Running Steam

As an engineer and trainer for the Minnesota Transportation Museum, operating the Osceola & St. Croix Valley route out of Osceola, Wisconsin, I thought maybe some of you might find it interesting to hear a description of what actually goes on in the cab of a steam locomotive when running.

Though we run diesel power most of the time, we bring out locomotive N.P. 328 for some operations. She's a slide valve 4-6-0, hand fired, with Johnson Bar reverse, Stevenson valve gear, 175 psi boiler pressure, saturated steam, and 57" drivers.

Sitting in the station, the automatic air brakes (the brakes on the cars of the train) are in the release ("running") position, and the independent brake (the air brake on the locomotive and tender) is in the fully applied position to keep things from rolling away unintentionally. The sight feed lubricator is set to the off position so as not to waste oil, which is administered to the cylinders while running, literally a drop at a time. (Master Mechanics used to treat oil like gold, and ranked engineers by how little oil they used.) The reverse lever ("Johnson Bar") is centered, the cylinder cocks are left open, and the throttle just cracked. This admits a bit of steam into the cylinders to keep them warm when not running, but does not generate enough force to overcome the independent brakes.

During this time, the engineer can "count the parts", "oil around", refill the lubricator if necessary, check for warm bearings, and otherwise make sure everything is as it should be. If the consist of the train has been altered in any way, brake tests must also be made under the direction of the conductor or brakeman.

The fireman spends this time preparing for the departure. The water level must be high enough to completely cover the crown sheet (the inside "roof" of the firebox) but not so high as to significantly reduce the amount of space available in the boiler for steam storage, nor to allow water to be lifted into the dome and thus into the cylinders upon starting. The fire must be low, so as to not cause the "pops" (safety valves) to open, but must have a good bed of coke, ready to put out a lot of heat the moment the train starts up. Too much and the draft will be choked off - too little and the draft will literally tear holes in the bed of the fire upon starting. The surest way to ruin a fireman's day is to delay the departure of a train that's ready to go. The blower is on just enough to keep air moving through the flues - but no more. The fire door is kept closed as much as possible, so only air that has been heated by the fire enters the flues. This helps keep temperatures even and reduce leakage of flues and stay bolts.

Water level is the responsibility of the fireman. It's put into the boiler with an injector - a marvelous device that takes steam from the boiler, mixes it with water from the tender, and forces it back into the boiler through another pipe - with no moving parts!!!! These things impress me. I know, thermodynamics says they work, and in actual practice they do work - but intuition says "No Way!"

OK. The stationmaster radios "Stationmaster to NP 328. You're clear to depart." The conductor shouts "All aboard," and gives a highball sign. The engineer acknowledges with two short whistle toots, and starts the bell.

The engineer releases the latch on the quadrant and drops the reverse lever into the full forward position - "in the corner." The fireman shuts off the blower and throws about 3 scoops of coal into the firebox. The engineer turns the lubricator on, turns on the sanders, and gives a gentle tug on the throttle, then feathers off (releases slowly) the independent brake so the slack stretches out gently. Once things start moving, the engineer can move the throttle out quickly, only being careful not to slip the drivers. Slipping the drivers damages track and running gear, and the sudden draft can tear holes in the finest fire bed. The engineer uses four of his senses to coordinate everything - sight, sound, smell, and feel. If the engine is going to slip, he'll feel a slight sideward movement of the back of the engine a split second beforehand. At that, reducing the throttle will prevent a slip.

Within about 10 seconds he'll have the throttle wide open, and the engine is accelerating in full cutoff - that's with the Johnson Bar in the corner. When he feels, or hears, that the rate of acceleration may be decreasing, it's time to "hook up" the Johnson Bar. The reason for this is that when starting the engine is running with maximum cutoff. For a slide valve engine, maximum cutoff is usually 100%, but may be lower, down to about 90%, but the maximum for any particular engine is fixed by the setup of the linkage at the shops. 100% cutoff means that for the full power stroke of the piston, steam is admitted into the cylinder, and full boiler pressure is applied to the piston. This gives maximum power, but is possible only at low speed due to the limited ability of the boiler to generate steam, and of the piping to supply it to the cylinders. 80% cutoff means that for 80% of the stroke steam is admitted into the cylinder, and for 20% of the stroke the expansion force of the steam in the cylinder pushes on the piston.

Hooking up the engine requires care and strength. The full boiler pressure is pressing each of the slide valves down on their seat with a force of up to 15 tons, though this is reduced somewhat by a balancing mechanism on the back of the valve, it is still considerable. Those valves don't want to move, so when the catch is released on the quadrant it takes a firm hand to prevent the reverse lever from jumping about wildly. I usually place my right foot at the position on the quadrant to which I want to move the lever, firmly grasp the lever and squeeze off the latch. The motion of the engine will push the lever back towards me, and the mass of my body will slow it down. When it hits my foot I release my grip on the latch and the lever is locked into its new position.

With the lever hooked up, the engine sort of "breaths" a bit easier. The exhaust becomes crisper, and the engine continues to accelerate.

After about 15 or 20 seconds of running, the cylinders are fully warmed, and cleared of any condensation, so the cylinder cocks may be closed. The sanders may be turned off.

About this time, we're far enough from the station to turn off the bell, too.

If the Johnson Bar had been pulled up too far, the engine would start to seem sort of wimpy, since the steam starved cylinders wouldn't have sufficient steam for expansion. Thermodynamics could tell us exactly the ideal position of the Johnson Bar at any time, but experience is heavily relied upon here.

The Johnson Bar may need to be hooked up several times before maximum speed is achieved. If track speed is reached before the optimum position of the Johnson Bar is found for most efficient running, then the throttle may be closed a bit. But, as much as possible, you want the expansion of the steam to take place in the cylinders, not in the dry pipe.

During this time, the fireman has been very busy. He's not shoveling constantly, though. You never put in more than 3 or 4 scoops of coal at a time. Then wait 15 or 20 seconds before putting in another 3 or 4 scoops. The firebox temperature has risen from about 900 degrees F. to almost 2500 degrees while starting out. A scoop of coal weighs about 15 lbs. Five lbs. of that is volatile gasses trapped in the coal, which is "cooked out" of the coal within the first 15 seconds of entering the firebox at that high a temperature. If more than 4 scoops is placed on the fire bed, the volatiles that are cooked out will not have enough oxygen for complete combustion, part of the available energy will be wasted, and the smoke turns black. What remains on the grate after the volatiles is cooked out is about 5% ash and other waste, but the rest is pure carbon coke, which will be consumed on the grate in about 3 minutes. It is therefore necessary to maintain a steady pace of placing 3 or 4 scoops every 15 or 20 seconds, then waiting. All of the coal in the firebox must be replaced every 3 minutes.

Once up to speed, it's usually not difficult to keep her hot.

Between periods of firing, the fireman checks his boiler pressure and water level, adding water whenever necessary with the injector. Water level is very important. Remember that firebox temperature of up to 2500 degrees? Well, steel melts at about 2000 degrees, so it is necessary to maintain at least 4 inches of water on top of the firebox to cool it, or the crown sheet (the roof of the firebox) will soften and collapse downward - the classic boiler explosion. He also keeps a lookout for signals, and confirms signals, track conditions, and grade crossing safety with the engineer.

There are two things he must guard against while tending the fire: clinkers and holes. A clinker occurs when the fire bed melts and fuses into a gooey mass that will not allow air (oxygen) through it. A hole can be caused by uneven distribution of coal while firing, by having too thin a bed of coke on the grates so the draft tears a hole in the bed, or by slipping wheels or mishandling of the Johnson Bar. In any event, these conditions cause a reduction of firebox temperature, and a resultant loss of steam generating capacity.

Stopping the train smoothly requires as much, or more, skill on the part of the engineer as starting it.

Approaching the station, the throttle is shut off, then opened a crack to keep lubrication flowing into the cylinders. The automatic air brake is applied, first with about a six psi reduction from the 90 psi that was carried while running. Setting the automatic air also sets the independent brakes on the engine, so a separate release of the independent brakes is made, which keeps the slack stretched out. A second four or five psi reduction is made with the automatic air, and the independent again released. The engineer plans this application to stop the train about 100 feet short of the ultimate stopping point.

When speed reaches about 5 mph, the Johnson Bar is again dropped into the corner, and the cylinder cocks opened. The brakes are released for about 4 seconds, followed by a brake reduction to about 75 psi and the independent brake released. If the train is stopping too soon, the throttle may be opened a bit more.

Just before or at the instant of stopping, release the automatic brake, fully apply the independent brake and shut off the throttle. You've just made a perfect smooth "two application stop."

Don't forget to shut off the lubricator.