HEADER TYPE FEEDWATER HEATERS AS RETROFITS FOR CYCLING UNITS

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ABSTRACT

Header type feedwater heaters have lower maximum stresses during transient operating condition and therefore fewer potential failure mechanisms than tubesheet heaters. The header type heater was developed in Europe and widely used there and elsewhere. All utility closed high-pressure feedwater heaters in the U.S. were of conventional tubesheet type design. The design limitations of tubesheet type feedwater heaters (FWHs) under cycling operation have impaired the reliability of these FWHs. The header type FWH provides a potential solution to this problem. Numerous ABB header type heaters are in service and the first U.S. application has paved the way for this promising technology in that country.

DESIGN DESCRIPTION

The header type, high pressure feedwater heater has been developed to meet the increasingly severe operating conditions in large turbogenerator plants. These may include high heat rates, sudden load variations and frequent start-ups and shut-downs, in the case of peak-load power stations.

Header feedwater heaters (Fig. 2) consist of a tube bundle with multiple bend tube coils enclosed in a shell. By means of nipples the tubes are individually welded to separate inlet and outlet header pipes (Fig. 5 and 6).

The major advantages of a header feedwater heater are inherent in its configuration. With this configuration, the cylindrical headers require only relatively thin walls, compared with tubesheet heaters (Fig. 1) designed for the same operating conditions (mass flow, pressure, temperature). The wall thickness of the headers is only 10-20% of the wall thickness in the tubesheet heaters.

Header type heaters are designed as single zone, two zone or three zone heaters with a condensing section and integral drain cooling section (two zones), or with a condensing section, an integral desuperheater and an integral drain cooler section (three zones). It is also possible to build the heaters as straight condensing heat exchangers (single zone). The type chosen is governed by thermal data, economy and mode of operation.

Header type heaters are built for vertical (Fig. 2) or horizontal arrangements (Fig. 3). The horizontal header heaters with an integral subcooler section are normally equipped with a partial-bundle, full-length and completely flooded drain subcooler (Figs. 3 and 4).

The configuration of the tube bundle and the steam path in the condensing section assures minimum steamside pressure losses and optimum removal of incondensible gases over the entire bundle length.

In heaters with an integral drain cooler zone the condensate flows around the tubes with a flow geometry similar to that existing in the integral desuperheater zone.
The tube bundle carrier consists of longitudinal beams, retaining and tube support grids. The bundle carrier is designed to protect the tubes from deformation and vibration, while allowing them to expand freely. The bundle support structure allows the shell to expand freely and the bundle to be dismantled easily.

By means of grid type support designs, the steam flow in the desuperheating zone and the condensate flow in the drain cooler zone reduce pressure losses in these regions.

The relatively greater size and weight of the header type heater makes retrofit replacement of existing tubesheet heaters difficult in some cases because of space limitations.

OPERATIONAL BEHAVIOUR

High stress levels occur during load cycling and transient conditions of a power plant. By eliminating the need to use thick tubesheets in the heater, thermal stress levels are minimized. With header type heaters a higher number of start-up and shut-down cycles and faster heat-up rates can be achieved with regard to the life time of the heater. On the other hand in many applications header type heaters are larger in size and weight, i.e. more expensive than the equivalent tubesheet type design.

No tube vibration problems have been reported for header type heaters. Tube vibration can be prevented by means of tube support designs and by varying different parameters.

In heaters with an integral desuperheating section the extraction steam first passes through the desuperheater in counterflow before entering the condensing section. The desuperheater is laid out such that the steam has adequate residual superheat before entering the condensing section. This ensures that the tube surface in the desuperheater remains dry in all cases of operation, thus avoiding tube erosion-corrosion.

Optimum water velocity: The feedwater flows in the tubes and the feedwater pressure drop is given by the tube diameter and the feedwater velocity in the tubes. This velocity must therefore be determined by an economical optimization. Excessive velocities that would lead to erosion at the tube inlet or other exposed parts must be avoided.

Experience and flow tests indicate that erosion in low-alloyed carbon steel tubes is not governed by feedwater velocity alone but in addition by feedwater turbulence, pH value and temperature of feedwater, and oxygen concentration in the feedwater. The economic feedwater velocities in the tubes of tubesheet types are usually < 3 m/s.

In header type feedwater heaters there is a further critical point in the header area, i.e. the bend in the tubes following a short straight stretch (Fig. 6). Now that the VGB guidelines for heat exchangers - R 110 L - stipulate a max. velocity of 2 m/s, a higher velocity is rarely selected even in cases where the calculated optimum lies considerably above it.

The long-term economic advantage of the header type heater, resulting from increased equipment life and a superior service factor especially under cyclic operation, often justifies the choice of a header type heater rather than a tubesheet type.
ABB HEADER TYPE HEATERS IN OPERATION:

Header type heaters of ABB technology have been manufactured and are successfully employed in several countries.

BORSSELE APPLICATIONS

In 1986 2 x 6 HP header type heaters were manufactured for the Borssele 300 MW power station (Netherlands). Figures 5 and 7 show two phases in the manufacture of the heaters at the works of B.V. Kon.Mij. de Schelde using licensed technology from Asea Brown Boveri (ABB). The Borssele HP heaters are of vertical design.

The Heaters 5 and 6 are constructed with a condensing section and integral drain cooler. Heaters 7 and 8 are constructed with a condensing section, integral desuperheater and integral drain cooler. The two heaters at the top are desuperheaters. The max. feedwater velocity in all these heaters is 2 m/s.

A summary of the heater design is contained in the following table:

<table>
<thead>
<tr>
<th>Heaters</th>
<th>Design Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heater 5</td>
<td>262 tubes, 26.9 mm O.D., 2.4 mm wall thickness, 1730 mm shell O.D., 8.75 m long</td>
</tr>
<tr>
<td>Heater 6</td>
<td>276 tubes, 26.9 mm O.I.D., 2.6 mm wall thickness, 1790 mm shell O.D., 9.15 m long</td>
</tr>
<tr>
<td>Heater 7</td>
<td>296 tubes, 26.9 mm O.D., 2.8 mm wall thickness, 1810 mm shell O.D., 11.25 m long</td>
</tr>
<tr>
<td>Heater 8</td>
<td>328 tubes, 26.9 mm O.I.D., 2.9 mm wall thickness, 1890 mm shell O.D., 9.25 m long</td>
</tr>
<tr>
<td>Desuperheater 9 and 10</td>
<td>108 tubes, 26.9 mm O.I.D., 2.9 mm wall thickness, 1400 mm shell O.D., 5.6 m long</td>
</tr>
</tbody>
</table>

The tests were performed by KEMA and the results have confirmed the theoretical values of the temperatures and the heat flux. The heaters have operating successfully since 1987.

LILCO-GLENWOOD APPLICATIONS

EPRI sought a participant for a host utility in a header heater retrofit project. The object was to demonstrate the promising feedwater heater technology to the U.S. utility industry. Under EPRI research project RP 1403-46, "Procurement and Demonstration of Header type Feedwater Heater Retrofits for Improved Cycling Fossil Power Plants", EPRI and LILCO (Long Island Lighting Co.) jointly demonstrated in 1990 the first U.S. retrofit at LILCO's Glenwood Power Station Unit 5, of 100 MW. It is a load-following unit and frequently peaks at weekends.

Specifications for the new feedwater heater were developed on the basis of U.S. and European standards. The header feedwater heater was manufactured by Yuba Heat
Transfer using the licensed technology from Asea Brown Boveri (ABB). The heater was installed in the summer of 1991.

The heater is arranged horizontally with a condensing section, integral drain cooling section and integral desuperheater (Fig.3). The heater tubes are connected to the headers by means of nipples. The tubes are supported with bands in grid type supports. Figure 8 shows the heater after operating. A summary of the heater design is contained in the following table:

<table>
<thead>
<tr>
<th>Design Summary of Glenwood Header type Heater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubes</td>
</tr>
<tr>
<td>219 tubes, 7/8&quot; O.D., 0.075&quot; wall thickness</td>
</tr>
<tr>
<td>SA-209-T1A material</td>
</tr>
<tr>
<td>Headers</td>
</tr>
<tr>
<td>11-7/8&quot; I.D., 1&quot; wall thickness</td>
</tr>
<tr>
<td>SA-508 Cl.3 material</td>
</tr>
<tr>
<td>Shell</td>
</tr>
<tr>
<td>64.5&quot; O.D., 34&quot; 10&quot; long, 1.25&quot; wall thickness</td>
</tr>
<tr>
<td>SA-387-11 Cl.1 material</td>
</tr>
<tr>
<td>Heater Characteristics</td>
</tr>
<tr>
<td>8.5 psi tube side ( \Delta p ), 0.6 psi shell side ( \Delta p )</td>
</tr>
<tr>
<td>5.38 ft/sec tube side velocity</td>
</tr>
</tbody>
</table>

The Temperature Surface Diagram (Fig. 9) shows the design data of temperatures on feedwater and shell side in the three heat transfer zones.

**GLENWOOD PERFORMANCE TEST**

Since this is the first time that this type of heater has been installed in U.S., a rigorous quality assurance program and a performance test program were developed. The programs were developed to determine the thermal performance of the heater and characterization of the mechanical and operating flexibility under different operating conditions.

The independent test was performed by ENCOR-America. ABB had technical observer status only.

The test program covered acceptance testing for thermal, hydraulic and mechanical performance of the heater, as well as its whole range of operation including variations in load, hot and cold start-ups.

In addition to the pressure, temperature and flow measurements, the outlet header on this heater was provided with strain gages in the higher stressed areas in order to demonstrate the lower peak stresses with this heater during transients in comparison with the conventional tubesheet design.

The final acceptance test was performed on February 25, 1992. The heater was tested at full unit load (99 MW) and under steady state conditions. Heater performance was evaluated with regard to the terminal temperature difference of the desuperheater zone, temperature rise of feedwater between outlet and inlet, approach temperature difference of the drain cooler, remaining superheat at the outlet of the desuperheating zone and pressure loss across the feedwater and shell sides.
The test results have confirmed the theoretical values of the temperatures and heat flux. According to the acceptance test results, the header type heater exceeded all acceptance criteria.

In addition to the steady state test, separate tests of mechanical stress levels during load changes in and around the headers were made. Initial strain gage readings indicated that very low levels of stress were measured in these areas during the transient conditions.

CONCLUSIONS

The greatest merit of the header design lies in its high flexibility with respect to transient operating conditions. The design minimizes thermal stresses by isolating the cold water from the hot water stream.

The long-term economic advantage of the header type heater, resulting from increased equipment life and a superior service factor, especially in cyclic operation, often justifies the choice of a header type heater rather than a tubesheet type.

The retrofit header type heater Glenwood has been successfully completed, and provides improved efficiency, operating flexibility and long term reliability. According to the results of the acceptance test which was performed by ENCOR-America the header type heater exceeded all acceptance criteria.

REFERENCES

1. EPRI RP1403-22, Feedwater Heater R&D for Improved Coal-fired Power Plants, TB.GS.46.7.88, 1988


3. EPRI CS/NP-3743, Symposium on State-of-the-Art Feedwater Heater Technology, 1984

4. A. Sonnenmoser: Design Considerations for and Experience with Feed heaters. EPRI workshop feedwater heaters, March 1979

Fig. 1. Tubesheet Type Heater  
Fig. 2. Header Type Heater  
Fig. 3. Horizontal Header Type Heater Design
Fig. 4. Cross section of Horizontal Header Type Heater with divided Drain Cooler

Fig. 5. Fabrication of Borssele Header Type Heater

Fig. 6. Tube bends in the Area of the Header

Fig. 7. Fabrication of Tubes to Header (Borssele)
Fig. 8. Glenwood Header Type Feedwater Heater

Fig. 9. Temperature Surface Diagram of Glenwood Header Type Heater (Design Data)

A: Partial Bundle with two Sections (2) and (3)
B: Partial Bundle with three Sections (1), (2) and (3)