“ENSURING A QUALITY FEEDWATER HEATER”

Mike Catapano	Eric Svensson
President	Vice President – Engineering
Powerfect, Inc.	Powerfect, Inc.

Often, when a feedwater heater is replaced, many companies choose to replace “in-kind”. While this may be a convenient option, the utility is not taking advantage of improvements in heat exchanger technology or utilizing state of the art designs. A better option typically is to write a new specification that reflects the current and potential operating conditions, and then allow the Feedwater Heater Vendor to come up with a new, robust design. Regardless of the method of procurement, the Purchaser should not assume that their responsibility ends once the Vendor has been selected and a delivery date agreed upon. Obviously, the Purchaser is responsible for reviewing and approving the drawings prior to fabrication. If there is no one familiar with heat exchanger designs or deciphering detail drawings, it may be difficult to discern whether or not the Vendor’s design has actually met the requirements of the specification.

One of the most overlooked portions of the replacement feedwater heater procurement process is the need to conduct Quality Assurance (QA) inspections at the Vendor’s shop. While the Vendor is ultimately responsible for ensuring the overall quality of the heater and meeting code requirements, the Purchaser should still be involved to make sure that the Vendor is performing the work correctly as well as meeting any special requirements of the specification that may be above and beyond their standard operating procedures. Historically, feedwater heaters were purchased using low-cost procurement, where the lowest bidder was awarded the contract without regard to the overall quality. Ensuring quality in a feedwater heater replacement project is the topic of this article.

A replacement feedwater heater can cost a utility anywhere from $300,000 upwards of $1 million, especially when installation costs are factored in as well. However, sometimes in a feedwater heater replacement project, the utility forgets to budget or is reluctant to spend additional funds to conduct inspections at the Vendor’s facilities to ensure that they are getting the quality that they paid for. Most likely, the additional cost of performing these Quality Assurance inspections is just a small part of the overall cost to replace the heater, but it is money well spent in order to protect the investment. If you also consider the cost of taking the heater out of service in order to repair a tube leak, or to correct a deficiency that could have been identified during fabrication, the cost of the inspections generally pale in comparison.

Additionally, documented inspections of "as built" conditions can assist in trouble shooting or eliminate potential variables when conducting failure cause analysis of future problems.

As part of the specification, the Purchaser should reserve the right to inspect the manufacturing facilities and equipment at any time during working hours. Several fabrication processes of concern should be monitored by the Purchaser's representatives and listed in the specification as required witness points. The Purchaser may decide to waive the witness point in order to allow fabrication to continue, however, a later dimensional/visual examination or a record review should be conducted. The below major components are recommended for Purchaser inspection/verification during fabrication.

<u>Tubes</u>

The fabrication of tubing is generally subcontracted by the Feedwater Heater Vendor. However, the tube mill should also be available for inspection by the Purchaser's representative, especially when you consider that the tubing of the heater is the single biggest material cost of the heater and is the most likely component to fail in operation.

Ideally, the inspectors should visit the tube mill while the tubes that will be used in the heater are in fabrication. The inspection should include any or all of the following:

- Dimensional Verification
- Witness of any required non-destructive examinations (NDE) such as eddy current tests or ultrasonic tests
- Witness of tube bending and stress relieving
- Witness of hydrostatic tests
- Witness or review of mechanical tests
- Final tube cleanliness and dryness prior to packaging.

Fig 1 – Stress Relief of a U-bend

Fig 2 – Tensile Test of Tube Sample

<u>Tubesheet/Pillbox</u>

The tubesheet is generally the thickest portion of the feedwater heater and provides the boundary between the tube side and shell side pressures. It is imperative that the drilling of the tubesheet be done in accordance with TEMA standards to ensure the proper fit of the tubes and proper tube expansion later in the fabrication process. Any tubesheet holes that are oversized or contain defects could result in tube to tubesheet joint leaks, which may result in catastrophic tube failure when the heater is in operation, and therefore is a very important QA witness point.

The inspector should conduct a 100% go/no-go check with an appropriately sized plug gage in order to check for any oversized holes. Additionally, a random sampling of tubesheet holes should be accurately measured using a micrometer to ensure the required tolerances are met. Other items to check during an inspection of the tubesheet are:

- Overall dimensional verification (including thickness)
- Tube hole surface condition and cleanliness (free of burrs/drilling defects)
- Quality of tubesheet overlay (including NDE)
- Proper ligament sizing (ensuring no drill drift over the tubesheet thickness)
- Proper hole chamfering
- Check of pillbox corner radius (if applicable)
- Tubesheet hole drilling layout

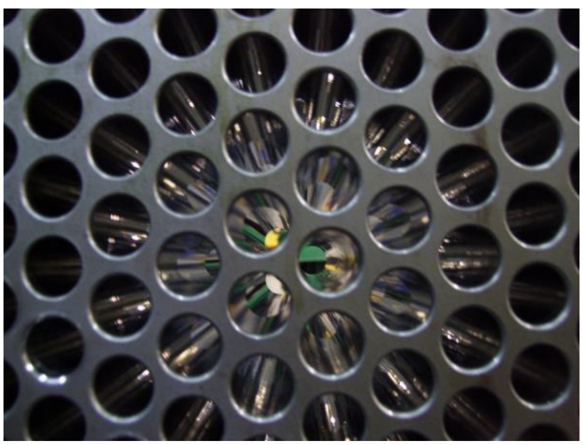

Fig 3 – Check of tubesheet hole cleanliness

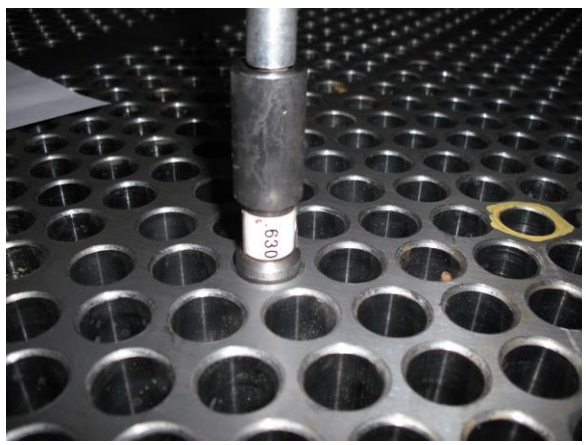

Fig 4 – go/no-go check of tubesheet hole

<u>Baffles and Support Plates</u>

The baffles and support plate drilling and sizing are another item that the Purchaser should consider inspecting. Often this inspection does not warrant a separate trip to the Vendor's facility, but should be conducted as time permits as part of any other major hold point. Prior to the tube bundle cage assembly, the Purchaser's representative should witness a stack check of the tubesheet, baffle plates and support plates in order to verify hole alignment. Solid rods, equal in OD to that of the tubing should be used as guides and fit the full stack. Additionally, the following items should also be checked:

- Baffle plate/support plate hole sizing
- Freedom from burrs, sharp edges, gouges
- Compliance with dimensional and surface finish requirements
- Proper cut line location
- Cleanliness of components and hole surfaces

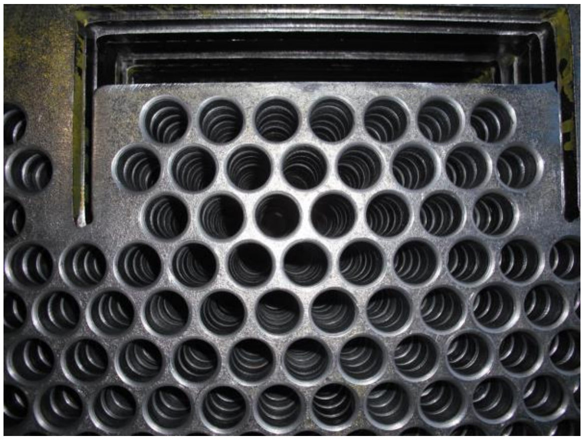

Fig 5 – Stack alignment check of support plates

Fig 6 – Dimensional check of baffle holes

Tube Bundle Cage Assembly

We routinely tell utilities who are purchasing replacement feedwater heaters that if you can only conduct one inspection at the Vendor’s shop, this is the one. Of all of the Quality Assurance inspections, this is the most important and offers the opportunity to inspect many different parts of the heater. If not done previously, the tubesheet and the baffles and supports can be inspected at this point (although at this point in fabrication, there may be little you can do if you find any problems, unless it is a major issue that will prevent further fabrication of the heater). Additionally, this inspection will be the point at which the tubing crates are opened in preparation for loading. This is the first opportunity to check the tubing as shipped from the mill.

At this point of fabrication, the internals of the heater will be accessible for the last time. It is important to check for general workmanship, quality of welds and cleanliness. Since the tubes will be loaded into the cage assembly immediately following this inspection, all internal surfaces should be free of dirt, grease and foreign material. Sharp scratches can be imparted to the tubes if the cage is not properly aligned and well cleaned. In certain situations, the tubes can become bent or dented if the cage is not “free running” and the tube gets hung up during insertion. In addition to the above, the other important items to verify during this QA inspection are:

- Impact plate location/sizing/weld quality/Dye Penetrant Tests (DPT)

- Overall alignment/perpendicularity of support plates, baffle plates, and DC end plate (if applicable).
- Ensuring the cage is "free running" (i.e. tubes can be inserted easily)
- Verify skirt nozzles/penetrations are in correct locations
- Vent duct assembly construction/weld quality/DPT requirements

Once the cage is inspected and approved, the purchaser's representative should stay and witness at least the initial stages of tube loading. Typically, if there are going to be any problems with tube loading, they will manifest themselves in the first couple of rows. This is where the bend radii are the tightest and there is the least amount of flexibility in the U-bends. Therefore, the differences in tolerances between the tubes and the supports are more critical. It is also important to ensure that the crew loading the tubes are being conscientious and handling the tubing properly (i.e., wearing gloves, not pushing the tubes in too fast or with too much force that could results in scratching or damage to the tubes).

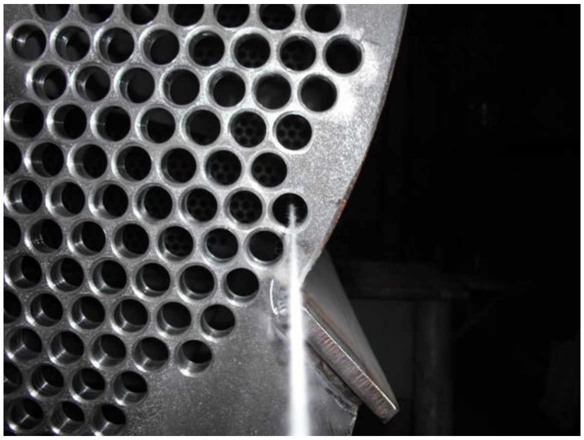

Fig 7 – Checking alignment with taut string

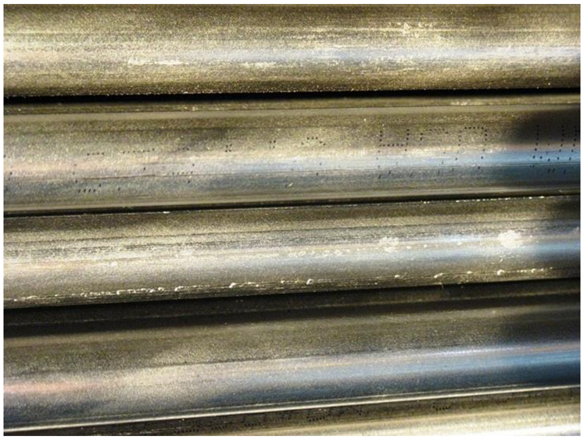

Fig 8 – Scratching of tubing upon insertion

Fig 9 – Tube Bundle Assembly

Shell

The bundle is inserted into the shell shortly after the completion of tube loading. The shell is typically fabricated in parallel with the tube bundle. Similar to the baffles and supports, this inspection is typically conducted concurrently with another inspection and typically does not require a separate trip to the manufacturer's facility. The inspector should verify the following:

- Nozzle location, size and weld prep
- Shell diameter, wall thickness and overall length
- Support and other miscellaneous lug location
- All welds have been properly NDE tested as required by the specification or code

Prior to the bundle insertion to the shell, both the tube bundle and the shell should be checked for any foreign material.

Fig 10 – Verification of Nozzle Placement

Fig 11 – Check of Shell Thickness

Fig 12 – Bundle insertion into Shell

Tube-to-tubesheet welding/expansion

Following the bundle insertion into the shell, the tubes are welded to the tubesheet if required by the specification. Prior to expansion of the tubes to the tubesheet, these joint welds should be tested to ensure they do not leak. This is typically done by pressurizing the shell side with air or helium and then using either a soap bubble solution or helium detector to check for any leak paths from the shell side to the tube side. Additionally, the all of the joint welds should be dye penetrant tested before and after expansion to ensure that they did not crack during the expansion process.

Regardless of the type of expansion process used, a percentage of the tubesheet holes should be identified as "control holes" in order to quantify the amount of tube expansion and ensure that the resultant tube wall reduction is in accordance with the Vendor's procedures or the specification. When witnessing the above processes, the inspector should:

- Verify pressure gages are with calibration
- Shell pressure is maintained for the required period of time
- All welds are free from cracks, splits and leakage at tube ends
- Range of required tube wall reduction is achieved during expansion process.

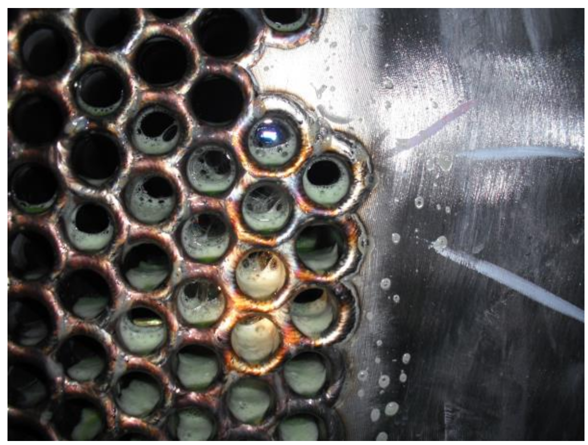

Fig 13 – DPT of Tube to Tubesheet Welds   Fig 14 – Soap bubble solution applied to test welds

Hydrostatic Testing

Following tube expansion, final assembly of the channel occurs. This includes installation of the hemi-head (based on the design), channel internal pass partition plates and the channel cover. Following assembly, the heater is subject to a final hydrostatic test on both the shell side and the tube side. While the ASME Authorized Inspector is required to witness these tests, many utilities decide to send their representative as well since it is the final test that the heater is subjected to prior to shipment. When witnessing a hydrostatic test, the inspector should verify:

- All pressure gages are within calibration

- The pressure gage reading is consistent with the specification/code requirements
- The pressure is maintained for the appropriate amount of time/number of cycles.
- Hydro water temperature is well above the Nil-Ductility temperature for the materials of construction.

Although the tube side and shell side hydrostatic tests are the last major witness point, several other processes occur before the heater is shipped. After the hydro, the tube side and the shell side is evacuated and dried out and then pressurized with nitrogen. If not already done, the heater must be painted if specified. Finally, the heater must be properly fastened and secured to the shipping skid mount.

Fig 15 – Heater prepared for shipment

Conclusion

As discussed, there are several parts of the heater fabrication process that warrant independent inspection by the Purchaser beyond the Vendor's own QA department. The amount of time and effort expended in conducting these inspections are well worth it, however they are often forgotten or overlooked as part of the overall procurement process. Identifying and correcting a problem during fabrication that will prevent a problem in operation easily justifies the expense. As the saying goes, "You get what you inspect, not what you expect".