

# PLS Boiler Inspection Standard

## Introduction

Boilers are complex devices that, in operation, contain large quantities of energy. Sudden release of this energy can cause property damage and serious injury. In the early days of steam railroading and steam navigation, such accidents caused many injuries and death of operators and passengers and great property damage. As a result, the design, fabrication, maintenance, and use of boilers were subjected to legal regulation. Boiler failure is now very rare.

Design and fabrication of power boilers is an engineering and manufacturing specialty field requiring knowledge of stress analysis, metallurgy, corrosion chemistry, welding technology and non-destructive testing technology as well as many, many others. Even professional practitioners are subject to many regulations and tests in order to practice their trade.

Model boilers are, at this time, less subject to regulation due *only* to the smaller volumes and generally lower pressures that result in lesser amounts of stored energy. In some states, model boilers are currently subject to state regulation and testing. The PLS regulations and required data and calculations address only some of the many factors affecting boiler safety. Adherence to PLS rules does *not* guarantee that a boiler is correct in every respect.

All Live Steamers should make every effort to educate themselves regarding these matters before purchasing, operating, maintaining and, especially, designing and building boilers. Some good resources for information are more experienced builders, the hobby press, the ASME and many hobby books on boiler construction.

## PLS Boiler Inspection Standard

### PLS Annual Boiler Inspection Procedure

1. Boilers will be categorized by operating pressure and gross internal volume. **Category A** boilers are those with a gross internal volume of 120 cubic inches or less and an operating pressure of 100 psig or less. Boilers with a gross internal volume of 50 cubic inches or less and with an operating pressure of 60 psig or less and which a recognized commercial manufacturer has manufactured are exempt from classification. The owner shall not modify such exempted boilers. **Category B** boilers are those with a gross internal volume of 120 cubic inches or less and an operating pressure greater than 101 psig and less than 125 psig. **Category C** boilers are those with a gross internal volume in the range of 121 to 8,000 cubic inches or less and an operating pressure of 125 psig or less.
2. PLS Approved Witnesses will be responsible for witnessing required inspections & tests, will conduct and report on all incident investigations, and will be responsible for collecting and filing all related records. The owner of the boiler will be responsible for conducting the tests.
3. PLS will not approve design or construction of boilers. PLS will issue cautions and advisories only, to assist members in building safe and efficient boilers. Cautions are safety related and must be followed; advisories are related to ease of construction, cost, etc. and are optional. The builder and owner are, finally, responsible for the safety of the boiler.
4. PLS shall not issue a Boiler Certificate for boilers that have been built in contravention of PLS cautions. PLS may forbid the operation of a boiler.
5. Boiler Data Sheets must be filed for all boilers granted certificates. Data sheets for boilers constructed before January 1, 2004 may be partially completed if all dimensions cannot be determined, as may data sheets for commercially produced boilers by recognized manufacturers. Any substantial repair or modification that alters the information on the design data record will require a new design data record to be filed.
6. Boiler Design Calculation Sheets must be completed for all boilers in Categories B or C before certificates will be issued. Category A boilers are exempt from this requirement. PLS will not issue certificates for boilers larger in volume than 8,000 cubic inches or with operating pressure higher than 125 psig.
7. To issue a certificate, PLS will witness on PLS property a hydrostatic and fired test as specified below and will visually inspect the boiler to determine that all required accessories are installed and functional.
8. Required hydrostatic test to issue a certificate for new boilers will be to twice the operating pressure. For the annual test of a previously certified boiler the hydrostatic test will be to 1.5 times the operating pressure. PLS will inquire of the owner as to whether modifications or repairs have been made since the last test, and record the data on the test record. Extreme modification or repairs to the boiler may require completion of a new Boiler Design Data Record.

9. PLS will check the boiler incident record prior to the test and reference any incidents involving the boiler on the test record. Prior to the test, PLS will check that the boiler has the required equipment installed. Any boilers that qualify for exemption due to age (construction prior to January 1, 2004) will have the actual equipment installed noted on the test report. It is recommended that boilers built prior to January 1, 2004 be brought into compliance as soon as possible.
10. The minimum required equipment shall be: Category A boilers shall be equipped with a relief valve, a water level gauge, a steam pressure gauge and either a water feed pump or injector. Category B boilers shall be equipped with a relief valve, a water level gauge, a steam pressure gauge and either a water feed pump or injector. Category C boilers shall be equipped with two relief valves, a water level gauge equipped for blowdown and a steam pressure gauge, two means of supplying feed water, and a blowdown valve.
11. Hydrostatic Test -The hydrostatic test will be performed as follows:
  - (a) Owner will remove any easily damaged gauges and safety valves and plug the resulting holes. Owner must supply plugs. One port may be used with a shutoff valve for venting air.
  - (b) The service pressure gauge may be removed or may remain in place if the owner chooses and the gauge range is appropriate. The test will be conducted based on the reading of the PLS master gauge. If the gauge remains in place, PLS will check the gauge reading by recording the reading of the service gauge when the PLS master gauge indicates a pressure of 0.5 operating pressure, 1.0 operating pressure and 1.5 operating pressure. If the gauge is removed during the hydrostatic test PLS will compare it separately at .5 and 1.0.
  - (c) The boiler will be filled with water (room temperature preferred) and residual air vented. The test apparatus will be connected to a washout plug opening or other suitable port by means of an adapter supplied by the owner which is provided with an NPT connection (any size male or female NPT from 1/8" to 1/2" inclusive) for the PLS test equipment.
  - (d) The pressure in the boiler will be raised by using either the service manual pump or the PLS test rig pump until the test pressure is reached. The boiler shall exhibit no visible bulging or deformation of any pressure surface, no serious leaks, no unusual sounds and no sudden pressure drops during the test, in the opinion of the person observing the test. Minor leakage from the throttle or fittings that does not adversely affect the operation of the locomotive will not be cause for failure or an incident report. The boiler will be kept at the test pressure by pumping long enough to enable the necessary inspection. This time should not exceed 5 minutes.
12. Fired Test - After the completion of a satisfactory hydrostatic test, the boiler will be restored to operating condition, and the water level will be adjusted to operating level in preparation for a fired test.

13. The fired test will be performed as follows:
  - (a) The PLS approved witness will determine that the boiler pressure gauge has been checked for accuracy either on or off the boiler before proceeding. **The fired test may not be performed with an unchecked gauge.**
  - (b) The owner will fire up the boiler and raise steam.
  - (c) The PLS approved witness will observe the increasing pressure and check for leaks on the hot boiler, determining that any leaks observed are not threatening to the integrity of the boiler.
  - (d) When operating pressure is reached, operation of the safety relief valve(s) will be observed. The valve(s) must open at or below the stated operating pressure except that multiple valves may be set to operate at graduated pressures.
  - (e) The owner will make such adjustments as are necessary to the valve(s) until the operating pressure is correct.
  - (f) When operation at the correct pressure is obtained, a forced firing test will be conducted. Using maximum blower or other appropriate method to reach maximum firing rate the pressure will be raised so that the safety relief valve(s) will open.
  - (g) With the valve(s) open, the firing rate will be maintained to check the capacity of the valves to limit maximum pressure to 6% or less above the operating pressure.
  - (h) If the pressure rise above the operating pressure exceeds 10%, with all safety valves open, the test will be terminated and the fire killed. The boiler will not be retested or fired on PLS property until the relieving capacity is increased. PLS will file a report of this happening in the boiler incident file, as well as reporting the corrective action taken prior to the subsequent retest.
14. Upon successful completion of tests, results will be entered in the boiler test log. Approval will be valid for one year and will expire on the last day of the month in which the hydrostatic test was performed, one year hence. A test certificate will be issued to owner(s) who are PLS members. Non-members will not be issued certificates but will be permitted to operate for the period of the approval.

# PLS Boiler Inspection Standard

## Instructions for completing PLS Boiler Design Data Record

- A. Fill in the owner data at the top. If there is more than one owner, information about the others can be listed on the back of the sheet. The listed owner must be a person. If the owner(s) is (are) not members of PLS, indicate club affiliation, if any.
- B. Fill in the locomotive information for identification purposes. Be specific as to fuel, e.g.; propane - not gas, #2 fuel oil - not oil.
- C. Boiler shell dimensions  $r$ ,  $t$ ,  $T$ ,  $p$ ,  $h$ ,  $v$ ,  $L$ ,  $W$  and  $L_{fb}$  are best taken from the boiler assembly drawings, but can be taken from direct measurements if necessary. Cross sectional area of stay ( $a$ ) must be based on the minimum diameter of the stay, for instance, if the stay is threaded, the thread root diameter must be used. If there is more than one stay size, list data for each size, additional sheets may be attached.
- D. Materials should be identified as specifically as possible, e.g.; A285 grade C. If materials are documented, use type numbers. If they are not, use generic terms.
- E. Estimated gross internal volume represents the internal volume of the pressure shell not reduced by the volume of the flue tubes and may be calculated by the owner. If the owner desires, the volume may be measured by the volume of the water required to fill the boiler for hydrostatic test. The water volume will necessarily deduct the tube volume, which will reduce measured volume to a smaller value than the calculated gross volume. The smaller volume can be used for classification purposes.
- F. The boiler category can be taken from Page 1, Paragraph 1 in the PLS Annual Boiler Inspection Standard.
- G. The questions at the bottom of the form should be self-explanatory.

# PLS Boiler Inspection Standard

## PLS BOILER DESIGN DATA RECORD Required for all boilers to be tested by PLS

Owner's Name \_\_\_\_\_ Date \_\_\_\_\_  
Owner's Address \_\_\_\_\_  
City \_\_\_\_\_ State \_\_\_\_\_  
Zip Code \_\_\_\_\_

Locomotive Number \_\_\_\_\_ Wheel Arrangement \_\_\_\_\_  
Scale \_\_\_\_\_ Fuel \_\_\_\_\_  
Gauge \_\_\_\_\_ Year Completed \_\_\_\_\_

### BOILER INFORMATION

Boiler Shell Material \_\_\_\_\_  
r = Outside Boiler Shell Radius \_\_\_\_\_ inches  
t = Boiler Shell Wall Thickness \_\_\_\_\_ inches  
T = Stayed Surface Thickness \_\_\_\_\_ inches Stayed  
Surface Material \_\_\_\_\_

p = Maximum Stay Pitch \_\_\_\_\_ inches  
a = Cross Sectional Area of Stay \_\_\_\_\_ in<sup>2</sup> =  $\pi d^2/4$ , (d= minimum dia., inches)  
Stay material \_\_\_\_\_ Stay fastening \_\_\_\_\_ (weld, thread, braze, etc.)  
h = Maximum Horizontal Staybolt Spacing \_\_\_\_\_ inches  
v = Maximum Vertical Staybolt Spacing \_\_\_\_\_ inches  
L = length of boiler shell \_\_\_\_\_ inches  
W = width over firebox \_\_\_\_\_ inches  
L<sub>fb</sub> = external length of firebox \_\_\_\_\_ inches  
Estimated gross internal volume \_\_\_\_\_ inches<sup>3</sup>

Boiler Category \_\_\_\_\_ (A through C)  
Boiler Designed by (indicate) Owner \_\_\_\_\_  
Commercial Builder \_\_\_\_\_  
Other \_\_\_\_\_

Boiler Built by (indicate) Owner \_\_\_\_\_  
Commercial Builder \_\_\_\_\_  
Other \_\_\_\_\_

Boiler Design has ( ) , or has not ( ) been reviewed by PLS. If reviewed, when was review conducted? \_\_\_\_\_

Are drawings of the boiler available? (Yes or No) \_\_\_\_\_

Date of beginning of boiler construction \_\_\_\_\_

Date of completion of boiler construction \_\_\_\_\_

Has boiler been PLS tested before? If so, when? \_\_\_\_\_

**Instructions for completing**

**PLS Boiler Design Calculation Record**

- A. Calculate **Maximum Allowable Pressure** for the boiler shell. Variables  $r$  and  $t$  can be taken directly from the Design Data Sheet, and must be the same on both sheets. Constant  $c_1$  will be 1.0 for seamless tubes and 0.7 for tubes having longitudinal seams (seams parallel to the axis of the boiler). For boilers with conical (tapered) sections use the largest radius for the computation. Conical sections nearly always have a longitudinal seam, so use  $c_1 = 0.7$ . Allowable working stresses are shown on the Boiler Design Calculation Record. **Documented** materials are those supplied with chemical and physical properties sheets for the batch of material. These reports will be furnished at extra cost **or** the material may be certified as meeting some relevant ASME standard. All other material is undocumented. Copper means copper. It does not mean brass, bronze, cupro-nickel, or any other tube material. When all of the variable values have been entered on the sheet, perform the indicated multiplication and enter the result.
- B. Calculate **MAP** for stayed surfaces.  
Variables  $T$ ,  $p$  and  $s$  can be taken directly from the Design Data sheet, and must be the same on both sheets. Enter the variables in the blanks together with the proper constant and perform the indicated operations. Enter the result as the stayed surface MAP.
- C. Calculate **MAP** for stays (stay bolts).  
Variable  $h$  and  $v$  can be taken directly from the Design Data sheet. Calculate stay area as shown and enter the area. For threaded stays calculate for the root diameter of the thread. Perform the indicated operations and enter the result.
- D. Determine the overall **Maximum Allowable Working Pressure** which is equal to the smallest of the three MAP's calculated above.
- E. Determine the operating pressure that the owner wishes to specify. This **must not** exceed the **MAWP** or 125 psi, whichever is smaller. If the owner wishes a Class A boiler the operating pressure must be 100 psi or less and the boiler volume must be appropriate.

# PLS Boiler Inspection Standard

## PLS BOILER DESIGN CALCULATION RECORD

Required for all boilers to be tested by PLS

**Maximum Allowable Pressure for Boiler Shell –**

$$P_1 = stc_1/r$$

Where:  $P_1$  = MAP for boiler shell

s = allowable working stress for shell material (lb/in<sup>2</sup>)

t = wall thickness (inches)

$c_1$  = joint efficiency constant (dimensionless)

r = outside shell radius (inches)

$U_t$  = ultimate tensile strength of material used (lb/in<sup>2</sup>)

Allowable working stresses –

Use  $s = 12,500$  lb/in<sup>2</sup> for undocumented steel,  $U_t/4$  for ASME documented steel.

Use the following for copper:

If Operating Pressure =

80 psig (temp. = 324<sup>0</sup> F), then  $s = 4,400$  lb/in<sup>2</sup>

90 psig (temp. = 332<sup>0</sup> F), then  $s = 4,300$  lb/in<sup>2</sup>

100 psig (temp. = 338<sup>0</sup> F), then  $s = 4,200$  lb/in<sup>2</sup>

110 psig (temp. = 344<sup>0</sup> F), then  $s = 4,100$  lb/in<sup>2</sup>

125 psig (temp. = 353<sup>0</sup> F), then  $s = 4,000$  lb/in<sup>2</sup>

Joint efficiency – use 1.0 for seamless tubing, use 0.7 if any longitudinal seam is used.

$$P_1 = [(s \text{ _____}) \times (t \text{ _____}) \times (c_1 \text{ _____})] / (r \text{ _____})$$

$$P_1 = \text{_____ psig}$$

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**Maximum Allowable Pressure for Stayed Surfaces –**

$$P_2 = T^2sc_2/p^2$$

Where:  $P_2$  = MAP for stayed surfaces

T = Stayed Surface Thickness (inches)

s = allowable working stress for stayed surface material

$c_2 = 2.1$  for welded or silver soldered stays

= 2.8 for welded or silver soldered stays with heads

p = Maximum Stay Pitch (inches)

$$P_2 = [(T \text{ _____})^2 \times (s \text{ _____}) \times (c_2 \text{ _____})] / (p \text{ _____})^2$$

$$P_2 = \text{_____ psig}$$



**Maximum Allowable Pressure for Stays (Stay Bolts)**

$$P_3 = as/hv$$

Where:  $P_3$  = MAP for Stays

a = minimum cross-sectional area of stay (inches<sup>2</sup>)

(calculate using root diameter of thread for threaded stay)

s = allowable working stress for stay material (lb/in<sup>2</sup>)

h = maximum horizontal stay spacing (inches)

v = maximum vertical stay spacing (inches)

$$P_3 = [(a \text{ _____}) \times (s \text{ _____})] / [(h \text{ _____}) \times (v \text{ _____})]$$

$$P_3 = \text{_____ psig}$$

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**Maximum Allowable Working Pressure for Boiler**

$$\text{MAWP} = \text{lowest of } P_1, P_2, P_3 = \text{_____ psig}$$

Operating Pressure (not greater than the lesser of MAWP or maximum permitted pressure in PLS Boiler Inspection Standard) = \_\_\_\_\_ psig

# PLS Boiler Inspection Standard

## PLS ANNUAL BOILER INSPECTION & TEST RECORD

Owner's Name \_\_\_\_\_ Date of Inspection \_\_\_\_\_

Owner's Address \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_ Zip Code \_\_\_\_\_

Is owner a member? \_\_\_\_\_

Locomotive Number \_\_\_\_\_ Wheel Arrangement \_\_\_\_\_

Scale \_\_\_\_\_ Fuel \_\_\_\_\_

Boiler Category \_\_\_\_\_ Estimated Boiler Volume \_\_\_\_\_ in<sup>3</sup>

Stated Operating Pressure \_\_\_\_\_ psig

Approved Witness \_\_\_\_\_

Other Observer(s) \_\_\_\_\_

Test Conducted By \_\_\_\_\_ (owner or name)

Installed Equipment (specify quantity of each)

Steam Pressure Gauge ( ), Water Level Gauge ( ), Relief Valve(s) ( ),

Water Feed Pump ( ), Water Injector ( ), Water Glass Blowdown ( ),

Boiler Blowdown Valve ( ), Washout Plugs ( ), Fusible Plug ( )

Is this the first PLS test/inspection? Yes ( ) No ( ) If no, what was date of last inspection? \_\_\_\_\_ psig \_\_\_\_\_ Required test pressure \_\_\_\_\_ psig

Any incident reports since last inspection/test? \_\_\_\_\_

Have any modification been done? Yes ( ) No ( )

Has a new Boiler Design Data Record been filed? Yes ( ) No ( )

When was boiler completed? \_\_\_\_\_

When was boiler last fired? \_\_\_\_\_

Was operating pressure gauge compared to the PLS test gauge during the hydrostatic test? \_\_\_\_\_ Separately? \_\_\_\_\_ Record comparison

readings below:

PLS Test Gauge: ½ op. press. \_\_\_\_\_ @op. press. \_\_\_\_\_ 1 ½ op. press. \_\_\_\_\_

Operating Gauge: ½ op. press. \_\_\_\_\_ @op. press. \_\_\_\_\_ 1 ½ op. press. \_\_\_\_\_

Did boiler pass hydrostatic test? \_\_\_\_\_

Remarks \_\_\_\_\_

Fired test observations (note leaks, other events & observations)

First relief valve operates at \_\_\_\_\_ psig, second valve operates at \_\_\_\_\_ psig.

Maximum pressure on forced firing test \_\_\_\_\_ psig

Did boiler pass firing test? \_\_\_\_\_

Remarks \_\_\_\_\_

Certificate issued? \_\_\_\_\_

Signature of Approved Witness \_\_\_\_\_ Date \_\_\_\_\_

## PLS Boiler Inspection Standard

### GLOSSARY OF BOILER TERMS

**Absolute Pressure** – Pressure measured in reference to a vacuum. In traditional units, denoted by psia. [Pounds per Square Inch Absolute]

**Gauge Pressure** – Pressure measured in reference to the ambient (atmospheric) pressure. In traditional units, denoted by psig. [Pounds per Square Inch Gauge]

**Design Working Pressure** – The *target* operating pressure used for choosing materials, methods and geometry of the boiler.

**Maximum Allowable Working Pressure** – The highest pressure that can be used in the boiler at the saturation temperature of water at that pressure. The lowest of the allowable pressures computed for the various failure modes.

**Operating Pressure** – The pressure chosen by the operator to maintain in the boiler. This pressure must be less than or equal to the Maximum Allowable Working Pressure. The pressure at which the safety relief valve(s) are set.

**Gross Internal Volume** – The volume of the boiler accessible to pressure, up to the first stop valve, without deducting the volume of fire tubes and stays.

**Net Internal Volume** – The volume of the boiler accessible to pressure, up to the first stop valve.