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A VIEW FROM THE PENTHOUSE: USEFUL INFORMATION FOR THE WORLD OF BOILERS

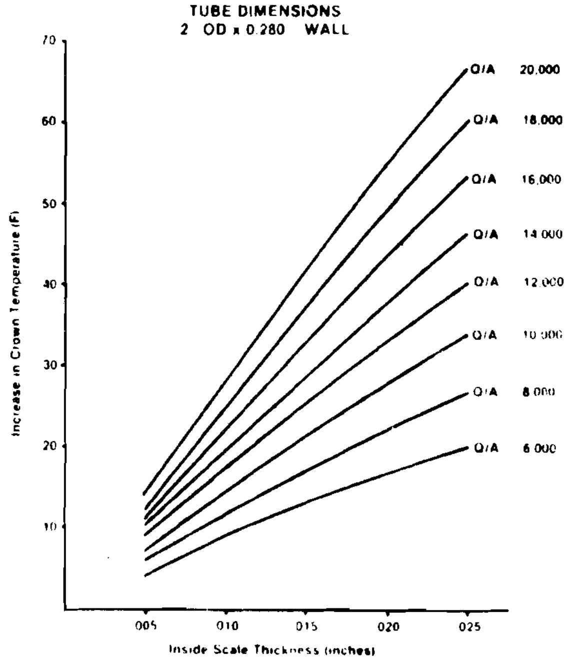
Thoughts on Superheater & Reheater Replacement

Over the life of a boiler, 40-50 years or so, the superheater(SH) and reheater (RH) will have to be replaced twice. Part or all of these components may be replaced after 12-18 years service. In many cases "nothing" has changed. The fuel analysis is no differnet now than previously. No changes have occurred in the operation of the unit. Steam temperatures are within the expected range. Yet external corrosion and a rapid increase in the frequency of SH and RH tube failures "suddenly" appear, usually before the design life is reached.

Before a decision is made on changes needed in the replacement SH or RH, several questions need to be addressed.

1. What is the overall condition? The design calls for a steam temperature of 1005°F, say, but individual tubes vary from 950° to 1065°F. It is a fact of life that the hottest tubes will be the most seriously, (only?) ones distressed. These few, perhaps 10%, will have the greatest metal wastage, corrosion, internal oxidation, and creep failures. It is likely that replacement of these will be sufficient to restore acceptable reliability. In any event, careful metallurgical evaluation may be required for a satisfactory inventory of the overall condition.

2. What has been the history, frequency, location, type, and nature of the tube failures? As noted above, the hottest tubes cause the majority of problems. Also, on the steam side of each tube, steam (H_2O) reacts with steel (Fe) to form magnetite (Fe_3O_4), an iron oxide: $4H_2O + 3Fe = Fe_3O_4 + 4H_2$. The reaction is inevitable and proceeds more rapidly as temperature is increased. This scale on the internal surface acts as an insulator to heat flow from flue gas to steam. One important consequence is to raise the tube metal temperature. The graph below gives the calculated increase in metal temperature, ΔT, compared with a clean, scale-free tube as a function of scale thickness for several heat flux conditions found in a SH or RH.



For the cooler tubes a small increase of 25° - 35°F is of no significance. However, for the hottest ones such an increase can be devastating. Thus, the suggested metallurgical evaluation should include a characterization of the internal scale thickness. By keeping good records of failures, by cataloguing the kinds; high temperature creep, ash corrosion, weld related, the amount of tube wastage, spacer and attachment, by mapping the location, the overall metallurgical condition is more easily metallurgical condition is more easily established.

3. What kind of materials should be used? Until the early 1970's the oxidation limit of SA-213 T22 ($2\frac{1}{4}$Cr-1Mo) was 1125°F. Because of deterioration of this alloy for reasons noted, the limit was reduced to 1075°F. Universally, boilers with 1005°F steam temperatures now contain stainless steel (SA-213 TP304, 304H, 321, 321H, 347 or 347H) tubing in the finishing legs. Thus if the existing unit has T22, an up-grade to 304 or 304H stainless steel would make sense. Either 321 or 347 grades are more expensive than 304 without any appreciable improvement in corrosion resistance. Note, a change from T22 to 304 will allow a thinner wall tube to be used as the ASME Boiler and Pressure Vessel Code has higher allowable stresses for 304. However, the steam flow conditions may have to be recalculated. A thinner wall gives a larger ID which changes the pressure drop and steam flow. If similar ID's are kept, the OD of the stainless will be smaller than the T22 and there may be inadequate surface for proper final steam temperature.

In the case of satisfactory performance for 12-15 years followed by rapid fuel ash corrosion, the feeling may be that "something" better than stainless steel is needed. A replacement in kind may make economic sense rather than shields to protect against coal ash corrosion or "super" alloys to protect against oil ash corrosion. If "nothing" has changed, the cause of the corrosion may be the internal scale that has raised the tube metal temperature so that fuel ash corrosion occurs. Rapid wastage is caused by liquid constituents in the ash. By keeping the temperature below the melting point of these compounds, ash attack cannot occur. Thus replacement in kind with a planned chemical cleaning after the first 8-10 years of service may make more sense. Again, thorough metallurgical evaluation can help make the proper decision.

4. Failures of attachment lugs and clips? Corrosion of these welded attachments poses a serious problem. These spacers are the hottest as they are farthest from the steam cooling necessary to hold temperatures down. Lugs in the "new" SH or RH may be shortened by using offsets to bring the tubes closer together at the spacer location and thus reduce their temperature with improved cooling. These attachments are commonly investment castings. One advantage to investment castings is the flexibility of choice of alloy. Usually these castings are made of a cast equivalent to a 18Cr-8Ni (304) stainless steel. However, for improved high temperature oxidation and corrosion resistance, higher alloy stainless steels 25Cr-20Ni, or casting alloys similar to the Inconel alloys of the International Nickel Co. may be used.

In the given examples, the metallurgical evaluation will help identify the fundamental cause of the failures and suggest the proper replacement fix. At the same time, microstructural analysis can be done to assess the remaining life of those portions of the SH and RH not replaced.

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