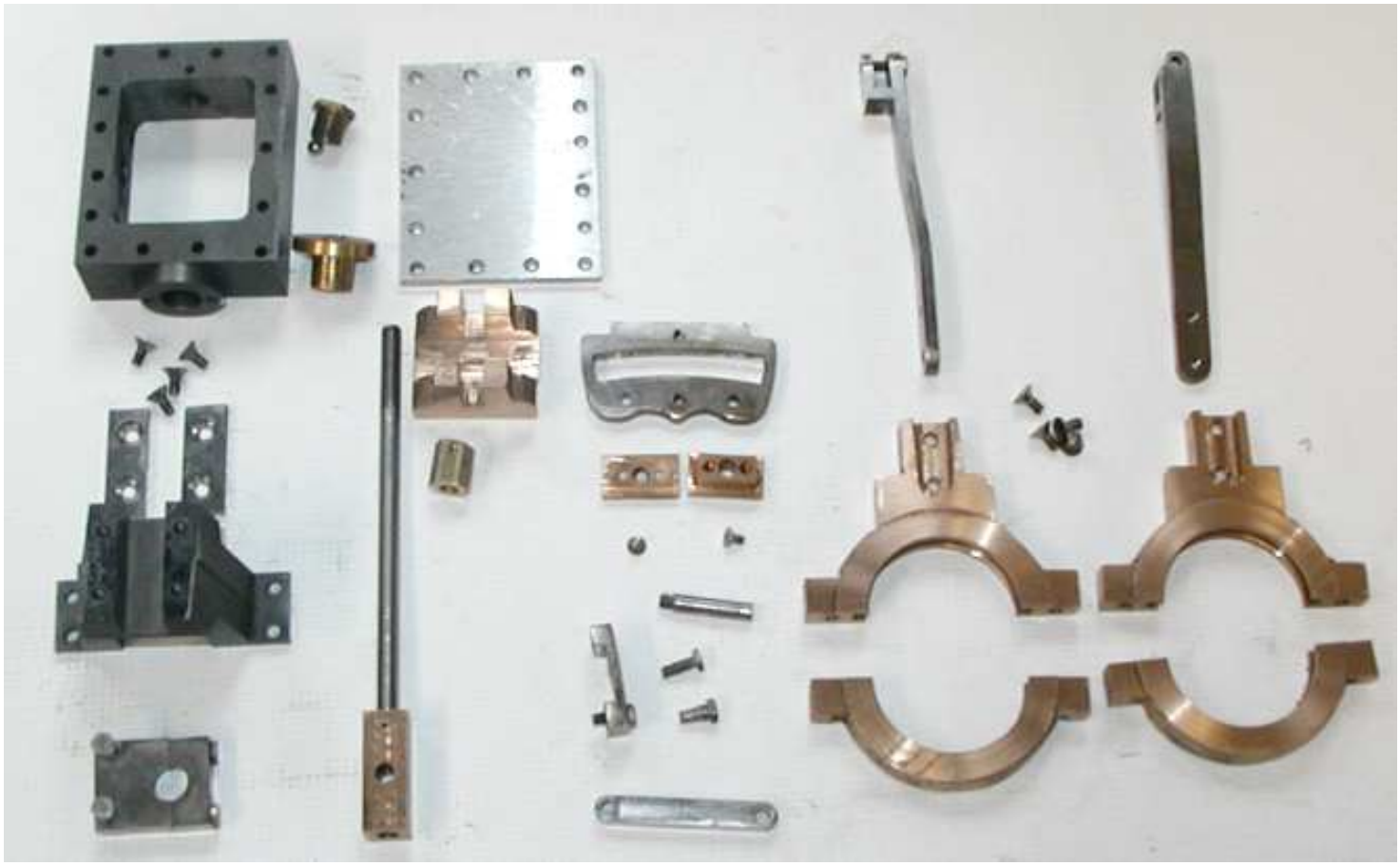
The parts below the piston rod are the crosshead machined from bronze stock and the connecting rod & connecting rod pin machined from stainless steel stock

The rod bearing machined from bronze stock and the stainless steel bearing strap are in the lower right.

Valve Components: The valve systems requires many small carefully machined parts. These parts for one cylinder are shown below. The part in the upper left is the steam chest casting that mounts to the side of the cylinder casting. The stainless steel steam chest cover is to the right of the steam chest. The brass part with little ball is the snifter valve that mounts in the top of the steam chest. The larger brass piece is the valve stem packing gland which mounts in the lower side of the steam chest.

The machined valve stem guide casting is below the stem chest. The two little straps screw to the top of the guide to retain the valve stem in the guide. The stainless steel reverse shaft bearing block is in the lower left corner. Both the valve stem guide and the reverse shaft bearing block mount to the cross head guide.

The bronze block below the steam chest cover is the valve. The hex brass part below the valve is the valve adjusting nut. The stainless steel and bronze valve stem is to the left of the valve.



The large bronze parts on the right are the machined eccentric straps. The links blades fabricated from stainless steel stock are shown are in the upper right.

The flat part with the curved slot in the center of the photo is the reversing link fabricated from stainless steel stock. The parts below the reversing link are used in the reversing link assembly. These were machined from bronze and stainless steel stock. Machining the curved slot in the reversing link and a matching curve on one of the bronze parts shown below the link was challenging for this amateur machinist using fairly primitive equipment. I got it right on the second attempt.

Note: Ken specified cold rolled steel for most the engine parts such as the connecting rods, heads, steam chest cover, link blades, etc. I chose to use 304 stainless steel for all these parts in an attempt to improve the finished appearance. This was probably a mistake since the 304 is really tough. It's going to be cold rolled steel for the trucks.

Valve Operation: The valve design is both simple and effective. The next photo shows the cylinder mounted to crosshead guide with the lower head sandwiched in-between. The lower end of the piston rod is screwed into the top of the bronze crosshead. The upper part of the connecting rod is shown fitting into the lower end of the crosshead.

I'm holding the valve with the recess in the underside visible. The valve moves up and down against the flat machined surface of the cylinder side. The steam chest bolts to this side of the cylinder. The steam chest is connected to the boiler via the throttle (valve) so that the interior of the steam chest contains uder pressure. (The steam chest contains steam ---- novel)

The center slot on the machined side of the cylinder cylinder connects to the exhaust port on the right side of the photo. The upper slot connects to the very top of the cylinder (the cylinder inside the casting) and the lower slot connects to the very bottom of the cylinder. The valve moves up and down over the slots to control the input of steam from the steam chest to the cylinder and the outlet of steam from the cylinder to the exhaust.

Assume the piston is at the top of the cylinder and the valve is near the lower extreme of it's motion. In this position the recess in the valve will be over both the middle and lower slots permitting steam to pass from the lower part of the cylinder out the lower slot, through the valve recess and into the middle slot and on out the exhaust port. At the same time the upper slot is starting to be uncovered permitting steam from the interior of the steam chest to go through the upper slot into the top of the cylinder and push the piston down. As the piston moves down, the crankshaft rotates and the eccentric will first push the valve down to fully uncover the upper slot and then up so that when the piston reaches the bottom of the cylinder the the valve will have moved to near it's upper extreme closing off the upper slot from the steam in the steam chest and opening the upper slot to the exhaust. At the same time the lower slot will start to be uncovered to let steam enter the lower part of the cylinder and push the piston back up. One of the neat things about a steam engine is that is that the piston is powered in both directions.

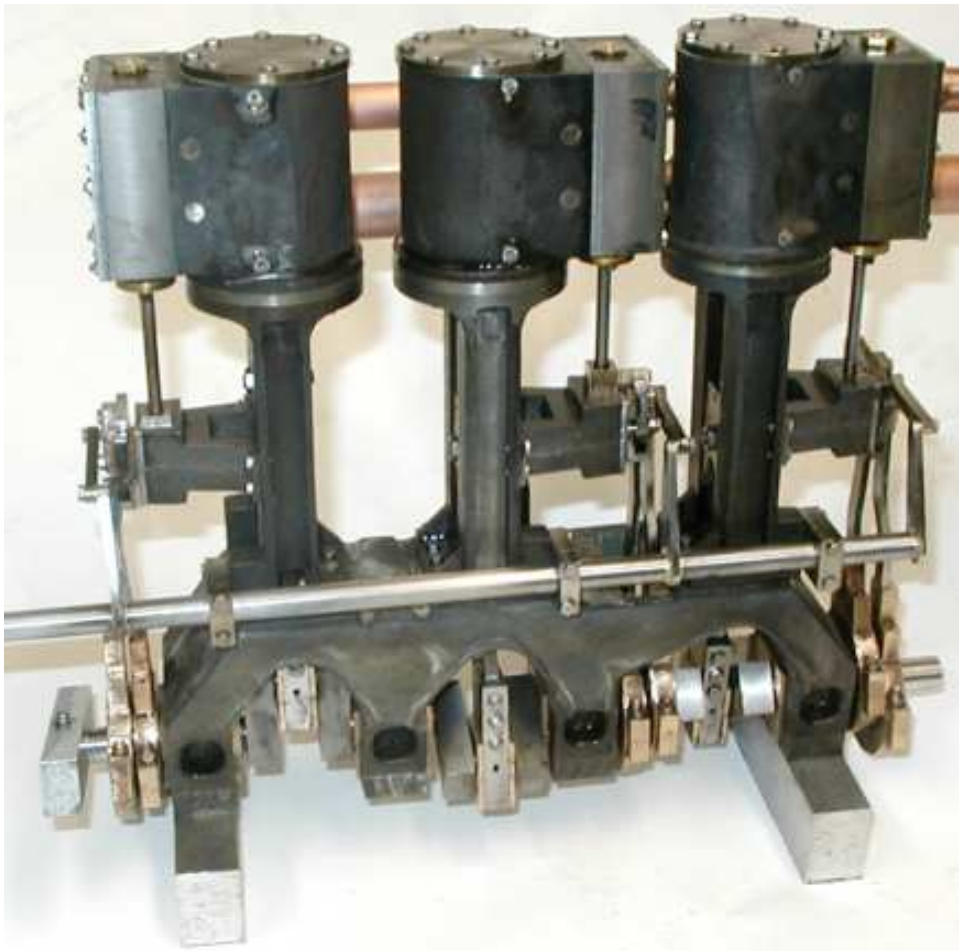
The photo on right shows the cylinder with the steam chest attached and the steam chest cover removed to expose the valve. The upper head is visible as is the snifter valve at the top of the steam chest. The valve stem packing gland is at the bottom of the steam chest. The steam inlet header bolts to the right outside of the steam chest. Steam enters the steam chest from the header via the hole barely visible in the right side of the steam chest.

The valve is pushed up and down by the valve stem. The long nut on the valve stem provides for adjusting the valve position such that operation is the same for both the up and down stroke. (Valve timing is adjusted by rotating the eccentrics on the crankshaft.) The little screw in the adjusting nut prevents the nut from moving after the adjustment has been made.

The valve is shown near the lower extreme position with the upper slot fully open. This valve position corresponds to a piston moving down and near the middle of the stroke.

These two photos show the view the front end of the engine. In the left photo the reverse lever is in the position for reverse where the valve for the #1 cylinder is driven by the second eccentric. In the photo on the right the reverse lever is set for the forward direction and the first eccentric drives the #1 cylinder valve.

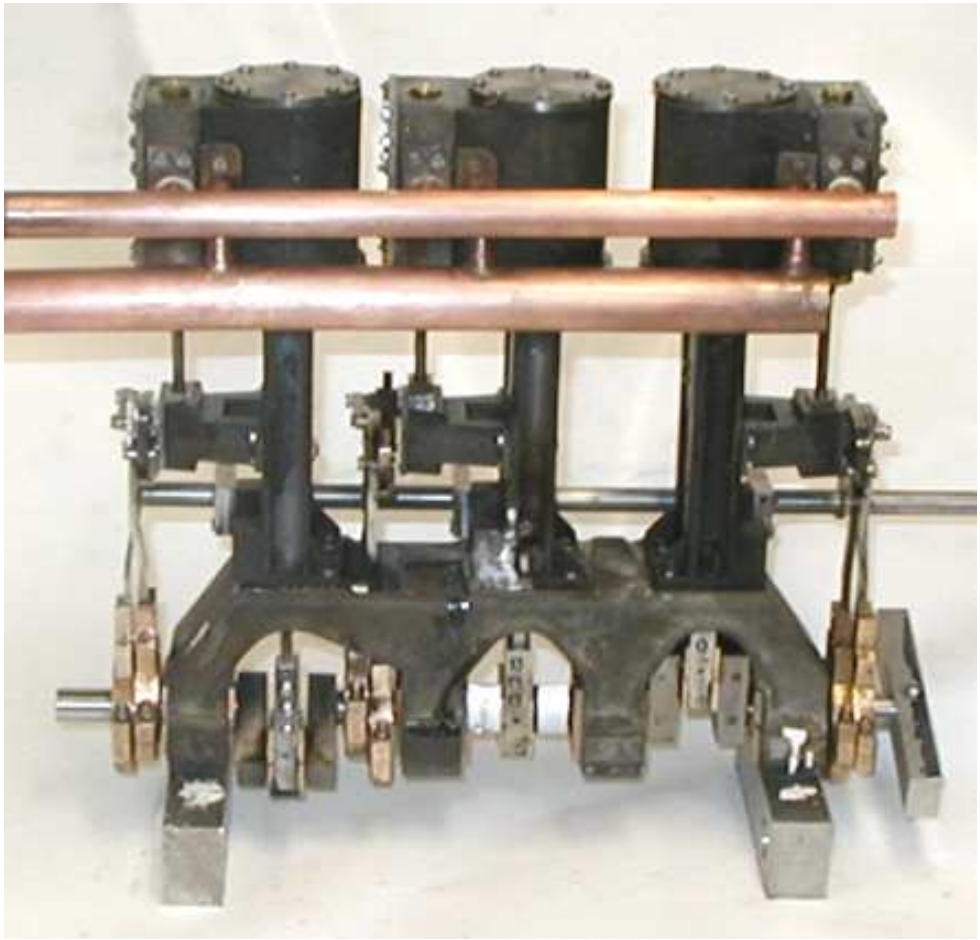
Side view of engine: Recall that the Shay engine on the right side of the locomotive. This photo show the outer side of the engine. The rod across the front controls the reversing of the engine. There will a lever attached to the left end of the rod which will in turn connects to a long reversing lever in the cab.



Rear side of engine: The is the rear side of the engine that is next to the locomotive frame and boiler. The upper copper pipe is the inlet header. This header has a valve and air line fitting off the photo to the left. These fittings permit engine operation with compressed air. When the engine is mounted to the locomotive this header will be cut near the left most cylinder and a steam supply pipe connected at that point.

The lower copper pipe is the exhaust header which will connect to the exhaust pipe that takes the exhaust steam to the smokestack via the smokebox at the front of the engine.

The engine as shown here weighs 27 pounds.



The engine has been operated a couple hours on compressed air and runs very smoothly. It will rotate on as little as 2 or 3 psi pressure. Being an engineer, I was compelled to do a quick power calculation that indicated a power in the 0.5 to 1 HP seems possible. I am now faced with the overwhelming urge to build apparatus to actually measure the power. That should best be postponed till next winter if I'm going to have anything running this summer.

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