"TAKE GOOD CARE OF YOUR FEEDWATER HEATERS"

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In the April 2011 issue of Energy-Tech Magazine, we wrote about the importance of conducting Quality Assurance (QA) checks when replacing a feedwater heater. Assuming that is properly specified and conservatively designed for the full range of load imposition, with the right materials of construction, and fabricated under a stringent quality program by an experienced manufacturer, most current feedwater heater (FWH) replacements are capable of a 40+ year life if they are properly operated and maintained. This article offers an overview of various inspection and testing methods that should be done periodically in order to obtain a picture of the overall health of this important piece of equipment.

Over time, all feedwater heaters will degrade. None are immune to failure. The most important thing that can be done to preserve the life of the feedwater heater is to take a proactive maintenance approach. Periodic condition assessment and trending over time is the responsibility of the system/component engineers. The Utility must be committed to establishing a programmatic approach that will aid in the understanding of why damage is occurring, and not just performing a knee-jerk reaction to the failures experienced. Traditionally, the determination of the reasons why a heater experienced failures was not the priority of plant maintenance managers and was often overlooked. Heaters were opened, leaks were found and plugged, then quickly returned to service as a part of a rush outage. Over time the number of tubes plugged increased without any knowledge of why failures were occurring. Ultimately, many heaters were replaced without knowing how to preclude the potential for future occurrences of the same failure mechanism. Therefore it is imperative to identify the root causes for the failures experienced. It is for these reasons that failure cause analysis (FCA) is the primary objective in feedwater heater life-cycle management.

The best life cycle management programs are ones that use a variety of complimentary techniques in order to validate failure mechanisms and help to identify their root cause(s). The most successful maintenance programs do not rely on only one method for assessment. They include but are not limited to:

- Visual Inspections
- Leak Testing
- Individual Tube Hydrotesting

- Non Destructive Examination (NDE)
- Tube Leak Location Detection
- Failed Tube Sampling

The results of all of the above techniques should point to the same root cause(s). However, do not eliminate the possibility of more than one contributing factor to failures.

Visual Inspections

The simplest inspection that can be done on a feedwater heater is a visual inspection of the accessible areas channel side while the heater is open. While station mechanics may enter the feedwater heater to conduct plugging or other tests, often times they are not instructed to also inspect the conditions of other areas susceptible to damage inside the heater channel. This is important as there may be early visible signs of failure. Responsible engineers should take the time to conduct (and document) a channel side inspection whenever their FWH is open for maintenance. Areas to inspect include:

- Tube inlets and tube-to-tubesheet joint welds for signs of erosion/wastage.
- Pass Partition components and sealing surfaces for signs of feedwater bypassing and damage.
- Channel barrel area, especially tubesheet to channel transition areas (i.e. corner weld joint or radius).
- Inlet and Outlet nozzles for signs of wear/surface cracking.
- Manway area – check seating surfaces condition/cleanliness.

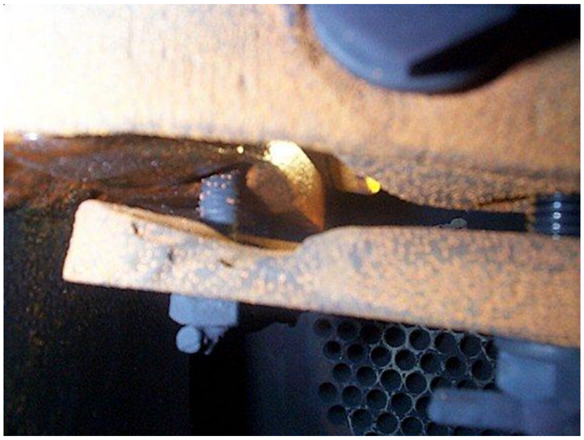

Figure 1 - Pass partition damage resulting in feedwater bypassing

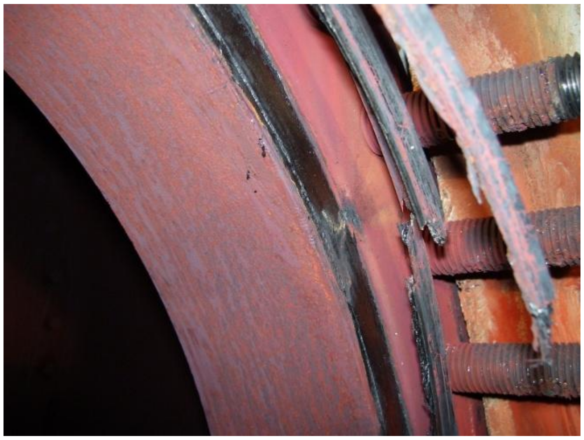

Figure 2 - Manway gasket failure and seating surface gouge

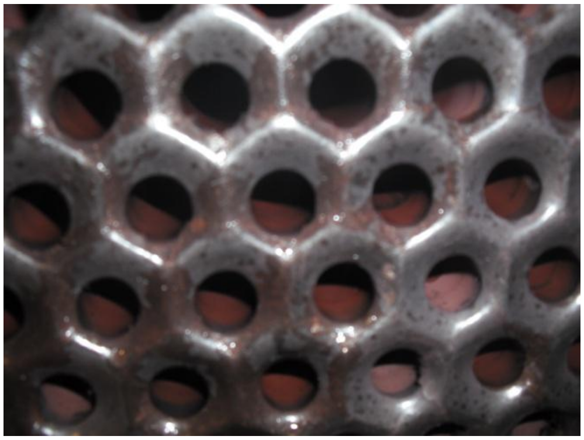

Figure 3 - Wastage of Tube-to-tubesheet joint welds that can lead to joint leaks

Figure 4 - Measuring inlet tube ID profiles for signs of inlet end erosion

The best way to get a look at the inaccessible internals of the FWH is through the use of fiber optic video probes. Probes may be introduced down the tube ID to locate and get a first-hand look at tube failures and characterize the nature of the failure (i.e. is the failure a crack in the tube, a hole, or is the tube completely severed). Additionally, video probes can be introduced through nearby available shell side connections to try to determine sources and extent of failed/damaged areas.

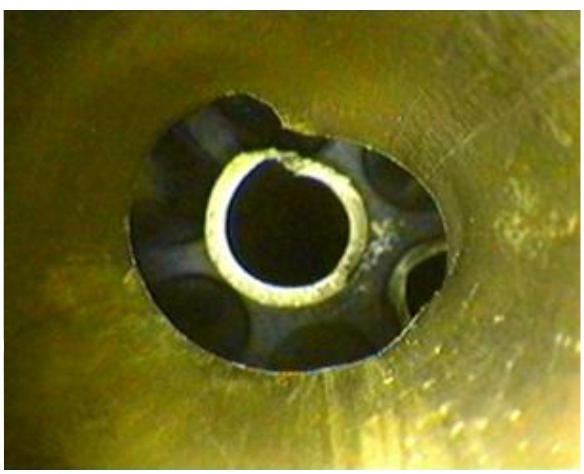

Figure 5 - Severed tube discovered by tube side video probe

Figure 6 -Shell side video probe of Desuperheating (DSH) Zone inlet window shows damage to bottom plate as well as tube failure.

In figure 6, impingement damage of the DSH zone bottom plate from the adjacent tube failure can be seen. This illustrates the importance of removing leaking heaters from service as soon as practical after a leak is detected. The secondary failures caused by the leak can become more damaging than the initial mechanism.

Leak Testing

Whenever the unit is coming down for an outage, suspected leaking heaters should be subjected to a tube-side leak test. This can be done simply by leaving the tube-side pressurized, and once the steam and drains to the shell side are secured, opening the shell side drains to check for leakage. Of course, this is simply a go/no-go check for leaks; it will not tell you which tube is leaking.

In order to identify the leaking tube location, the heater should be subjected to a shell side pressure test. This can be done a number of ways; the most common involves filling the shell side with water or pressurizing the shell with air and checking the face of the tubesheet for leaking tubes. The advantage of the shell side leak test is 1) it is much easier to identify the leaking tubes and 2) existing tube plugs in failed tubes can also be tested to ensure they are holding. When the shell is pressurized with air, a soap bubble solution can be applied to the tubesheet to quickly identify leaks. It is important to distinguish between tube failures and tube-to-tubesheet joint leaks. The approach to the repairs (plugging) are predicated on this discovery.

Figure 7 - Tube-to-tubesheet joint weld failure

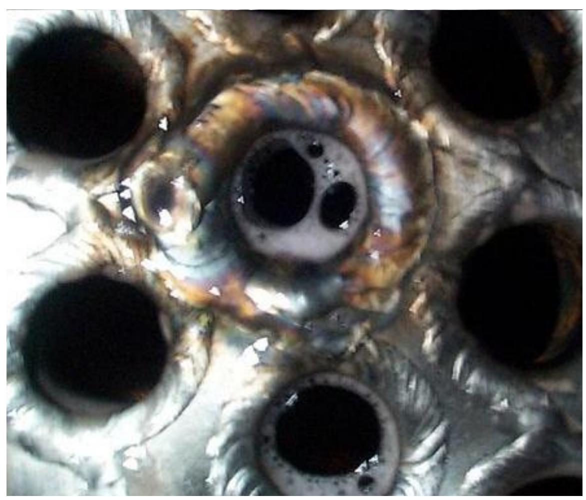

Figure 8 - Tube Leak identified by Soap Bubble Test

Individual Tube Hydrotesting

Once a tube failure is confirmed, some utilities will insurance plug the six tubes surrounding the failure in order to prevent another forced outage in case one of the adjacent tubes had been weakened due to leak impingement. This tends to dramatically increase the percentage of tubes plugged in the heater (often a criteria for heater replacement). This can also result in localized hot spots in the tubesheet where there is no longer feedwater flow, which may cause additional damage or failure of weld repairs. An individual tube hydrotest of the surrounding tubes can prevent the need for insurance plugging by testing each tube to a much higher pressure than the FW operating pressure. Any weakened tubes on the verge of failure will not pass this go/no-go integrity test and will be plugged. Tubes that pass the test can be returned to operation with a high level of confidence.

Figure 9 - Individual Tube Hydrotesting System

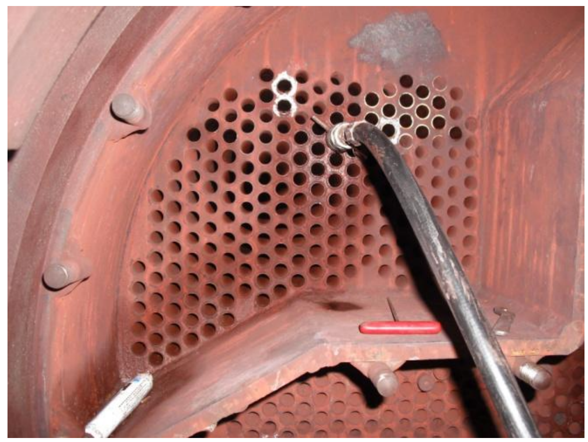

Figure 10 - Hydrotesting an individual tube to high pressure

Non Destructive Examination (NDE)

One of the most common forms of NDE is Eddy Current Testing (ECT), which provides an assessment of the FWH tubing. ECT can identify the location of most defects, determine if the defect is ID or OD originated, and even estimate the size of the defect. ECT has the advantages of having a relatively fast inspection rate and can be used to evaluate heater condition over time by comparing current results with past inspections in order to trend defect growth rates. However, it must be understood that Eddy Current Testing is a subjective test. The results can be affected by such factors as operator experience and proficiency, fill factor (percentage of tube ID cross section filled by the probe) and calibration of the probe relative to a tube standard. Tubes must also be clean and free from deposits as a prerequisite. While ECT testing is very popular in the nuclear industry based on almost exclusive use of austenitic stainless steel tubing, plants with carbon steel and other ferritic tube material in their FWHs require specialized methods of ECT to compensate for the inherent magnetic permeability. ECT is known to have error factors and in certain instances can miss thru-wall failures. Therefore, we advise caution when using ECT results as the <u>only</u> basis for tube plugging criteria.

ECT vendors will typically provide a color coded tubesheet map that shows the location of tubes with defects and the amount of wall loss determined by the test. While this shows where in the tube field damage is occurring, it is just as important to identify the location of the defect down the length of the tube (i.e. is the defect within the Drain Cooling Zone, Condensing Zone or Desuperheating zone, and is the defect at a baffle location or at the midspan). This information is critical to the primary objective, failure cause analysis.

A baseline ECT is recommended for future survey comparisons. Even new FWHs with no apparent issues should be opened, inspected and evaluated after the first five years of operation.

<u>Tube Leak Location Detection</u>

Regardless of the limits of a particular outage, it is important to determine where in the span the tube failed. This information is critical in determining the root cause. For example, failures experienced in close proximity to steam or drains inlet locations may indicate undersized or dislodged impact plates. Tube failures at baffle/support plates or at the midspan of a tube can be signs of tube vibration. Failures in the U-bends or at the transitions between stressed and unstressed portions of the tube can reveal a material problem. A group of failures in the same location may indicate the presence of foreign material or an operational problem (such as a “wet wall” condition at the exit of the desuperheating zone).

The location of a tube failure can be quickly determined by a number of methods. Probably the easiest method is by using a video probe to locate the failure and then measuring the length of probe inserted into the tube. Another method is to introduce compressed air into the failed tube from one end, and then insert a tight fitting rod or probe down the opposite end until the leak is covered, at which point the pressure in the tube will increase. The length of rod inserted will give the location of the leak. In vertical channel down heaters, the manometer principle can be employed using clear plastic tubing coupled to the failed tube leg.

When documenting and trending tube failures, it is important to look at the heater three dimensionally by superimposing the location of baffle cuts on to the tubesheet in order to determine which baffles the failed tube is contained (see figure 12). This can provide useful information when determining potential failure causes. Sometimes it may take a little expertise in determining the location of the baffles and cut lines, especially if heater internal drawings are not available.

Figure 11 - Probe with rubber seals for tube leak location detection

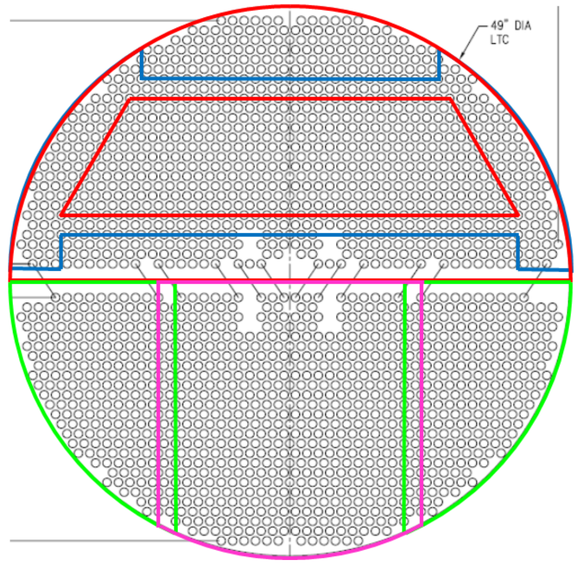

Figure 12 - Location of Baffle Cuts superimposed on tubesheet

Failed Tube Sampling

Following ECT or a tube failure, the best way to get a first-hand look at the nature of the defect is through tube sampling. Pulling a tube section from the heater has several advantages; 1) the defect can be viewed visually or under a microscope, 2) it can be used to confirm the credibility and reliability of the ECT results and 3) the tube can be sent to a metallurgical lab in order to identify suspected failure mechanisms. When sending a tube sample to a third-party laboratory, the Utility should provide certain background data to the lab such as material compositions, typical pressures and temperatures experienced, and typical water chemistry. A good lab should be able to provide useful information such as photo micrographs, chemical and metallurgical analysis and provide likely failure and/or corrosion mechanisms.

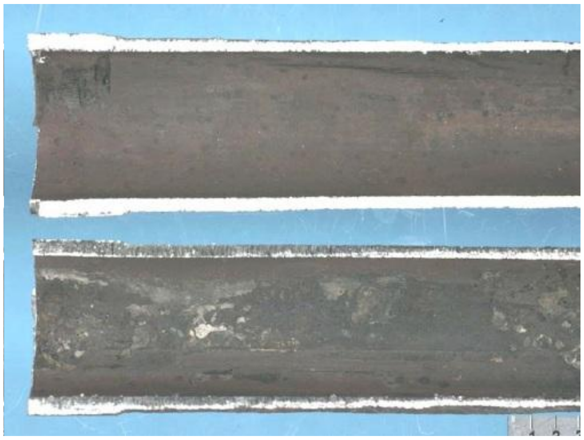

Figure 13- Tube Sample sectioned to view tube ID

Figure 14 - Tube Defect viewed under microscope

Conclusion

When it comes to prolonging the life of feedwater heaters, the primary objective for the system engineer is to establish a programmatic approach for heater maintenance and to commit to conduct failure cause analysis. A complete life cycle management program is one where the results of all of the complimentary tests and inspections are evaluated. The findings of which should all point to the same potential contributing factors, and thus the most likely root cause(s).

Relying on only one method of evaluation may not provide all of the required information; therefore, your assessment may be limited and incomplete. Maintenance history, heater configuration and archived operating data can also add valuable information when conducting root cause analysis. When problems begin to develop, there are two simple rules: Know your heater and be a good detective.