Inspection Key To Keeping Locomotive Steam Engines On Track

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Steam locomotive engines were at the heart of the Industrial Revolution, but advances in technology eventually phased them out with diesel engine and electric designs.

They still are used on tourist and heritage lines, although most have been retired; however, some countries are exploring design improvements in the manufacturing of steam locomotives, and ASME Section I, construction rules continually are revised. Yes, steam engines still are being built today.

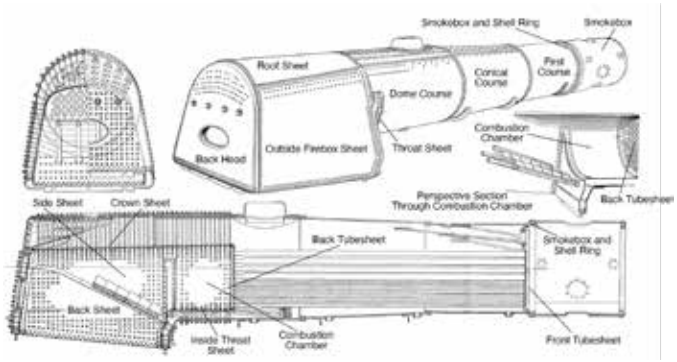
Regardless of improvements, steam locomotive engines require constant maintenance, periodic inspection, and repair; therefore, standards and regulations exist for inspection and repair.

In the US, for example, steam locomotives are regulated by the US Department of Transportation, Federal Railroad Administration. In addition, the *Code of Federal Regulations* (CFR), Title 49, Part 230.29, states the *National Board Inspection Code* (NBIC) is one of the permitted "accepted industry standards" for welded repairs to steam locomotive boilers. Others may be found in lower levels of government, i.e., states and provinces.

The National Board (NBBI) has not wavered in its commitment to its mission/vision statement. Steam locomotives still are the first supplement in Section 6 in the NBIC Parts 2 and 3. The NBIC Committee Task Group Locomotive Boilers remains committed to this work which first saw inclusion into the NBIC in the 1992 edition/1993 addenda. This article will focus on the inspection requirements.

As with any inspection activity where an NBIC requirement presents a direct or implied conflict with any jurisdictional regulation, the jurisdictional regulation shall govern.

Inspectors should become familiar with the applicable inspection requirements and should not be tasked with inspecting a steam locomotive if not experienced in this area. This is a fire-tube type boiler, but there are notable differences to a typical scotch marine boiler. Refer to the diagrams in the NBIC, the 49 CFR Part 230, or another standard to become familiar with construction and components. There also are useful cutaway diagrams available on the internet. Another useful resource available on the NBBI website (nbbi.org) is a summer 1994 *BULLETIN* article by Richard Stone, who described the design and fabrication of steam locomotives.



Locomotive boiler general arrangement

Because of the size and number of components, such as rivets and staybolts, a thorough inspection may take hours to complete. Also, access to pressure retaining areas in a steam locomotive can be limited due to its construction. However, many parts still are accessible. As with any internal inspection, cleaning the boiler is particularly important.

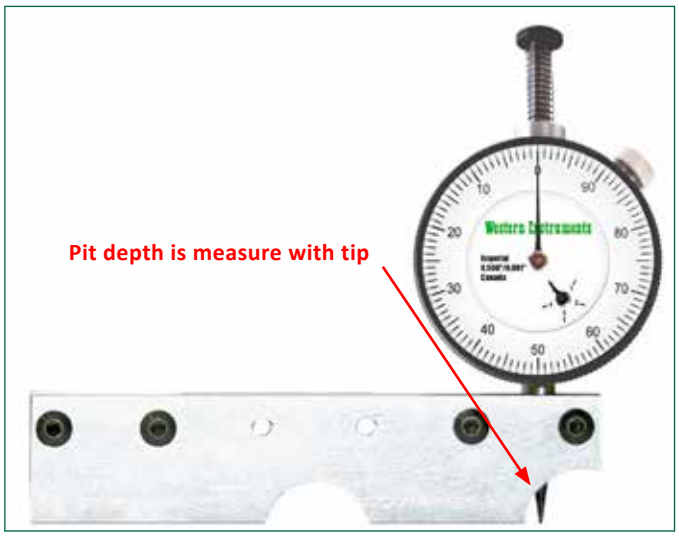
The inspection methods include:

Stayed and Unstayed Sections

Pitting depth may be determined by use of a depth micrometer or pit gage. Where general corrosion is evident, plate thickness and corrosion depth may be determined by use of ultrasonic (UT) examination.

Stays are widely used on a steam locomotive. When employing UT on stayed sections, readings should be taken on a grid not exceeding the maximum pitch at the center of each section of four staybolts. For unstayed sections, the grid should

not exceed 12-inch centers, but additional readings may be taken, if warranted. Nondestructive examination (NDE) methods also may be used to identify any cracks. Accelerated deterioration often occurs within approximately 3/8 of an inch radial perimeter around staybolts in some portions of a firebox. This can be caused by erosion or stress-induced corrosion. It is advisable to spot check throughout the firebox for this condition. If found, adjacent stay perimeters also should be checked.



Western Instruments Pit Depth Gage

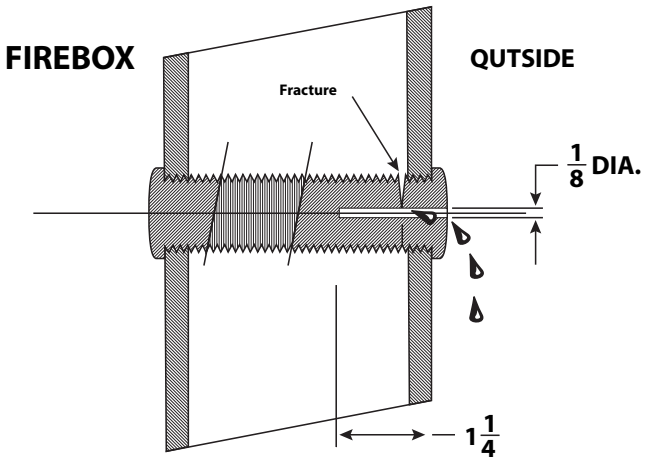
Plates may experience separation at the riveted seam, which may be detected with a feeler gage and magnifying glass. Inspection lights are useful when conducting a visual inspection. Varying the intensity or changing the angle of the light may facilitate the discovery of defects, especially pits and surface irregularities. A fixed light source placed within a stayed zone when inspecting internal parts will aid the inspection.

Telltale holes and the hammer test are two methods for determining the soundness of staybolts. The best results are obtained when both methods are used under a hydrostatic pressure – at least 95% of MAWP. When this isn't possible, the hammer test may be performed with the boiler drained.

Broken or deteriorated staybolts shall be replaced in accordance with NBIC Part 2. In addition, adjacent staybolts should be closely examined because of the additional stress absorbed due to any broken ones.

Some fireboxes may have numerous staybolt replacements where the sheets have been tapped to the next larger size to ensure good thread engagement. Typically, the larger staybolts aren't as flexible and can lead to premature breakage and added sheet stress, which can lead to star cracking in the sheet.

The use of these methods and a checklist of components or "inspection zones" is highly recommended. The inspection requirements are similar for all components and important distinctions will be described. Refer to the NBIC Part 3 or the 49 CFR for more information.



Defective staybolt detected by drilling

Riveted Seams and Rivet Heads

A common method of construction for steam locomotive boilers was the use of riveted seams and heads.

This may be a good zone to begin the inspection. The boilers shall be inspected for grooving, corrosion, cracks, pitting, leakage, separation of plates, excessive or deep caulking of the plate edges and rivet heads, seal welding of the plate edges and rivet heads, weld build up or complete covering of rivet heads by welding, rivets replaced by patch bolts, defective components of the seam, and rivet head wastage for rivet joint in tension.

A general damage mechanism on rivet heads and plates is hydroxide cracking (caustic embrittlement). NDE methods should be used on longitudinal lap seams where this damage mechanism is typical. Refer to NBIC Part 2 when determining rivet head wastage. Only those thermal fatigue cracks determined by engineering evaluation to be self-arresting may be left in place.

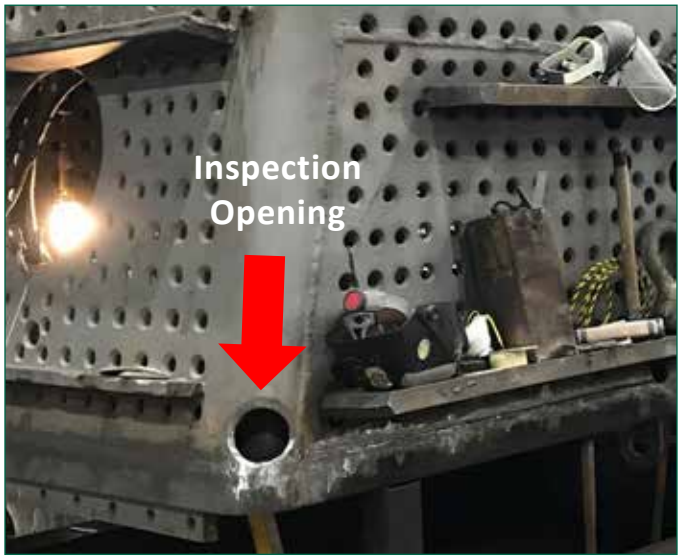
Shell Course, Dome, and Dome Lid

Moving to the boiler shell course and dome, the inspector should concentrate on grooving or cuts, cracks, pitting, dents or other mechanical damage, leakage, separation of plates, and stretched, bent, or corroded dome studs. As construction allows, the internal surfaces should be inspected using inspection tools, such as mirrors and flashlights. The dome and shell course joint fasteners should be examined carefully to ensure the connection is still sound.

Firebox Sheets and Mudring

The firebox sheets, crown, door, rear tube, throat, and sides are subject to elevated temperatures. On the waterside, scale can form due to water conditions.

As the thickness of the scale increases, so does the operating temperature of the sheets, which, if permitted to get too high, will allow the sheets to bulge and possibly fail. Additionally, the sheets share the same damage mechanisms as the shell course and rivets, i.e., cracks, pitting, corrosion, and grooving. The mudring area is typically where grooving on the sheets can occur, especially in the corners of the firebox. Access to the mudring is facilitated by use of inspection openings. Flue sheets are prone to bulging and cracking. A close inspection of the joint between the front flue sheet and shell shall be made.



When bulging is present, the maximum depth shall not exceed the firebox sheet thickness. Depth is defined as the protrusion of the sheet beyond its original position. Plate thickness must be verified in bulged areas and shall be replaced if it's less than required thickness. Staybolt engagement also shall be verified. If the bulged sheet is not replaced, that section and adjacent plate sections shall be inspected for cracking and thinning by NDE to verify suitability for safe operation.

Stays, Staybolts, and Braces

Stays, staybolts, and braces are frequent in locomotive steam boiler construction.

Staybolts are found in the firebox where they support the wrapper and firebox sheets in the waterleg area. Radial stays are around the firebox above the waterlegs and below the main arc of the crown sheet. Crown stays support the crown sheet of the firebox. Radial stays can be particularly susceptible to breaking due to bending since they usually penetrate the roof sheet at angles considerably below 90 degrees. Often, radial stays are of the flexible style.

Stays may be welded through the sheet thickness, fillet welded, or threaded. All three attachment methods have advantages and disadvantages and require different methods of inspection. All three styles should have telltales on locomotive boilers. It's important that telltales be clear before conducting a hydrostatic test and while the locomotive is in service.

Stays welded through the entire sheet thickness were not required to have telltale holes until the advent of Part PL of ASME Section I, so it's possible to find locomotive boilers without telltale holes. About the only way they can be inspected is by using the hammer test.

Fillet welded stays depend entirely on the weld on the outside the sheets. It's important to ascertain that the section of the fillet weld is not less than required for the load. Visual inspection for corrosion and erosion is the first step. If evidence of these conditions exist, further examination may be required.

Braces typically are found on the backhead above the crown sheet, the front flue sheet above the flues, and on the rear flue sheet between the throat staybolts and flues. These are attached by many different means, all of which must be inspected visually during an internal inspection.

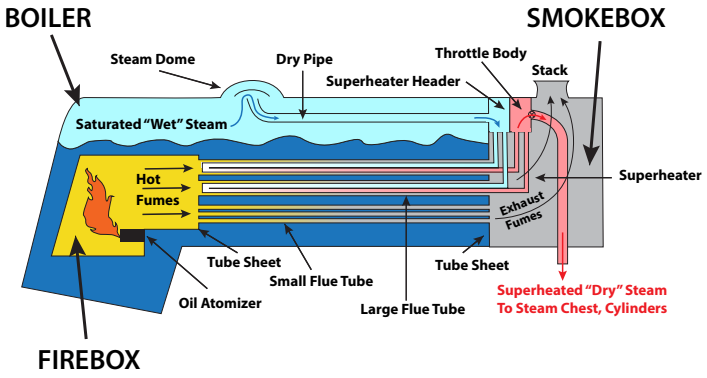
Flues

On saturated or "wet" locomotives, there's typically only one size of flue which usually is in the range of 1.5 to 2.5 inches, with 2 inches being the most common. Superheated locomotives have two sizes of flues. The larger flues, or superheater flues, contain the superheater units. Both large and small flues, or boiler flues, carry the products of combustion from the firebox to the smokebox where they exit the boiler. All flues shall be inspected for fire cracks, pitting, corrosion, erosion especially at the flue sheet, obstruction, waterside fouling, and leakage. The flue sheet connections shall be inspected for correct application, including expanding/rolling and belling, beading, or seal welding of the flue end. Repaired flues by welding or re-ending shall be numbered and

compared to the previous inspection. Use of copper ferrules may result in galvanic corrosion.

Dry Pipe, Superheater Unit, and Header

The superheater unit and header design are unique to locomotives. It's different in design than a power watertube boiler, but it serves the same purpose to add latent heat to the saturated steam for use in the engine cylinders as "dry steam."



Typical General Arrangement Pacific Railroad Preservation Association

Damage mechanisms specific to this component are missing shields; missing or broken bands or supports on the superheater unit; and missing, damaged, or welded attachment bolts, nuts, clamps, studs, and washers, and inadequate structural bracing and support of the superheater header. The dry pipe leading to the superheater header also shall be inspected for all the above including leaks. This is key because a steam leak into the dry pipe of a dome mounted throttle valve will send an unregulated flow of steam to the cylinders.

Throttle Valve

The throttle valve and associated mechanism shall be inspected for ease of operation; loose, bent, or damaged fasteners; and adequate structural bracing, support, and attachment to the boiler, dome, and firebox. The throttle valve shall be equipped with a latching mechanism to prevent inadvertent opening by steam pressure.

Washout Plugs and Inspection Openings

Screw-type washout plugs and inspection openings and components are prone to corrosion. Routine maintenance and inspection of these components should minimize damage, corrosion, cracks, and looseness to the plug threads, holes, and sleeves. Sealing and seating areas should be inspected for evidence of leakage, steam cuts, and distortion. A "blue check" of the handhole door and seating surface is a good method to determine an adequate leak-free seal. The material of the handhole door components and gaskets shall be suitable for the pressure and temperature rating of the boiler.

Huron style washout plugs have large square threads and a separate seat for sealing. This type of plug should have the threads inspected for cracking at the root of the thread. This can occur due to repeated over-tightening of the plug.

Fusible Plugs, Water Glass, Water Column, and Gage Cocks

Fusible plugs shall be inspected for the same damage mechanisms and tampering, height of the plug above the waterside of the crown sheet, evidence of melting or overheating, and proper marking. The water column, components, and connections and piping shall be inspected for scaling/blockage, damage, proper material and size, and proper installation.

Steam Pressure Gage, Fittings, and Piping

The pressure gage must be calibrated to ensure safe operation of the boiler, and the range must be adequate for the operating pressure. The piping, siphon, and shutoff valve shall be free of kinks, restriction, and the material must be adequate for use. The assembly shall be properly installed and supported to prevent vibration.

Firebox Refractory, Fire Door, Attachments, and Brackets

The firebox refractory shall be inspected for proper application and integrity. The fire door and its operating/locking mechanism shall be free of cracks and damage. The locking mechanism shall be verified it will prevent the door from opening if the firebox becomes pressurized by applying pressure from inside the firebox. Fasteners, pins, and attachments should operate as designed and without obstruction.

Smokebox and Smokebox Steam Pipes

The smokebox area is at the opposite end of the firebox and is an important part of the boiler. This is where the products of combustion are removed from the boiler. The smokebox is subject to erosion, corrosion, pitting, and leakage. The braces and fasteners shall securely support the smokebox steam pipes and skirts.

Steam locomotives are not as commonly used as in the 19th and 20th centuries, but they remain in operation. Construction, inspection, and repair standards – if properly followed – make for safer operation. Not all the steam locomotive components are described here, but they are described in the NBIC Part 2 and other standards.