Plugging Firetubes

Considerations & Concerns
Why is the tube plugged?

• The tube leaked
  – Where?
  – Did the repair organization perform a PT on the tube and joint to determine where the leak was?
Evaluating the leak

• Before plugging a tube, you need to determine the cause of the leak. For instance, if the leak is at the tube to tube sheet joint, it could affect the holding power of the plug. If the leak is a through wall leak resulting from corrosion, it implies that the tube wall strength has been compromised. If the leak is a through wall leak resulting from a longitudinal heat stress (hoop stress) crack – such a crack usually occurs from the tip of the tube inward across the tube sheet to the water side (Figure 1) – the crack may be closed by installing the plug. However, it will eventually open up again.
Operational Concerns

• the affects on the waterside pressure boundary or membrane
  – the tube plug creates a flat head segment on the tube sheet.
  • What is the pitch of the stays? Pitch is the maximum center to center distance of the stays as determined by the manufacturer.
  • Initially, the tube may act as a stay. However, fireside water doubles the corrosion rate on the tube. Its staying time is limited.
  • Tube plug suppliers instruct the installer to puncture the tube wall before installing the plug. This allows water pressure on the plug.

\[ t = p\sqrt{\frac{P}{SC}} \]
No calculations required.*

*Recent NBIC changes may require weld load calculations
The 10 % Rule

• There are boilers that are designed for a larger heat transfer surface than required to achieve the specified output.
• The U.S. Navy has specified that all of their heat exchangers be designed assuming 10 % of their tubes were plugged without a loss in the minimum capacity specified.
• Commercial boilers are not usually designed with tube plugging in mind. In fact, “Ohio Specials” are fired over the standard firing rate of the boiler which make them more sensitive to the affects of plugging tubes.
Operational Concerns cont’d

• the second concern is the affects on the combustion process throughout the boiler.
  – When it comes to the combustion process, the impact of plugging tubes results in back pressure of combustion gases through the boiler. A plugged tube reduces the cross sectional area of the flow path. The reduction in area reduces the flow through the boiler and increases the pressure drop across the boiler. The increase in pressure reduces the air output of the blower (forced draft or induced draft). Less air reduces boiler capacity and contributes to incomplete combustion that produces carbon monoxide and soot and thus increases the cost of boiler operation. Smaller boilers or over fired Ohio Specials would be more sensitive to this impact on combustion because there are fewer tubes per pass.
Plug Installation

• Sometimes the plug is welded to ensure it doesn’t leak or blow out and turn into a projectile.

• When it is welded, the plug should have a material test report.

• The welding must be done in accordance with the jurisdiction’s requirements.
• As shown below, the fillet weld may only attach to the tube. The holding strength of the plug depends on the holding strength of the leaking tube.
One Plug may cause another
NBIC Part 3 Proposed Change
NB11-1001

• **3.3.4.9 TUBE PLUGGING IN FIRETUBE BOILERS**

  When replacement of a tube in a firetube boiler is not practicable at the time the defective tube is detected, with the concurrence of the owner, Inspector and when required, the jurisdiction, the tube may be plugged using the following course of repair:

  a) The scope of work, type of plug and method of retention; whether welded or mechanical interface, shall be evaluated by the “R” Certificate Holder performing the repair and reviewed with the Inspector, and when required, the jurisdiction.
3.3.4.9 Tube Plugging cont’d

- b) When the method of plugging is by welding, strength calculations for the size of the weld shall be in accordance with the original code of construction. The “R” Certificate Holder performing this repair shall weld the plug to the tube, or to the tube sheet, or a combination of both.
Load(force) on the plug

• Assume filler metal 6010 (60,000psi)
• 3” OD tube/ plug size gives us \((1.5)^2 \pi = 7.07\text{in}^2\)
• Assuming a boiler MAWP of 550psi
• Load on the plug is 550psi*7.07in²=3889 lbf (pounds force)
• For Heating boilers 15 psi steam creates 106 lbf and 160 psi water creates 1131 lbf
Weld size needed to hold the plug?

- Taking the worst case of pressure with no added design margin.
  - \( \frac{3889 \text{ lbf}}{60,000 \text{ psi}} = 0.0648 \text{ in}^2 \) area of weld
  - \( 0.0648 \times 16 = 1.04 \) sixteenth square inch
Plugging socket welded tube
Evaluate Weld Strength

Verify strength of Compensation

• PG-37.2 , PW-15.1.6
• \( W = (A-A_1)S \quad W=(3-0.0625)20000 =58750 \)
• Path to be considered will be through the external fillet weld \( (W_{ef}) \) (See PW-15.2 for weld factors)
• External Fillet weld \( (W_{ef}) \)
Minimum Nozzle Weld Sizing Are Defined in PW-16 and Fig. PW-16.1

Typical Example:
Solve minimum weld sizes (PW-16.2)
\[ t_{\text{min}} = \text{Smaller of } t_n, t, \text{ or } 3/4 \text{ inch} \]

Both \( t_1 \) and \( t_2 \) shall each be not less than the smaller of \( 1/4 \) inch or \( 0.7 \cdot t_{\text{min}} \)

Assume a 0.75 tube sheet = t
Therefore, \( 0.7 \times 0.75 = 0.525 \), take smaller

Weld leg = Weld throat \( \times 1.4142 \)

Weld leg = \( 0.25 \times 1.4142 = 0.35 \) in

Fig. PW-16.1
Evaluate Weld Strength (cont.)

PW-15.2

\[ W_{ef} = 0.49 \cdot \frac{1}{2} \cdot W_{leg} \cdot \pi (d + 2t + W_{leg})S \cdot fr1 \]

\[ W_{ef} = 0.49 \cdot 0.5 \cdot 0.35 \cdot \pi (3 + 2(0.75) + 0.35)17100 \]

\[ W_{ef} = 22341 \]

The only factor that can be increased to increase \( W_{ef} \) is the Wleg (0.35)
3.3.4.9 Tube Plugging cont’d

• c) Plugging a tube in a firetube boiler is recognized as an alternative to the replacement of a firetube and may be further limited as a method of repair by the number of tubes plugged and their location; scattered or clustered. The operational effects on the waterside pressure boundary or membrane and the effects on the combustion process throughout the boiler should be considered prior to plugging.

• d) The boiler may be returned to service for a period of time agreed upon by the owner, Inspector, and when required, the jurisdiction.

• e) The Form R-1 shall be completed for the plugging of firetubes, identifying the means of plug retention; mechanical or by welding.
Rationale NB11-1001

• Tube plugging is presently being performed using a variety of mechanical retention methods through driving, expanding or by welding plugs to existing tubes (sleeved or un-sleeved) or tube sheet holes when tubes are removed. Acceptance may be conditional depending on number of tubes plugged, their location; whether clustered or scattered, and a host of variables that may otherwise render an accepted practice as “not viable” or “compromising” in nature.

• The judgment of the Inspector, evaluation and experience of the “R” Certificate Holder, and interaction with the owner and Manufacturer as needed, all represent the interests of the Industry as a viable method of repair when immediate replacement of the firetube cannot be performed; not yielding to safety.

• The item presents tube replacement as the most conservative method of repair, but provides considerations for tube plugging as a method of repair when NOT-LIMITED by conditions stated in 3.3.4.9.c); “scattered or clustered” suggesting the potential need for calculating the maximum pitch allowed by ASME Section I, PFT-31.2.
PFT-31.2 Stay Tubes

The required tubesheet thickness and maximum pitch of stay tubes shall be calculated using the following equations:

\[ t = \sqrt{\frac{P}{CS}} \left[ p^2 - \frac{\pi d^2}{4} \right] \]

\[ p = \sqrt{\frac{CS t^2}{P} + \frac{\pi d^2}{4}} \]
INTERPRETATION 95-35

- **Subject:** R-200 Definition of Terms
- 1992 Edition with the 1994 Addendum
- Question 1: Is the welding in of a plug to seal tubes in a boiler or pressure vessel considered a repair?
  - Reply 1: Yes.
- Question 2: Does the NBIC apply to plugging tubes by welding plugs to tubes and/or their joints to tube sheets of tubes that have leaked, tubes that have corroded to an unacceptable thin wall thickness, and tubes required to be removed from service for operating reasons in boilers and pressure vessels?
  - Reply 2: Yes.