AFTER MORE THAN 60 YEARS, STEAM LOCOMOTIVE BOILERS GET A PLACE OF THEIR OWN IN THE ASME CODE.

Powering the Cylinders

Bill Habjan, a volunteer at the Oregon Rail Heritage Center, works in a locomotive’s steam dome among the auxiliary dry pipes and main dry pipe. This is where steam passes from the boiler to the cylinders.

Photo: Bruce Miller, Cooper Mountain Photography
Steam locomotive boilers have not been built in the United States since 1952. Well, not exactly. They have not been built in the same numbers and sizes, but they have been built.

When the 1952 edition of the ASME Locomotive Boiler Code—Section III of the Boiler and Pressure Vessel Code—was issued, it was the last formal Code acknowledgement of steam locomotive construction. The “L” stamp was retired, and eventually the nuclear folks absconded with Section III.

It was felt by all that any steam locomotive boilers could be built in accordance with the current Section I, Rules for Construction of Power Boilers, and that is where matters have stood until 2015. This July, Part PL, Requirements for Locomotive Boilers, made its debut in the latest edition of BPVC Section I.

As the decades passed since the demise of the original Section III, many boilers have been built and put on steam locomotives. These were mostly smaller affairs that would never see many of the service demands that their ancestors did in the heyday of steam railroading.

Once in a while a boiler did find its way into “normal” railroad service and some did not fare very well.

By Linn W. Moedinger
Additionally during this period, the Code rules advanced to provide sound guidance for the construction of higher and higher pressure boilers that utilized an ever-increasing number of advanced materials.

Design margins came down as it became impractical to keep boilers in service for the historically common longer periods simply because technology was advancing quickly enough to make a perfectly sound boiler obsolete long before it was worn out.

This is where we begin to see the need for steam locomotive boiler construction rules. In the railroad heritage industry, people expect a new boiler to last as long as their old one did—one hundred years not being uncommon—and they expect to be able to use it just as hard as it was originally designed to be used. It will not become obsolete other than by its own accord.

Prior to 1950, boilers for steam locomotives were built in the United States using primarily lower carbon steel products. Riveting was the joinery of the day with some minor experimentation with arc welding. Staybolts were made from wrought iron or very ductile steel and they were invariably threaded through the sheets.

Flanging was required to form the various shapes necessary for the riveted lap seams used in circumferential seams and firebox seams. Plate strength commonly ranged from 55 ksi to 65 ksi and flanging was done both hot and cold. Rivet seams needed to be caulked after riveting and hard sheets were not amenable to that process.

One of the curious things about locomotive boilers is that they work at all, especially the bigger ones. If you think about it, attaching a steel box rigidly to a steel box with steel or iron rods doesn’t seem like such a great idea considering the mean

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**Friends of SP449**

The Southern Pacific 4449 locomotive is maintained by volunteers at the Oregon Rail Heritage Center. Gary Oslund has been primary welder since the 1980s.

Photo: Bruce Miller, Cooper Mountain Photography
Steam on the Rails
A view of the throat sheet and lower outside portion of the combustion chamber (right) shows staybolt sleeves and caps. Crown sheet and roof sheet (below) are supported by an array of crown stays. OR&N 197 undergoes restoration work at the Oregon Rail Heritage Center in Portland (bottom).
Photos: Bruce Miller, Cooper Mountain Photography

As the ‘normal’ boiler world embraced welding, steam engines came along for the ride.

more than 30 old-time railroads across Canada. The steam-powered railroads range from former logging and mining lines to short lines and newly constructed tracks for historic equipment. Some operate in public parks; others are privately run non-profit systems staffed by dedicated volunteers, and many, including the Ghost Town and Calico Railway at Knott’s Berry Farm in California, are commercial tourist attractions.
Heritage railroads operate in dozens of countries around the world on all six habitable continents. They include electric railways, trams, trolleys, and funiculars. But the majority of the world’s heritage railroads are devoted largely or entirely to the age of steam.
We couldn’t find a heritage railroad in Antarctica. The closest one we could identify was the End of the World Train in Tierra del Fuego.
Something needs to give and that something is the staybolt.

temperature of the inner box will be 300 degrees hotter than the outside box and that both boxes are subject to wide thermal swings that can sometimes be rather abrupt.

Obviously, something needs to give and that something is the staybolt. It bends. Often. Eventually, it breaks and you replace it. In the early days, wrought iron was used for staybolts exclusively and this stuff was very flexible. Later on, ductile steels were used instead of iron.

Larger locomotives made it evident that even the most flexible material would not hold up in the extreme distances from the mud ring, and the flexible staybolt was developed to help cut down on breakage. Staybolts were threaded into the sheets, bucked and hammered to expand into the threads to make a steam-tight joint. If the staybolt material was harder than the sheet material, the metal in the sheet deformed and the harder staybolt had a tendency to oval the hole in the plate during service as it tried to bend.

Welding was just beginning to be discussed in railroad circles as diesels came into favor. The subject of the staybolt became irrelevant and was dropped.

As the “normal” boiler world embraced welding, steam locomotives kind of came along for the ride and took advantage of the easier construction methods that welding afforded. Usually these methods worked before higher strength materials became the norm. Probably the first problems arose in the repair field as riveted plates were replaced with much harder material that did not lend itself to riveting.

Welded staybolts mitigated the hardness differential between stay and sheet material, but the change also deleted the requirement for a key feature that monitors the staybolt.

That change was a very bad idea for steam locomotive boilers simply because the feature, known as a telltale, is the best indicator...
of when the staybolt breaks.

A telltale is a 3/16-inch diameter hole on the longitudinal axis of the staybolt. This hole can be drilled from each end a distance of no less than one-half inch beyond the water side of the sheet so as to include the highest stress area of the staybolt. Hollow staybolts have the hole all the way through, which is preferable.

When a staybolt cracks, it typically cracks on one side only. Once this crack reaches the telltale hole, leakage will be observed and the staybolt can be replaced before it breaks completely off and throws all the pressure load on adjacent staybolts.

Square corners in fireboxes are easy to make but they impede circulation and often lead to a staybolt pitch problem on the wrapper sheets in the front and rear. This led to much thicker sheets being used than would otherwise be necessary which could increase the weight beyond the limits of the frame. It became quite common for firebox sheets to be the same thickness as wrapper sheets in order to minimize the number of stays used. Staybolt
Steam locomotives operate in densely populated environments. Millions of people stand next to these things.

Interior Repairs • Restorers work on a superheater header. The viewer is looking from the front of the smokebox toward the front flue sheet.

Photo: Bruce Miller, Cooper Mountain Photography

Diameters grew to accommodate the larger pitch. All this led to far less flexibility in the firebox and much poorer heat transfer through the thicker sheets.

A key element that disappeared with the 1952 Code was the 7,500 psi stress limit on staybolts. This limit served the railroad industry well and was an acknowledgement that the stays did indeed bend and that minimizing the tensile stress tended to lengthen the staybolt’s service life, especially when a stay broke between inspections and the stress was thrown on the adjacent staybolts.

On the flip side, some advances in materials were not accommodated by the successive Boiler Codes. A great example is the roof sheet calculation that began life predicated on a safety factor, or design margin. At some point the design margin became fixed at 5 and eventually was dropped altogether and the number 11,000 was substituted based on the assumption of 55 ksi steel and a design margin of 5. This was changed in Section I subsequent to a Code change request early in this century.

Other changes were made in Section I to the point that it appeared steam locomotive boilers needed their own home again.

Some have questioned why a modern code should address this arcane technology. The simple reason is that steam locomotives operate in densely populated environments where the need to ensure safe boilers is paramount. Millions of people ride behind and stand next to these things every year.
Heritage railroads operate across the United States. Here is a brief look at four out of the many that offer excursions.

1. **Strasburg Rail Road** (www.strasburgrailroad.com) is a short-line railroad established in central Pennsylvania in 1832. In the 1950s, the railroad was rescued by a group of investors. The heritage railroad today runs five steam engines and one diesel over 4.5 miles of track between Strasburg and an Amtrak station in Paradise, Pa. Strasburg Rail Road also hauls freight for local customers, often using its steam locomotives. The group offers its restoration services to other organizations.

2. **Cass Scenic Railroad State Park** (www.cassrailroad.com) in West Virginia runs Shay steam locomotives on a rail line built in 1901 to bring timber from the mountains to the town of Cass. Many passenger coaches are remodeled flat cars that were used to haul logs. The line rises 4,800 feet to Bald Knob, third-highest peak in West Virginia. The train travels on a switchback and at times climbs a grade of 11 percent. The 22-mile round-trip to Bald Knob takes about 4 ½ hours. Exhibits at a museum along the way include a Lidgerwood tower skidder, which was mounted on railcars to carry logs out of the woods on aerial cables for distances up to 3,000 feet.

3. **The Oregon Rail Heritage Center** (www.orhf.org/oregon-rail-heritage-center/) is a museum established to house three historic steam locomotives that had been donated to the city of Portland. It took thousands of volunteer hours over three decades to get two of the engines operational. A third locomotive, the Oregon Railway & Navigation 197, is still being restored. The tracks at the heritage center connect to the Union Pacific Railroad’s north–south main line to enable excursion trips. The center also houses other engines and freight cars.

4. **The Illinois Railway Museum** (www.irm.org) in Union, northwest of Chicago, claims to be the largest railroad museum in the country. In addition to electric and diesel equipment, the museum has 25 steam locomotives, two of which are operational. The facility includes ten equipment storage barns with a total of about two miles of track under cover, five miles of track for excursions, and a depot that dates to 1853.

Secondly, real working knowledge of what these boilers see when in service and how their various structures work together while bouncing down the track is not too prevalent. Since the late 1950s there has been a growing knowledge base about locomotive boilers, but it has been pretty much outside the mainstream boiler industry. It had become such that it was quite possible, if not probable, that a perfectly reputable “normal” boiler shop could legitimately build an unsatisfactory steam locomotive boiler in accordance with the Code and with all good intentions.

When the ASME formed the Subgroup for Steam Locomotives, the intent was to get this special information in print. The subgroup has taken the approach of codifying both best practices and Code material from steam days. Additionally, we have attempted to meld modern technology into the process where that technology has been tested and proven.

While this may seem to be a once and done process, it is far from that. People worldwide are tinkering with, building, and operating steam locomotives. Many countries advanced the technology beyond what the United States did because they waited much longer to dieselize. The new locomotive code, Part PL in Section I can truly be looked at as a beginning. New materials and methods will now have a place to be vetted within the unique perspective of steam locomotive operation so as to ensure safe steam locomotive boilers for centuries to come.

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