Memorandum

U.S. Department
of Transportation

Federal Railroad Administration

Date: June 15, 1998 Reply to Att. of: MP&E 98-12

Subject: Hydrostatic Testing of Steam Locomotive Boilers

From: Edward R. English
Director, Office of Safety Assurance and Compliance

To: Regional Administrators, Deputy Regional Administrators,
Motive Power & Equipment Specialists and Inspectors

Section 230.17 of 49 CFR requires "Every boiler, before being put into service and at least once every 12 months thereafter, shall be subjected to hydrostatic pressure 25% above the working steam pressure. Section 230.18 of 49 CFR states, "The dome cap and throttle standpipe must be removed at the time of making the hydrostatic test and the interior surface and connections of the boiler examined as thoroughly as conditions permit." In case, the boiler can be entered and thoroughly inspected without removing the throttle standpipe, the inspector may make the inspection by removing the dome cap only, but the variation from the rule must be noted on the margin of the report. "Boiler entered through auxiliary dome" or "throttle standpipe not removed." If the boiler cannot be entered because of its construction, it should be so stated. "Not entered because..."

Section 230.19 of 49 CFR states, "When the test is being made by the railroad company's inspector, an authorized representative of the company, thoroughly familiar with boiler construction, must personally witness the test and thoroughly examine the boiler while under hydrostatic pressure." Section 230.20 of 49 CFR requires, "When all necessary repairs have been completed, the boiler shall be fired up and the steam pressure raised to not less than the allowed working pressure, and the boiler and appurtenances carefully examined." All cocks, valves, seams, bolts and rivets must be tight under this pressure and all defects disclosed must be repaired.

Hydrostatic testing is a process whereby a fluid, usually water, is forced into the boiler to determine the constructive soundness of the complete boiler structure to withstand such test pressure. This test can only be performed properly when all air has been purged from the boiler being tested. After all air has been purged from the boiler, the pressure should be slowly increased by use of a suitable water pump or other device that will not introduce air into the boiler during testing. Air in the boiler under test will defeat the principle of hydrostatic testing. Pressures exerted in this manner subjects all internal surfaces and parts of the boiler structure to equal pressure. Also of very significant importance is the matter of safety. Water is practically incompressible and can store extremely little energy. The energy force exerted is furnished by the pump. On the other hand, if air is trapped in the boiler being tested, it will be compressed to the test pressure attained and build up an energy source that can be extremely dangerous and damaging to the boiler being tested should a failure occur. In the event of a structural failure, the trapped air pressure will continue to expend its built-up energy until exhausted. With a true hydrostatic pressure, stopping the pump ends the pressure source.

In almost all boilers of horizontal fire tube type, the highest part of the boiler will be the dome. During the filling of the boiler, preparatory to hydrostatic testing, air should be vented from as near the top of the dome as possible as pressure can be applied more quickly and easily when there is no air present.

The safety valves are either removed and plugs inserted in their places or else they are closed and clamped. An accurate test gauge is applied to the boiler and the pressure must be watched closely to see that the prescribed testing pressure is not exceeded, as it is very easy to strain, unduly, some part of the boiler. Cold water is not satisfactory for testing, because the boiler plates are cold and contracted to a minimum and leaks could appear. A boiler that is in good condition and tight under steam will usually show numerous leaks when full of cold water under pressure, so that the use of cold water makes the test unnecessarily severe.

After all defects, such as leaky seams and broken staybolts and crown stays have been taken care of, the boiler is fired up and the pressure raised to not less than working pressure so as to determine the permanency of the repair made.

Broken staybolts are more easily detected by hammer testing when the boiler is under a hydraulic test pressure, than when it is not. The reason is that the broken ends may be separated slightly. Whereas, when the boiler is not under pressure the broken ends may be in contact, thus giving a sound like a good staybolt.

Attached is further information concerning problems associated with trapped air in boilers during hydrostatic testing.

WHERE AIR CAN BE TRAPPED

1. If not properly vented or purged during filling of the boiler as described above, air can also be trapped in the superheater system if the locomotive is so equipped, or in the piston valves and cylinders and related piping, if included in the hydrostatic test.

2. If the locomotive is provided with a throttle valve located in the dome and type “A” superheating, and the throttle valve is opened to permit testing of the superheating system during the hydrostatic test, additional air venting procedures will have to be made in order to obtain a true hydrostatic or hydraulic block of water during the test.

3. If the locomotive is provided with a throttle valve located in the outlet side of the superheater header, special precautions are very necessary in order to prevent the trapping of air in the superheater system. Unless it can be known without a doubt that all air has been purged from this system, a true hydrostatic head will not be attainable.

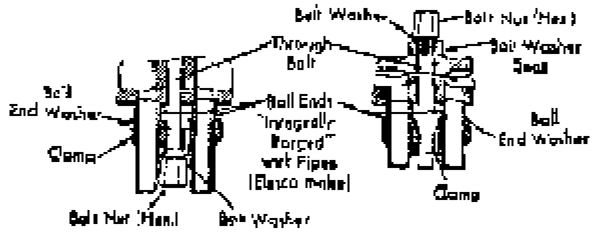
It is therefore recommended that a suitable blanking plate and gasket be applied to the entrance to the dry-pipe prior to hydrostatic testing of boilers and vent the boiler, as previously described, from the highest point of the boiler.

As a matter of information to make you aware of hazard of trapped air, the following example is provided, covering a locomotive having a multiple type throttle that is integral with the superheater header:

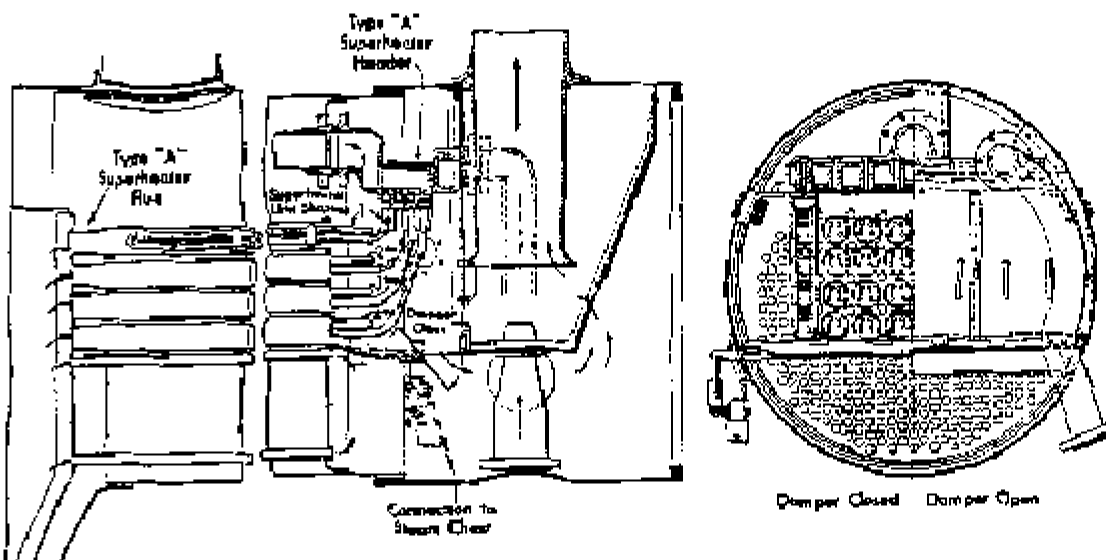
A locomotive having 1,946 square feet of type E superheating surfaces and having superheater units within 202 superheater flues, or 404 unit tubes, will require approximately 34.15 cubic feet, within the system. This is equivalent to two cylindrical reservoirs 21 inches inside diameter and 85 inches in length, a comparable 34.06 cubic feet. The working pressure in this example locomotive is 245 psi working pressure, requiring a hydrostatic test pressure of 25% above working pressure, or 306.25 psi.

Whether type “A” or “E” systems are provided, during filling of the boiler water enters the dry pipe near the top of the dome, as possible, then passes into the unit pipes located below and at right angle to the filling water level, and then forces the air from each unit. Type “A” units consist of four pipes, and three return ends. In the type “E” system, a unit may consist of four pipes and three return ends entering two flues, or as many as eight pipes and three return ends entering two flues, or as many as eight pipes and six return ends entering four flues comprising a very complex system of pipes and turns. This is compounded when the type “A” or “E” systems utilize the multiple valve throttle and all air must be purged from the systems through the throttle if it is opened. If the throttle is not opened, all air within the unit system will be compressed by the incoming water and leaks will probably appear.

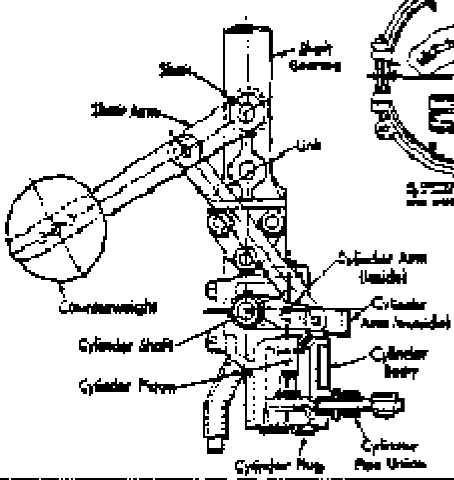
It is important to know the safe condition of all parts of the locomotive, but other appurtenances should not interfere with a proper hydrostatic test of the boiler. 49 CFR Section 23.17 addresses testing of the “... boiler”. Attached is a composite diagram that will aid in understanding the superheating systems of the more popular types.



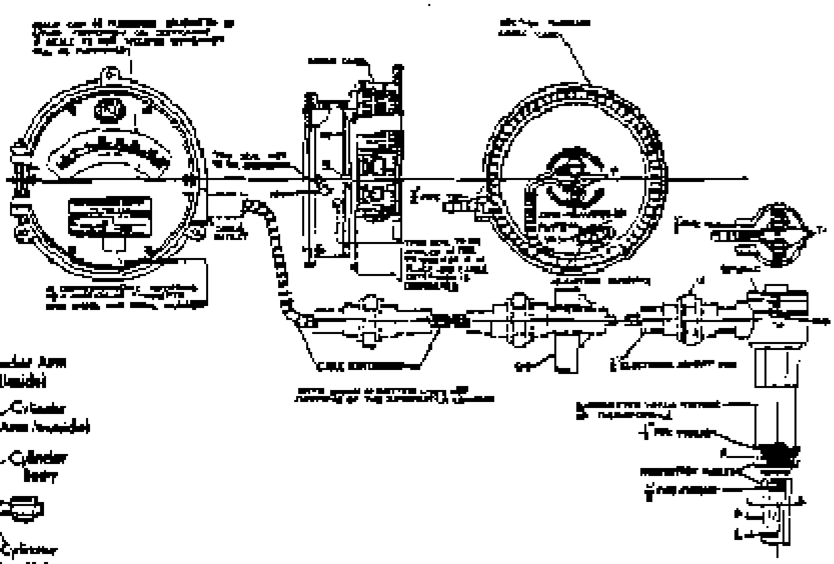
Detail of Superheater Unit Joint. Left—With nut at bottom of bolt. Right—With nut at top of bolt.



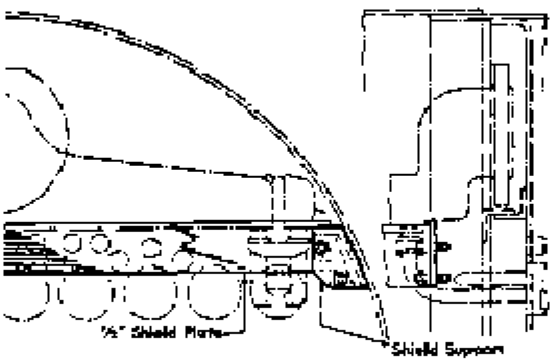
Arrangement of Elesco Type A Superheater with Dome Throttle.



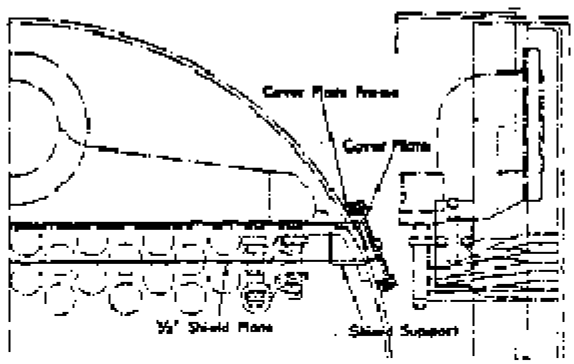
Superheater Damper Cylinder—Closed position. Used with dome throttles.



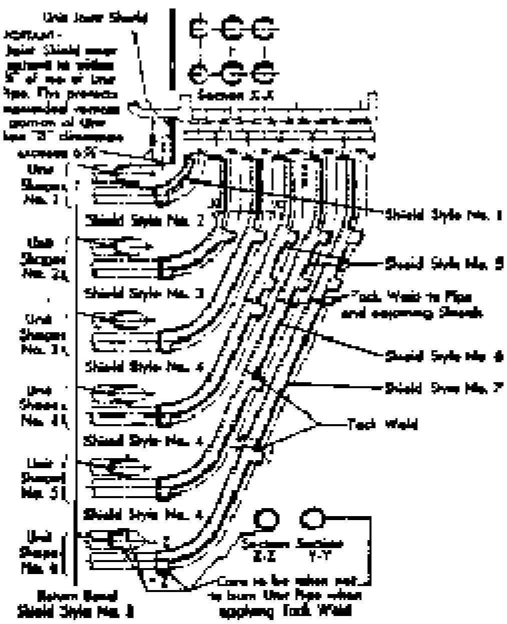
Elesco Model 495 Electric Pyrometer for showing temperature of superheated steam. Includes a thermo-couple in one of the steam pipes, a cable connection and an indicating gage in the cab.



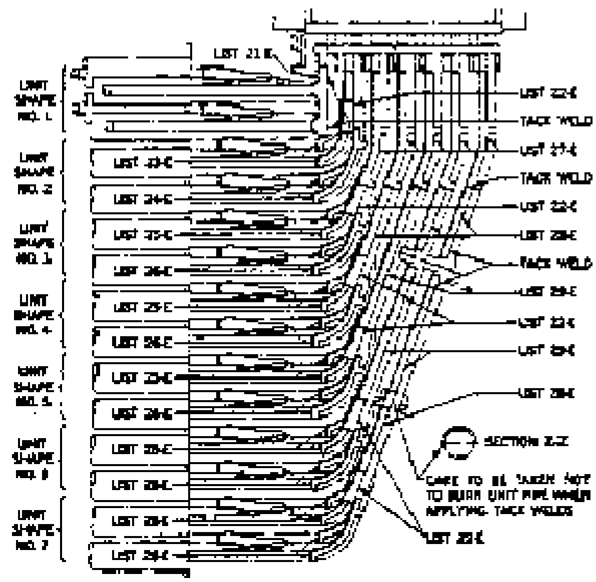
Shield for protecting Type A Unit Joints.



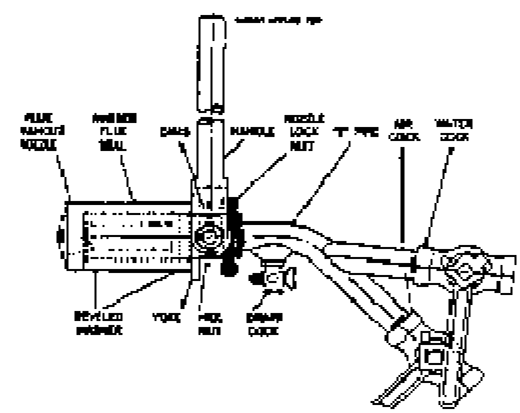
Shield for protecting Type E Unit Joints.



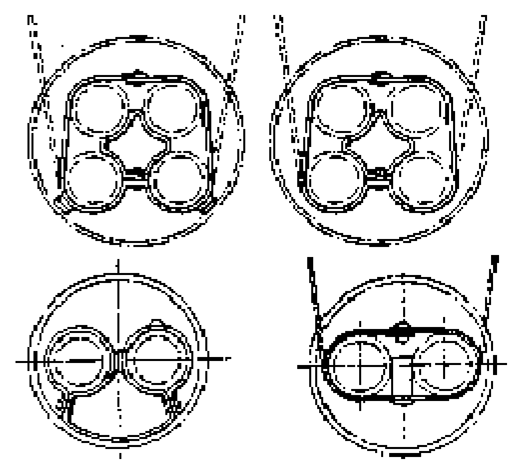
Shields for protecting Type A Units from action of cinders.



Shields for protecting Type E Units from action of cinders.



Elesco Flue Washout Nozzle.

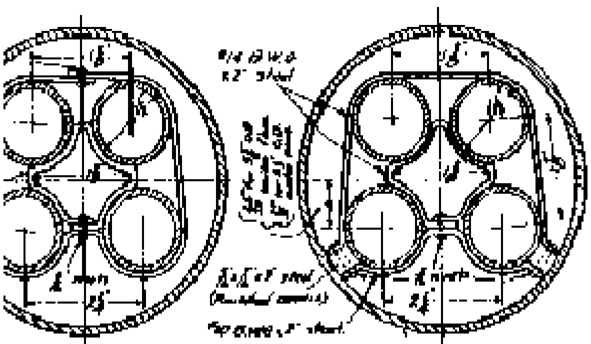


Supports and Bands Type A above, Type E below.

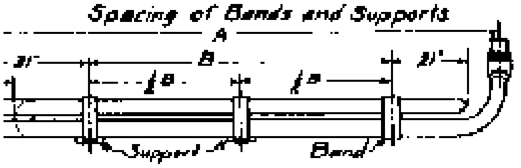
SCHMIDT SUPERHEATERS

Unit Bands and Supports

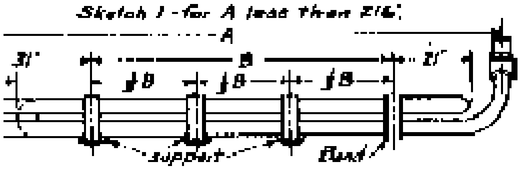
TYPE 'A' SUPERHEATER



Spacing of Bands and Supports



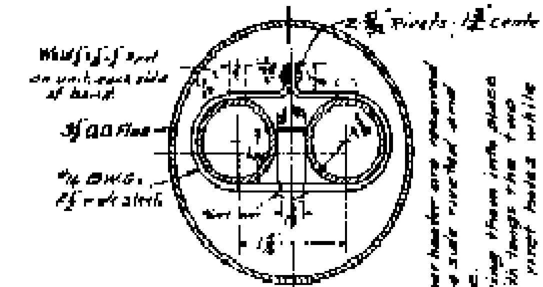
Sketch 1 - for A less than 216".

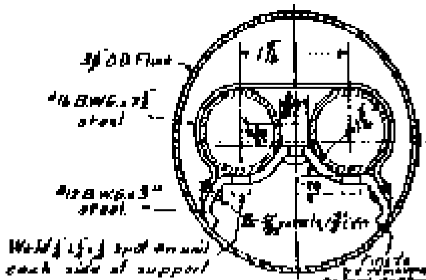


Sketch 2 - For A 216" or over.

...plication of bands and supports to Type A ...rheater units is shown by page 121 J.

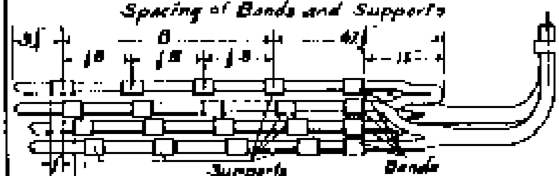
TYPE 'E' SUPERHEATER





Unit supports for Type E superheater are obtained from The Superheater Co. with one side riveted and formed to approximately shape.
To apply unit supports spring them into place over the two pipes and grip with tongs the two protruding ends between the rivet holes while

Spacing of Bands and Supports



Double Unit Assembly

Single Unit Assembly

Superheaters

STEAM GENERATED IN A BOILER at a given pressure is known as saturated steam and has a definite temperature which rises as the pressure increases. If the law of associated pressures and temperatures is carried to an extreme point, and the pressure is increased, say, to 1300 lb. per sq. in., the steam would have a temperature of about 640 deg. F. and its working efficiency would be correspondingly raised. If, however, with common locomotive boiler pressures—up to 300 lb. per sq. in.—the temperature is raised to a higher level, as for instance to 640 deg. F. without an increase in pressure, it follows that its working efficiency becomes in some measure comparable to that of saturated steam at the high pressure mentioned.

If heat is added to steam after it has left the boiler and when it is no longer in direct contact with the water from which it was generated, its temperature is raised considerably above the temperature that corresponds to its pressure; all particles of water are then converted into steam, and the volume of steam is increased. Superheated steam, therefore, can be defined simply as steam having a higher temperature than that corresponding to its pressure. The temperature difference between superheated steam and saturated steam at the same pressure is known as the degree of superheat.

The properties of superheated steam make it more effective and more economical than saturated steam for use in locomotives. In the first place, superheated steam prevents condensation losses. Under ordinary conditions the steam generated in a boiler contains considerable moisture or particles of water, the presence of which is largely responsible for the readiness with which some of the steam condenses, either when it comes into contact with the relatively cold walls of the cylinders or when it expands and does its work. The condensation losses with saturated steam are considerable.

Superheated steam has greater volume per unit of weight than saturated steam. When superheated to a high degree it does more work during admission and expansion on a smaller consumption by weight per stroke. Experience shows that it is only with a high degree of superheat—as is customary in American practice—that the full benefits of superheating can be realized. Only with high superheat is there more efficient expansion, volumetric increase and minimum cooling of the steam by the cylinder walls during the working stroke, which together enables the steam to be utilized in the most satisfactory manner.

The use of high degree superheat as developed by the modern superheater today produces marked economies in fuel and in water for the same output of power, or with the same fuel and water consumption, effects a considerable increase in boiler horsepower.

Type A Superheaters
(Large Tube Design)

Locomotive superheaters are of the fire-tube type with a top header and system of units extending back into the flues where the steam passing through the units is subjected to intense heat from the fire gases. Most superheater headers are now furnished in combination with a front end throttle. In locomotives equipped with type A superheaters some of the upper rows of flues in the boiler are of larger size than usual so as to accommodate the superheater units which consist of four lengths of tubing joined into single units by machine-forged return bends, thus providing for four passes of steam in each flue.

Type E Superheaters
(Small Tube Design)

The units for type E superheaters may occupy all flues in the boiler and provide for two passes of steam in each flue. The header in the smokebox receives the steam from the boiler at the saturated steam compartment—and the steam then passes through the superheater units, making two or four passes as the case may be, and then is delivered to the other section of the header or superheated steam compartment, from where it passes through the multiple valve throttle to the cylinders. This design of superheater unit provides more superheating surface and a better balanced boiler.

Throttle Valves

Formerly the throttle valve was located in the dome and the superheater header was connected to the throttle by a dry pipe. By this arrangement there was no steam in the superheater units when the throttle valve was closed and a superheater damper was required. In modern locomotives a front-end throttle valve is used, this being located between the superheater header and the steam pipes leading to the cylinders. This arrangement permits the use of superheated steam for the auxiliaries. As steam is always in the units the damper is omitted.

All locomotive superheaters are along the lines of a common standard except for variation of length over tube sheets, diameter of tubing and arrangement of superheating surface. In operation they furnish steam with from 200 to 250 deg. F. of superheat; superheated steam temperatures with ordinary pressures, are from 650 to 750 deg. F.

Installation, Care and Maintenance of Superheater Equipment for Locomotives

A. A. R. Recommended Practice [illegible], 1930
([illegible])

Steam Driers and Purifiers

Steam separators, also known as driers or purifiers, are now applied on many modern locomotive boilers. They are located in the dome on the inlet end of the dry pipe when front-end throttles are used.