"THE IMPORTANCE OF PROPER LEVEL CONTROL OF FEEDWATER HEATERS"

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One of the most common causes of tube failures in a feedwater heater (FWH), and a resulting source of additional operational and maintenance costs that typically lead to ultimate premature replacement is the improper control of the internal liquid level. These problems are not new; they have been experienced by many Utility plants throughout the industry over the past 50 years. However in many cases, the resulting damaging phenomenon has seldom been totally understood, and the loss of corporate knowledge and failure of some utilities to identify and rectify level control problems continues to bring this issue to the forefront of root causes of FWH operational failures.

In general, the performance of the Drain Cooler (DC) Zone is tied to the operational parameter of Drain Cooler Approach (DCA). DCA is defined as the temperature difference between the drains leaving the heater and the feedwater entering the heater. Most FWHs are designed with a DCA of approximately 10 °F. While DCA is a good indication of whether or not the DC Zone is operating properly, it is not the only parameter that should be considered. DCA is a measurement of temperatures only. The pressure of the drains must also be known in order to determine the degree of subcooling and whether or not there is a potential for flashing, either withing the DC itself or the downstream piping before the level control valve. Flashing and two phase flow in either of these areas can cause significant damage to the heater.

Figure 1 – Areas of two-Phase flow can be seen near DC Zone Baffels

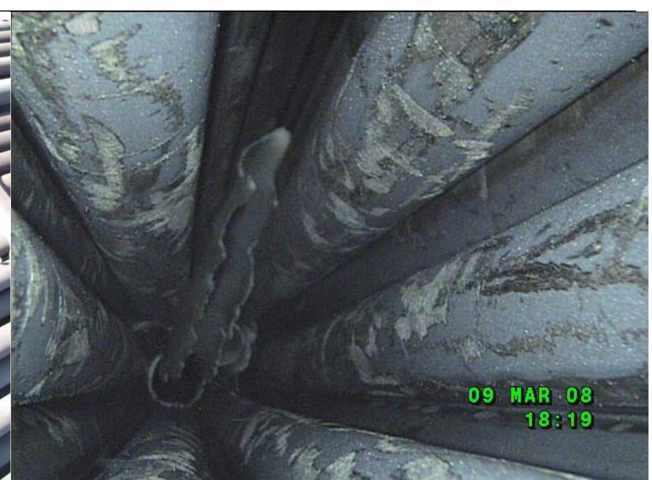

Figure 2 – Tube Damage due to flashing within a Drain Cooler Zone

It is important to remember that the Drain Cooler is designed to be a water-to-water exchanger. It must remain that way to function properly. Any admission of vapor into the zone typically results in problems. This may be a result of a low liquid level in which steam is admitted directly from the condensing zone into the DC zone, the result of flashing within the DC zone itself, or can be the result of leakage into the zone via the endplate or shroud cracks. In most cases, the OEM designs the DC zone such that the linear velocity of the liquid within the DC zone remains a reasonable 2-4 feet per second. When velocity increases, the pressure drop increase exponentially (approximately a square function). When flashing occurs, the localized velocity can be much greater than designed and tube vibration and/or tube OD erosion may occur, as well as damage to the carbon steel cage components.

Flashing by definition is the change of state of liquid to vapor. While in most cases, this change of state results from the addition of heat (as in the boiler), in a FWH the most common cause of flashing is a result of a reduction in pressure (or pressure drop). Pressure drop may be a result of the geometry of the Drain Cooler Entrance window, the fact that the drains must travel around the tubes and change direction many times due to the baffling arrangement, and also due to changes in elevation and elbows in the downstream piping. If the liquid drains are not subcooled enough, any one of these pressure drops could result in flashing and two phase flow. Two phase flow is known to cause problems to piping, tubing, the cage and the shell, especially in the case of carbon steel components.

This flashing phenomenon is typically more problematic in LP heaters than in HP heaters, although both are susceptible. To understand this, one need only to consult the steam tables and look at the specific volume of saturated liquid versus saturated vapor. Let's consider a HP heater operating at approximately 250 psia and a LP heater operating at approximately 10 psia. From the steam tables, we observe the following

Pressure (psia)	Sat. Temp (F)	Specific Volume Liquid (ft^3/lb)	Specific Volume Vapor (ft^3/lb)	Ratio Sat Vap./Sat Liq.
250	401	0.0187	1.843	98.5
10	193	0.0166	38.42	2314

It can be seen that in the case of the HP heater, when the liquid flashes within the drain cooler, it wants to occupy a volume that is approximately 100 times the volume that the liquid previously occupied. As mentioned above, this drastically increases the localized velocity (and can result in further pressure drop and more flashing). In the case of the LP heater, the same amount of flashing liquid now wants to occupy over 2000 times the volume, which can lead to significant failure mechanisms.

One thing that must also be considered is the effect on the drain cooler when operating with other feedwater heaters out of service (i.e. single string or downstream heater out of service). This can result in a significant overload condition in which the DC Zone must now pass a significant amount of drains and most likely above the normal design point. If these abnormal modes of operation were not considered by the FWH designer, than the high liquid velocity and therefore high pressure drop within the DC zone could also result in failures.

Feedwater heaters are provided in a number of different arrangements, each one with its own unique level control problems. Each case is addressed below:

Horizontal Feedwater Heaters

Horizontal feedwater heaters may be provided with a "short" full pass DC zone or a "long" partial pass DC Zone. It most modern horizontal FWHs, the short DC is provided. As mentioned, the DC zone must remain a water to water exchanger; therefore the boundary of the DC zone is well defined by a thick DC endplate, and a DC shroud which generally consists of a flat top plate and a bottom semi-circle enclosure. The entrance to this zone is via a cutout window (figure 3) or snorkel (figure 4) which is below the bottom row of tubes.

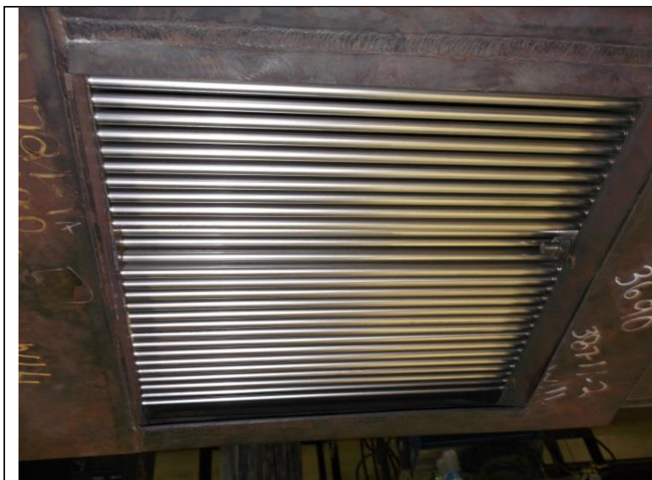

Figure 3 – DC Entrance Window

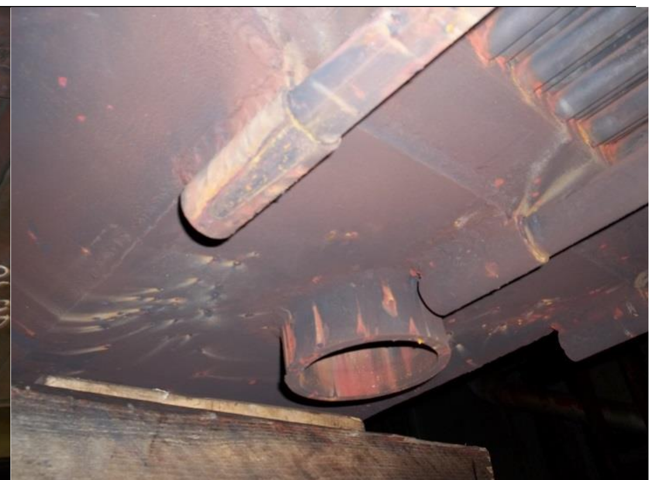

Figure 4 - DC Snorkel Pipe

The snorkel must remain submerged in the liquid in order to prevent steam from the condensing zone from entering the zone (even throughout transient conditions). Additionally, the liquid velocity through the DC entrance must remain low in order to ensure that the resulting pressure drop does not result in flashing. The optimum level in which to operate can be determined by performing a "knee of the curve test" as described in Paragraph A2.2 of the HEI for closed feedwater heaters, which is derived from a paper by Mr. Fred Linley entitled "A review of Salient Conditions Affecting Closed Feedwater Heater Availability and Performance", (recommended reading for all engineers with FWH responsibility). By plotting DCA versus FWH level, the point at which flashing occurs can be determined. This point is represented by the marked increase in DCA over a small change in liquid level and generally equates to the entrance to the DC zone. The normal liquid level (NLL) should then be set approximately 2" above this point. This typically results in approximately the bottom three rows of tubes being submerged during normal operation. The submerged tube surface has the benefit of providing some subcooling to the drains prior to entering the DC Zone, and ensuring that that liquid does not immediately flash into vapor when it experiences the initial pressure drop as it traverses through the DC entrance window.

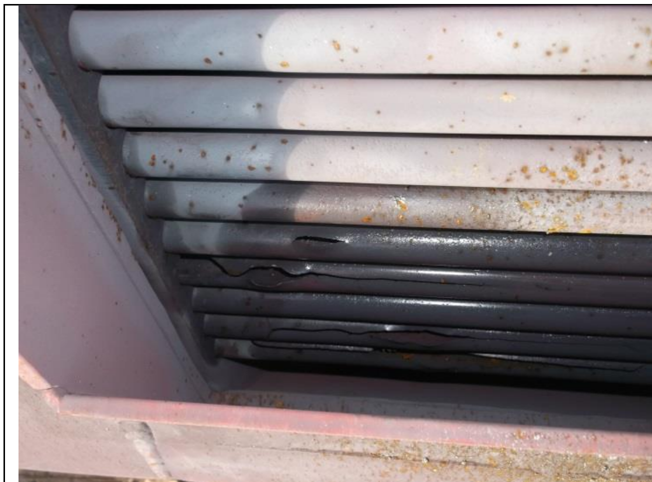

Figure 5 – Failures at the DC Entrance window due to low liquid level

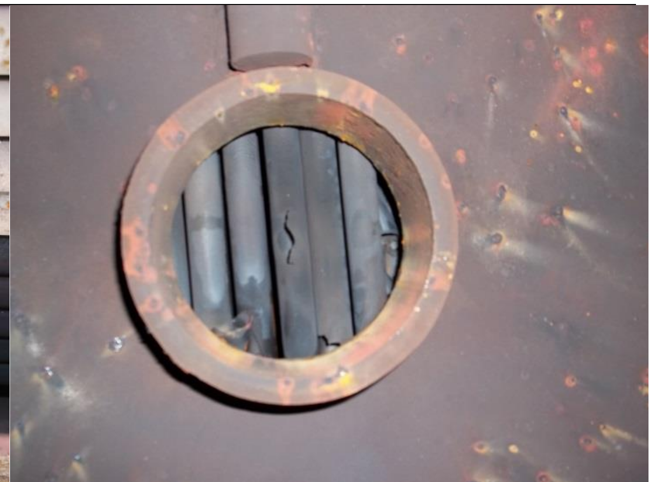

Figure 6 – Failures at DC Snorkel Pipe due to flashing/high pressure drop at entrance.

Over time, the liquid level may be required to be changed. This is especially true if there are a significant number of plugged tubes. If there are plugged tubes in the bottom rows that are submerged in the normal liquid level, the ability to "pre-cool" the drains prior to entering the DC zone may be lost and flashing may once again occur, In this case, the "knee of the curve test should be performed again and the NLL adjusted higher.

For heaters with a "long" partial pass drain cooler, level control is a little more straightforward, although the same principles as described above for the "short" drain cooler can be applied. As before, it is imperative that the drain cooler remain a water-to-water exchanger. This generally means keeping the liquid level in the heater above the flat DC top plate at a minimum. In these heaters, there is no DC endplate and the shroud simply ends prior to the start of the U-bends. This has two distinct advantages. First, there is essentially no pressure drop as the liquid enters the zone, and second, there is some precooling of the drains prior to entering the DC Zone due to the U-bend surface that is submerged near the entrance. Both of these minimize the potential for flashing. Of course, the normal liquid level is maintained higher than that of a short drain cooler, which lessens the margin to a high liquid level condition which could result in a flooded venting system or in a worst case scenario, turbine water induction.

Vertical Feedwater Heaters

Vertical FWH's may be designed with the Channel Down or the Channel Up. Each of these designs is unique when it comes to level control. While maintaining a constant level in a horizontal FWH is relatively easy, it is typically hard to maintain a constant level in a vertical FWH, and as a result, the design of the heater must take into account the potential for level swings. The ability to maintain a constant level is a function of the capacitance of the heater. Capacitance can be defined as the available free volume per inch of level. In a horizontal feedwater heater, the capacitance is quite large, in that it takes a significant amount of liquid to change the water level by one inch. Capacitance in a vertical feedwater heater is much more limited, especially in the case of a Vertical Channel Down 3-zone heater, where the entire outlet pass is not available for liquid level due to the presence of the Desuperheat Zone (DSH). A small capacitance combined with an improperly sized control valve can result in significant level swings. This can lead to significant problems to the heater. If the level swings too low, the DC zone will be exposed to the steam, and if the level is not restored quickly, the DC zone will lose its effectiveness and flashing in the downstream piping may occur. Conversely, if the level gets too high, in the case of a 3-zone heater, the liquid will spill into the exit of the DSH zone, where steam is traveling at velocities on the order of 100 to 150 feet per second. When the water becomes entrained in this steam, it has the effect of a "shot-gun" blast on the tubes and internal components as shown in Figures 7 and 8.

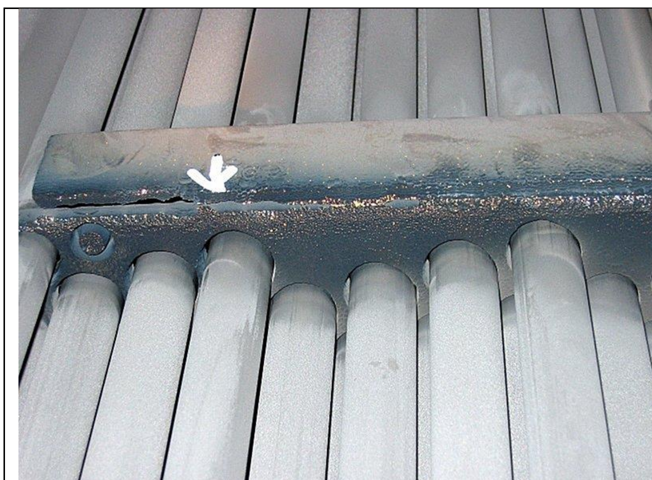

Figure 7 – Erosion of Tubes and Side Bars in a vertical FWH

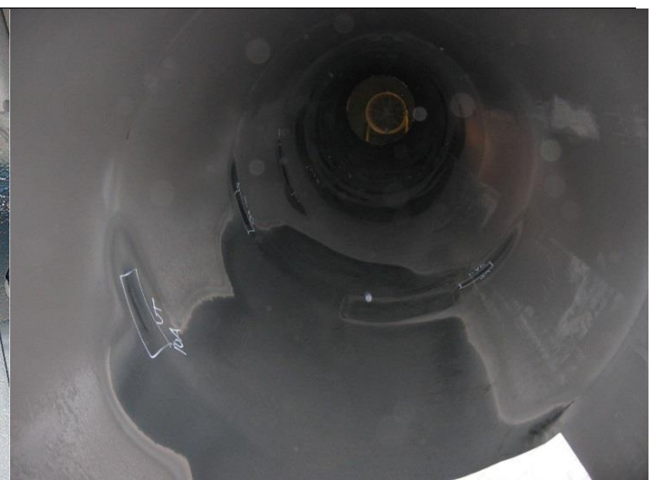

Figure 8 – Flow accelerated corrosion of Vertical FWH Shell due to moisture entrained in the steam.

In most cases for vertical channel down heaters, the level is established at about 5 inches above the top of the DC zone. Additionally, for 3-zone heaters, the top of the DSH zone should be at least 36 inches above the top of the DC Zone in order to allow for the worst case level swings that can be expected. Similar to the Horizontal heaters, the worst case overload condition must be analyzed, higher drainage flow due to heaters out of service typically results in more drastic level swings, especially if the control valve is not very responsive (or overly responsive). In some cases 5 inches above the DC zone may not be enough, in which case the level should be set higher based on operational test and observations.

Vertical Channel Up heaters obviously have the level controlled at the bottom of the heater near the U-bend region. For single zone heaters, this is no problem at all as the drains outlet nozzle is simply placed at the bottom of the heater and as long as the liquid is subcooled enough to safely transit to the lower pressure heater or condenser without flashing, then problems do not occur. However, for Vertical Channel Up heaters with a Drain Cooler, maintaining level is similar to drinking from a straw. In these heaters a “long” partial pass drain cooler as described above is employed. The start of the DC zone must continually be submerged in the liquid level in order to maintain the suction and flow through the DC Zone. Not only is there a pressure drop due to the baffling arrangements within the zone, but there is a change in elevation from the bottom of the heater to the top of the heater, and the potential for flashing is exceptionally high.

Best Practices

Utilities tend to have the most success when the effect of liquid level on FWH performance is known and level control problems are recognized quickly by operators. In addition to displaying FWH inlet and outlet temperatures on control room monitoring screens, DCA and heater level should also be displayed, monitored and recorded in historical data systems such as PI

The location and number of liquid level taps also play a significant role. The liquid level within the heater is not flat, there is a gradient within the heater and it changes with load, therefore, the liquid level taps should be placed close to the entrance of the DC zone, where the level is most important. Generally, the column that is used for the control valve should be approximately 12 inches from the DC Entrance. In cases where this is not possible due to the physical arrangement (i.e. condenser neck heaters) then the NLL should be optimized based on the “knee of the curve test” described above. Simply setting the level based on the Vendor’s recommended level on the calibration plate may not be adequate since the level at the DC entrance may be significantly different than at the location at which the level is being measured.

It is preferred to have separate level taps (about 12” apart) for normal control, local indication, and emergency/alarm control as opposed to having all the columns manifolded together. In the latter case, a problem with the one line (such as clogging due to FME) will affect all indications and therefore you will lose the intended redundancy.

Emergency drain lines that provide alternate dumps should be via a separate nozzle in the condensing zone, as opposed to simply branching off the normal drains line. This has the benefit of being able to bypass the DC zone and in the case of an overload condition, relieve the DC of the high velocity condition and additional pressure drop that may be experienced. However since these drains will be at saturated conditions, there is additional concern for pressure drop. Slower velocity limits are important to ensure non-flashing situations

Level control valves (both normal and emergency) should be located as close as possible to the lower pressure source. Flashing of the drains will occur at the control valve, the amount of piping that will then experience the resulting two phase flow should be minimized. As mentioned above, the condition of the drains exiting the heater (temperature and pressure) should be monitored to ensure that there is enough subcooling to ensure that the drains do not flash prior to reaching the control valve.

In Summary

Inadequate liquid level control can lead to tube failures and DC zone damage. It is important to optimize the normal liquid level set point to avoid flashing or vapor ingestion within the DC zone. The DC zone is designed to be a water to water exchanger. When the conditions which allow it to remain as such are violated, problems can quickly develop.