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HEADER TYPE FEEDWATER HEATERS AS RETROFITS FOR CYCLING UNITS

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ABSTRACT

Header type water-heaters have lower maximum stresses during transient operating conditions and therefore lower potential fatigue mechanisms than tube-sheet type header. The header type heater was developed in Europe and widely used there and elsewhere. All utility class high-pressure water-heaters in the U.S. were in conventional tube-sheet type design. The design limitations of tube-sheet type header water-heaters (FWH) under cavitition operation have impeded the reliability of these FWHs. The header type FWH provides a potential solution to this problem. Numerous AEC header type boilers are in service, and the first U.S. application has shown the way for the promising technology in that country.

DESIGN DESCRIPTION

The header type, high-pressure water-heaters have been developed to meet the increasing service operating conditions in large water-heaters, which may include high load rates, sudden load variations and frequent start-ups and shut-downs. In the case of pressurization power stations.

The header type water-heaters (Fig. 1) consist of a tube bundle with multiple header coils connected together by means of pipes that are individually welded to separate inlet and outlet header pipes (Fig. 5 and 6).

The advantages of a header type water-heater are inherent in its configuration. With this configuration, the cylindrical headers require only relatively thin walls, compared with sheet-type headers (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 tube-sheet type.

Header type headers are designed as single zone, two zone or three zone headers 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 headers as straight condensing heat exchangers (large type). The type chosen is governed by thermal data, economy and mode of operation.

Header type headers 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 partly flooded drain subcooler (Fig. 2).

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

In headers 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 heater consists of longitudinal bundles containing 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 or plate 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 header makes retrofit replacement of existing tube-sheet heater difficult in some cases because of space limitations.

OPERATIONAL BEHAVIOUR

High stress levels occur during start-up and transient conditions of a power plant. By minimizing the need to use high temperatures in the heater, thermal stress levels are minimized. With header type heaters, a higher number of start-ups and shut-down cycles and lower 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 tube-sheet 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 headers with an integral desuperheating section the steam flow is forced through the desuperheater in countercurrent flow, before entering the condensing section. The desuperheater is laid out such that the elements are spaced at sufficient distances before entering the condensing section. This ensures that the tube surfaces are not affected by radiation heat transfer, which could lead to erosion at the tube inlet or other exposed parts must be avoided.

Optimum water velocity: The water velocity in the tubes and the water flow pressure drop between the tube diameters and the header velocity in the tubes. Higher velocities lead to increased erosion. 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-carbon steel tube banks is not governed by feedwater velocity alone but in addition by feedwater turbulence, pH, kL values and temperature of feedwater, and oxygen concentration in the feedwater. The economic feedwater velocities in the tubes of tube-sheet type are usually 4-6 ft/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. 8). Note that the VGB guidelines for heat exchangers - R 110 L - stipulate a max. velocity of 2 m/s. A higher velocity is rarely accepted 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, then justifies the choice of a header type heater rather than a tube-sheet type.
ABB HEADER TYPE HEATERS IN OPERATION:

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

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 the heated sections of the header. The headers are manufactured by ABB (ABBA). The Borssele HP heaters are of vertical design.

The headers 5 and 6 are constructed with a condensing section and integral drain cooler. Headers 7 and 8 are constructed with a condensing section, integral desuperheater and integral drain cooler. The two headers at the top are desuperheaters. The inlet fluid velocity at all three headers is 2 m/s.

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

<table>
<thead>
<tr>
<th>Design Summary of Borssele Header Type Heaters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Header 5</td>
</tr>
<tr>
<td>292 tubes, 26.5 mm O.D., 2.4 mm wall thickness, 1730 mm shell O.D., 4.75 in long</td>
</tr>
<tr>
<td>Header 6</td>
</tr>
<tr>
<td>279 tubes, 26.0 mm O.D., 2.6 mm wall thickness, 1780 mm shell O.D., 4.25 in long</td>
</tr>
<tr>
<td>Header 7</td>
</tr>
<tr>
<td>258 tubes, 26.8 mm O.D., 2.8 mm wall thickness, 1810 mm shell O.D., 4.25 in long</td>
</tr>
<tr>
<td>Header 8</td>
</tr>
<tr>
<td>229 tubes, 26.9 mm O.D., 2.9 mm wall thickness, 1900 mm shell O.D., 4.25 in long</td>
</tr>
<tr>
<td>Desuperheater 9 and 10</td>
</tr>
<tr>
<td>108 tubes, 26.3 mm O.D., 2.6 mm wall thickness, 1460 mm shell O.D., 5.6 in long</td>
</tr>
</tbody>
</table>

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

LILCO-GLENWOOD APPLICATIONS

EPRI sought a partner for a host utility in a header heater retrofit project. The client was to demonstrate the promising feedwater heater technology to the U.S. utility industry. Under EPRI research project RP 1400-04, Houdaille and Demonstration of Header type Feedwater heater Retrofits for Improved Cycling Feasibility. The U.S. and U.K. teams jointly demonstrated in 1980 the first U.S. retrofit at LILCO's Glenwood Power Station Unit B, of 100 MW. It is a turbine-following unit and frequently peaks at weekend.

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 license, technology from Asse Boulevard ABB. The heater was installed in the summer of 1985.

The header has a horizontal section, integral drain cooling section and integral desuperheater. The header tubes are connected to the headers by means of nipples. The tubes are supported with bands in grid type supports. Figure 6 shows the header. The design of the header 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, 14.6 mm O.D., 0.093 in wall thickness, SA-203-T1/A material</td>
</tr>
<tr>
<td>Headers</td>
</tr>
<tr>
<td>11-7/8 in O.D., 1 in wall thickness, SA-513-0.3 material</td>
</tr>
<tr>
<td>Shell</td>
</tr>
<tr>
<td>64.5 in O.D., 2 in wall thickness, SA-367-11.3 material</td>
</tr>
<tr>
<td>Heater characteristics</td>
</tr>
<tr>
<td>5.5 psi tube side 0.05 psi shell side 0.5 psi tube side 0.05 psi shell side 0.5 psi</td>
</tr>
</tbody>
</table>

The Temperature Surface Diagram (Fig. 9) shows the design data of temperatures on feedwater and steel side in the three tube 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 program was 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 wide range of operation including variations in load, fuel and inlet steam temperature. In addition to the pressure, temperature and flow measurements, the outlet header was provided with drain gages in the higher rated areas to demonstrate the lower peak stresses with this heater during transients in comparison with the conventional subcooler design.

The final acceptance test was performed on February 16, 1985. The heater was tested at full load (99 MW) and under steady state conditions. Header performance was evaluated with regard to the terminal temperature difference of the desuperheater zone, temperature data of feedwater between outlet and inlet, approaches temperature difference of the drain cooler, remaining superheat at the outlet of the desuperheater zone and pressure loss across the feedwater and shell side.
The test results have confirmed the theoretical nature of the temperature and heat distribution. According to the acceptance test results, the header-type heater exceeded all acceptance criteria.

In addition to the normal step tests, specific tests of monitored steam 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 stress by isolating the feedwater from the hot water stream.

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

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

REFERENCES
