Presentation to Feedwater System Reliability Users Group
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Jim Sechrist, Manager, Market Application – Westinghouse Electric Company, LLC
## Agenda

<table>
<thead>
<tr>
<th>Topic</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introductions</td>
<td>J. Sechrist</td>
</tr>
<tr>
<td>SPFHW Description</td>
<td>J. Sechrist</td>
</tr>
<tr>
<td>SPFHW Prototype Testing</td>
<td>P. Mickus</td>
</tr>
<tr>
<td>SPFHW Maintenance &amp; Servicing Schemes</td>
<td>P. Mickus</td>
</tr>
<tr>
<td>Questions</td>
<td>All</td>
</tr>
</tbody>
</table>
Shell & Plate Low Pressure FWH
Shell & Plate Feedwater Heater Description

Westinghouse Electric Company and Tranter Inc. have collaborated to develop the modular, low-pressure, horizontal Shell and Plate Feedwater Heater (SPFWH™) heat exchanger product

- Addresses Shell and Tube FWH design challenges of:
  - Component degradation due to FIV and FAC
  - Limited shell and tube side access
  - Loss of system thermal and hydraulic performance over time
Key Features – Heat Transfer Plates

• In this design, heat transfer surface is comprised of welded heat transfer plates
• Corrugated heat transfer plates are pressed from a single sheet of metal (i.e. 316L SS)
• Designed for pressures and temperatures consistent with Low Pressure FWH applications
• Corrugated plates create highly turbulent flow resulting in high heat transfer coefficients
Key Feature – Counter Current Flow HX

- Flow channels created by welded plates
- Plates function as pressure boundary and heat transfer surface between two fluids
- Counter current flow provides maximum thermal efficiency
- Shell side (steam) heat transfer
  - Condensing
  - Sub-cooled liquid forced convection
- Plate side (FW) heat transfer
  - Forced convection
Key Features - Welded Plate Modules

- 2 plates are welded together to make a cassette. Cassettes are welded together at the circumferential joints to make a module.

- Plate Core Assembly made up of plate modules connected to each other by welds or gaskets and connecting hardware.
Design Advantage – Resistance to common degradation mechanisms

- Reduced potential for common degradation mechanisms
- Potential for Flow Accelerated Corrosion (FAC) is minimized by selecting high quality alloy materials
  - Stainless steel (316L) plates
  - 0.1% chrome material used in all areas susceptible to FAC
- Potential for Flow Induced Vibration (FIV) is significantly reduced due to a heat transfer plate geometry that features tightly-spaced, corrugated plate-to-plate contact points which are typically less than ~ 0.5” apart. This configuration is fundamentally different than “long span” supported tubes.
Westinghouse and Tranter Present a New Feedwater Heater Design

Modular Low Pressure Shell and Plate Feedwater Heater (SPFWH)

- Removable Head
- Feedwater Outlet Nozzle
- Feedwater Inlet Nozzle
- Replaceable Heat Transfer Plates
- Full Access to Shell for Inspection
- Drain Outlet Nozzle
- Drain Inlet Nozzles
- Extraction Steam Nozzle
- Extraction Steam Nozzle
SPFWH
Relevant Experience, Key Features, & Innovation

Key Features/Differentiators

• Welded heat transfer plates replace tubes
• Common degradation mechanisms (FIV & FAC) are minimized due to plate geometry and material selection
• Component inspection and maintenance is improved because removable head provides easy access to plates and shell
• Long-term performance is improved since heat transfer plates can be easily replaced

WEC/Tranter Experience

• Design represents an extension of existing Tranter Shell & Plate heat exchangers of which Tranter has sold over 7000
• Prototype fabricated and tested to validate the functionality of design and benchmark correlations
• Developed SPFWH design to meet specifications for AP1000 LPFWH No 3A/B and 4A/B
  – Smaller footprint – (11ft - 14 ft length)
  – Approximately 30% lower cost
  – Under consideration for use in future AP1000 plants
SPFWH - Prototype Testing
Prototype Test Objectives

• Provide a test demonstration of the major design concepts in an integrated scale model test.
• Provide experimental validation of design tools used for prediction of overall performance.
• Tests performed included:
  – Hydrostatic Test
  – Heat-up / Cool-down Test
  – Level Test
  – Vent Test
  – Nominal Design Condition Test
  – Abnormal Design Condition Test
  – Fatigue Test
Prototype Design

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Prototype</th>
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<tbody>
<tr>
<td>Plate Model Number</td>
<td>SPW-40</td>
</tr>
<tr>
<td>Plate Material</td>
<td>316L Stainless Steel</td>
</tr>
<tr>
<td>Outer diameter of plate, mm (in.)</td>
<td>440 (17.3)</td>
</tr>
<tr>
<td>Port diameter of plate, mm (in.)</td>
<td>80 (3.1)</td>
</tr>
<tr>
<td>Plate thickness, mm (in.)</td>
<td>0.6 (0.024)</td>
</tr>
<tr>
<td>Number of modules</td>
<td>3</td>
</tr>
<tr>
<td>Flow configuration</td>
<td>Counter-current flow</td>
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</tbody>
</table>
# Test Conditions

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet vapor pressure, kPa (psia)</td>
<td>117 – 662 (17 - 96.2)</td>
</tr>
<tr>
<td>Inlet vapor temperature, °C (°F)</td>
<td>104 – 163 (219 – 325)</td>
</tr>
<tr>
<td>Drain Cooler Approach (DCA) temperature, Δ°C (Δ°F)</td>
<td>0 – 87 (0 - 157)</td>
</tr>
<tr>
<td>Terminal Temperature Difference (TTD), Δ°C (Δ°F)</td>
<td>3.9 – 129 (7 -232)</td>
</tr>
<tr>
<td>Outlet condensate sub-cooling, Δ°C (Δ°F)</td>
<td>0 – 127 (0 - 229)</td>
</tr>
<tr>
<td>Heat duty, kW (MMBTU/hr) based on cold side</td>
<td>52.8 - 721.0 (0.18 - 2.46)</td>
</tr>
<tr>
<td>Number of data points</td>
<td>82</td>
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Conclusions

• The prototype test program objectives have been met.
• The test results:
  – demonstrate that the close thermal approaches required of a high performing feedwater heater are achievable with a properly sized SPFWH™ heat exchanger in an appropriately designed and operated feedwater system
  – indicate that the SPFWH™ heat exchanger design is a viable alternative to a shell-and-tube type heat exchanger due to the performance, compactness, modularity, and robustness of the new design.
SPFWH Maintenance and Servicing Schemes
Leak Detection

Note: Leakage during operation is determined via use of level control alarm in shell to detect feedwater breach into Condensing section

- Depressurize system and drain vessel and plate pack
- Remove spool pieces
Leak Detection

- Install blind flanges with dripless disconnects
- Perform high pressure test – check cross leakage on shell side inspection port
- If leak is present remove core and perform soap bubble test
Core Removal

- Remove head bolts
- Pull crane used to remove core
- Install rail extensions
Core Removal (no wheel assemblies)

- Pull core out using lateral lugs
- Install blocking around tie rods
- Lift core with vertical lugs
- Low pressure soap bubble test to verify leak location
Core Removal (with roller assemblies)

- Loosen nuts on all tie rods.
- Slide clamping plate away from core assembly to provide room for module movement.
- Remove tie rods on top half of the unit.
- Use jacking bolts to separate the last module from the core assembly.
- Repeat module movement as required to provide access to the module to be repaired / replaced.

- Remove module from core assembly
- Service or replace module as appropriate.
- Reverse steps, replacing any gaskets associated with modules that have been separated.
- Reassemble clamping plate and tie rods.
- Perform visual inspection on unit.
- Perform low pressure air and soap bubble test.
- Install new head flange gasket.
Module Removal/Replacement

Note: The modular design allows removal of any plate module without breaking any welds, or if fully welded, connecting joints between modules contain a small, circumferential weld that can be ground and rewelded in a short amount of time.
Core Cleaning

• How would the plates be cleaned, if necessary? What is the process to clean and the cost?
  – Plates can be cleaned at site or sent to Tranter Service Center for cleaning

Hydroblast
Core Cleaning

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  - Plates can be cleaned at site or sent to Tranter Service Center for cleaning
Failure Rates

- Based upon ~ 5000 Units in service have 1-2 failures/year. Therefore overall failure rate = 0.05%
- Given average unit has ~ 80 plates even if all failures were plate failures = .001% of plates
Distortion of Plates

- There are no gaskets in Shell & Plate that provide with reaction forces during compression of the gaskets — ~30% gasket compression
- Shell & Plate use very low compression forces to prepare for welding
- During final assembly of the core, approximately 100 tons of compressive force ensure 100% metal to metal contact of all plates
Maximum Design Temperature

- Design pressures and temperatures are consistent with Low Pressure Feedwater Heater applications
  - Maximum design pressure for shell and plate feedwater heater is as follows:
    - Fully welded – 1000F
    - Modular welded – 1000F
    - Modular gasketed – 366F
Maximum Pressure Drops

• What is the Plate and Shell side Delta P?
  – Plate side Delta P (feedwater) – 13.2 psi allowed and 5.94 psi calculated
  – Shell side Delta P – (steam) – 5.6 psi allowed and 2.2 psi calculated
Fouling

• Is there a concern on fouling of the plates?
  – Feedwater heater system is non-biological (clean water coming in). Given this and the fact that there are high flow velocities and turbulent flow in plates, fouling is not a concern
  – Maximum Particle Size – Shell and plate heat exchangers feature tightly spaced, corrugated channels that develop high heat transfer rates. As such, particle size is limited to 50% of the plate gap. Plate gap for this proposal is 2.1mm and therefore the maximum particle size is 1.0mm
Wrap Up & Discussion