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

MATERIALS UPGRADE

Boilers that have been in service for more than 20 years are ready for a thorough materials condition study. These boilers came on line in the late 50's or early 60's. Water treatment procedures have changed from a free caustic pH control to a coordinated or congruent phostate or all volatile treatment. Furnace wall tubes may still have metal wastage caused by corrosion due to the older style water treatment. Slope tubes, especially reverse slopes where heat is applied from above and gravity aids in separating steam from liquid, may have more corrosion than expected or found in the rest of the furnace. Superheaters and reheaters were designed when the usual practice was to use T-22 up to 1125°F rather than the present limit of 1075°F. Higher chromium ferritic alloys like T-5 and T-7 (5Cr-½Mo and 7Cr-½Mo) were also commonly used at metal temperatures above 1100°F. The ASME Boiler and Pressure Vessel Code gives allowable stresses for these ferritic alloys above 1100°F below 4000 psi. For a 2400 psi SH outlet pressure, the finishing legs look like "gun barrels", 1 3/4" OD x 0.50" MWT, or worse. Thus for both portions of the furnace and SH and RH a meterials evaluation and upgrade makes sound sense.

In the furnace walls of drum style boilers, the common alloy used is SA-210 seamless tubing, a plain carbon steel. This material is still a proper choice. Steam/water temperatures are approximately 680°F and normal metal temperature is usually below 750°F. At the highest heat release zones, around the burners where heat flux is 125,000 BTU/hr-ft^2 or higher, metal temperatures may be 800°F. Reverse slope tubes are also apt to have these higher metal temperatures. Screen tubes heated around the entire perimeter may also show waterside distress even though heat fluxes at this location are lower than at the burner level. With high heat input the percent steam in the boiler water may occasionally lead to near DNB (departure from nucleate boiling) conditions. Tube metal temperatures increase and creep failures may occur.

Corrections for these problems may be approached in a couple of ways. One is to use alloy tubing, for example, SA-213 T-11, which is stronger at higher temperatures than 210. T-11 has the same allowable stress at about 935° F as SA-210 has at 800°F. The advantage to this route is that the original tube dimensions can be continued in the tube replacement. No special precautions are required to assure the same pressure drop and the same fluid flow through each riser. The principle disadvantage is that nothing is done to improve steam-side flow conditions which are the cause of the problem in the first place. A minor concern to the user with T-11 is the greater care necessary during fabrication of all welded panel construction to prevent weld cracks. None ofthe manufacturing problems are difficult to overcome. Indeed some supercritical boilers now routinely use T-22 tubing in waterwalls. The use of suitable preheat and post weld heat treatment prevents welding problems in T-11 or T-22, but neither preheat nor PWHT is employed when SA-210 material is used. The purchase specification for replacement wall panels should require such manufacturing precautions.

The second, and in many ways the better approach, is to use internally ribbed or rifled tubing. By imparting swirl to the fluid motion, steam bubbles are kept well mixed and steam blankets are prevented. These changes in the waterside heat transfer condition keep tube metal temperatures down and there is no need to use higher alloy material. Rifled tubes of SA-210 alloy are adequate. Several years ago similar swirled fluid motion was obtained by the use of flow promoters or twisted, helix-shaped metal tapes on the inside of smooth-bore tubes. Such devices are not recommended. The gap between the steel tape and the fireside of the tube bore may lead to crevice corrosion or chemical attack even in the best regulated boilers.

The drawback to rifled tubing is the greater pressure drop required for equal mass flow rate. There is no free lunch. The energy needed to impart swirl to the fluid comes at the expense of pressure drop. Rifled tubing has greater flow resistance or friction factor, and this effect must be adjusted for, when only a portion of a furnace is retubed.

For a SH or RH material upgrade, the usual choice is to substitute 304 or 304H stainless steel for the chromium-molybdenum ferritic alloys of T-22, T-5, or T-7. While 304H stainless steel is more expensive than T-22, about $2.00 vs $1.20 per pound, the allowable stress is higher. From the ASME B & PV Code, Table 23.1, the allowable stresses for T-22 and 304H are given below. Also given is the specified minimum wall, t, required for these alloys for a 2600 psi SH pressure and a 2.0 inch OD. The OD dimension sets the amount of heat absorbing surface for the required steam temperature. The third line is the cost per foot at the prices given above. Another way to look at effective cost is the price per unit of strength, dollars per KSI, line four.

TEMP.	950	1000	1050	1100°F
T-22				
S,KSI	11.0	7.8	5.8	4.2
t,in	.221	.296	.376	.483
$/ft.	4.62	5.93	7.18	8.62
$/KSI	.109	.154	.207	.286
304H				
S,KSI	14.4	13.8	12.2	9.8
t,in	.176	.182	.203	.244
$/ft	6.29	6.49	7.15	8.40
$/KSI	.139	.145	.164	.204

A comparison of either cost line indicates 304H becomes a lower cost material at a metal temperature somewhere between 1000° and 1050°F.

When changes from ferritic steel to austenitic stainless steels are made, a recalculation of steam flow, pressure drop, and overall heat transfer is necessary. These are not difficult calculations to do but must be done to assure proper final steam temperature, quantity and distribution through each SH element.

At this time of replacement, it also makes sense to correct excessive steam temperature imbalance, even if no changes are made in materials. While most SH/RH have a miximum deviation from the average of 35°F or so, an unfortunate few may have a tube to tube variation of 75°F. Quite simply, when the outlet steam temperature is 1005°F, the steam temperature of individual tubes may vary from 930° to 1080°F. Prior to replacement, steam temperatures just below the outlet header should be remeasured. The location of all creep failures should also be tabulated by tube and position. Such data will identify the hottest section. The steam flows can then be adjusted to smooth out the peaks and raise the valleys of steam temperature.

An upgrade from T-22 to 304H requires that these calculations be done. Probably the simplest way to achieve suitable steam flow distribution is to vary the ID of the T-22 safe ends applied to the stainless. (The DMW is shop made and the T-22 safe end is welded to the T-22 tubes left on the headers in the field. All field welds then are between like alloys). In effect the safe end becomes a flow controlling oriface.

Any surface adjustment required to correct average outlet steam temperature should also be done at this time. Fuels may have changed over the years. A change in the coal slagging characteristics affects the heat absorption in the furnace. A change from a lower slagging coal to a higher slagging coal will decrease furnace heat absorption and increase furnace exit gas temperature. Thus there may be too much SH or RH surface or an imbalance in heating surface between SH and RH. In effect an overhaul in SH/RH surface should be done, if necessary, to return the unit to optimum performance.

Another area where materials improvement may be desirable is in SH/RH supports, tube ties, clips or spacers. Some of the nickel base alloys have superior high temperature strength, corrosion or oxidation resistance compared with the austenitic stainless steels previously used. Investment castings of 50Cr-50Ni alloy may be used where especially difficult ash corrosion environments have been encountered. All of these austenitic nickel base alloys are readily weldable.

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