2017 FSRUG
Thermal Performance
Feedwater Heater Troubleshooting
Feedwater Heater Troubleshooting

General Discussion on the process

Example walkthrough
Feedwater Heater Troubleshooting - know the boundary conditions

Two Zone Feedwater Heater
TTD 5F
DCA 10F
Temp Rise 53 F

Feedwater Flow
Outlet
2,788,698 lbm/hr
291 psia
212.4 F

Upstream Heater Drain
206,507 lbm/hr
56.8 psia
224.0 F

Extraction Steam
162,987 lbm/hr
16.3 psia
217.4 F

Feedwater Flow Inlet
2,788,698 lbm/hr
300 psia
159.5 F
128.1 BTU/lbm

FW Heater Drain Outlet
369,494 lbm/hr
169.5 F
137.5
Understand Actual Plant Configuration
Know What is Inside
## Troubleshooting Entry Points

<table>
<thead>
<tr>
<th>MW Output Is Lower Than Expected And The Cause Is Not Obvious.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final FW temperature is lower than expected.</td>
</tr>
<tr>
<td>Operations Personnel Have Observed An Abnormal Condition In Feedwater Heater Operation.</td>
</tr>
<tr>
<td>Trending And Monitoring Activities Have Detected An Unexpected Change In DCA, TTD Or Temperature Rise (TR).</td>
</tr>
</tbody>
</table>
Questions to Ask

- What kind of change has occurred; a step change or a gradual change?
- Did other indications occur simultaneously with other equipment: Turbine Extraction Pressures, Dump Valves Opening?
- Has there been a significant change in ambient conditions?
- Has there been a recent plant transient or other abnormal operating conditions such as a condensate pump or heater drain pump out of service?
- Was there any major work performed recently?
- Was any maintenance or calibration recently performed on the instrument, data acquisition system, or plant computer settings?
Common Problems

Instrument Issues

- Seldom calibrated
- Step change could indicate instrument failure
- Validate with alternate instrument or heat balance if possible

Level Control Issues

- Adjustments not reset for normal operation after transient
- Wear on pneumatic controllers causing erratic control
- Uneven upstream drain flows causing level oscillations
- Binding valve stems, improper dampening
- Proportional band controllers need to be tuned
- Low and high level controller setpoints overlap
Common Problems

Performance following startup is important!

- Bypass valves opened during startup not fully closed
- Startup vents not fully closed
- FWH level or normal level control valve positions different from pre-outage
Feedwater Heater Parameters

- Shell Pressure
- Terminal temperature difference TTD
  - $\text{TTD} = \text{Shell saturation temp} - \text{tube outlet temp}$
- Drain cooler approach temperature DCA
  - $\text{DCA} = \text{Drain outlet} - \text{tube inlet}$
- Temperature rise across heater
  - $\text{FW Delta T} = \text{Tube outlet}$
- Feed water heater level
## Feedwater Heater Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Purpose</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell-side pressure</td>
<td>TTD, Obtain extraction steam saturation</td>
<td>If not measured directly on shell, compare steam inlet pressure and shell side temperature, if available, to account for pressure drop at steam inlet nozzle.</td>
</tr>
<tr>
<td></td>
<td>temperature from shell pressure</td>
<td></td>
</tr>
<tr>
<td>Drain Cooler Differential Pressure</td>
<td>Assess Drain Cooler Damage</td>
<td></td>
</tr>
<tr>
<td>Feedwater inlet temperature</td>
<td>DCA, FW delta-t</td>
<td></td>
</tr>
<tr>
<td>Feedwater outlet temperature</td>
<td>TTD, FW delta-t</td>
<td></td>
</tr>
<tr>
<td>Extraction steam temperature</td>
<td>TTD (alternate indication)</td>
<td>Reading from a steam pipe instrument may not reflect shell pressure and saturation temperature of interest. If a shell temperature reading, it should corroborate the shell-side pressure for saturated steam conditions.</td>
</tr>
<tr>
<td>Feedwater flow</td>
<td></td>
<td>May not be measured directly for condensate flow.</td>
</tr>
<tr>
<td>Shell-side level</td>
<td>Level control verification</td>
<td></td>
</tr>
<tr>
<td>Heater drain outlet temperature</td>
<td>DCA</td>
<td></td>
</tr>
<tr>
<td>Drain cooler flow</td>
<td>Tube leak detection</td>
<td>Infrequently measured value. An indirect indication of change may exist from level control valve position change (and air signal demand, if pneumatic controlled)</td>
</tr>
</tbody>
</table>
Drain Cooler Damage
And setting Heater Levels

Detail of the drain cooler section

- tube bundle
- end plate
- baffles
- shroud
- tube sheet
- water level
- shell
- exit

Knee curve
## Basic Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTD Too High</td>
</tr>
<tr>
<td>TTD Too Low</td>
</tr>
<tr>
<td>DCA Too High</td>
</tr>
<tr>
<td>DCA Too Low</td>
</tr>
<tr>
<td>Temperature Rise Too High</td>
</tr>
<tr>
<td>Temperature Rise Too Low</td>
</tr>
<tr>
<td>High Level Dump Valve Partially Open Or Cycling Open</td>
</tr>
</tbody>
</table>
TTD Too High

Instrument Issues - common
- Extraction inlet or shell pressure indications biased high
- FW or condensate outlet temperature indications biased low

Increased Heat Transfer Load - common
- Upstream heater performance issues
- Upstream heater out of service
- Change in unit load (has there been an uprate?)
- Low shell pressure – extraction check valves partially closed

Partition Plate Bypass Flow – somewhat common
- Check for a decrease in the temperature rise with a slight increase in shell pressure at a nearly constant DCA
- Leakage at bolted joint of internal manway
- Cracked weld at heater shell (often overlooked)
TTD Too High

Operating Level Set Too High
- DCA may be lower (better) than expected

Startup Vents Open Or Operating Vents Closed/Degraded
- Startup vents may have been left open after an outage – check position
- Operating vents may have been left closed after an outage (slow increase in TTD which resets after shut down but returns again)

Heater Controlling Level On Alternate Drain Control
- Drain cooler damage
- Flashing in the drain line
- Normal level control valve full open

Excessive Plugged Tubes
- Verify changes following an outage
TTD Too High

- **Fouled Tubes - uncommon**
  - Decreased heat transfer coefficient, check for a decrease in cleanliness calculation

- **Bypass Valve Leaking Or Partially Open - uncommon**
  - Not heater problem, but measured TTD is high because outlet temperature is measured downstream of bypass flow
  - High drain flow, check drain valve position
  - Use mass/energy balance to identify leakage from tube side to shell side or change in total condensate flow

- **Tube Leak - common**
  - Outlet temperature measured too close to heater outlet

- **Design Issues - uncommon**
## TTD Too Low

<table>
<thead>
<tr>
<th>Category</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument Issues - common</td>
<td>• Extraction inlet or shell pressure reading too low</td>
</tr>
<tr>
<td></td>
<td>• FW or condensate outlet temperature too high</td>
</tr>
<tr>
<td>Superheated Extraction Steam -</td>
<td>• Possible for TTD to be negative</td>
</tr>
<tr>
<td>common</td>
<td>• On some nuclear first LP turbine extractions are superheated</td>
</tr>
<tr>
<td>Low Level - common</td>
<td>• Check if DCA is high for verification of lower than expected TTD</td>
</tr>
<tr>
<td>Bypass Valve Leakage - common</td>
<td>• Low flow through heater decreases heat duty</td>
</tr>
</tbody>
</table>

2017 FSRUG FWH Troubleshooting 17
**DCA Too High**

**Steam In The Drain Cooler - common**

- Very common in horizontal heaters with internal short end drain coolers due to shroud erosion or low level
- Check for popping or banging sounds inside heater
- Check for gradual trend over time
- Verify Heater level is normal

**Tube fouling – uncommon**

- Rule out other causes to determine if fouling is the cause unless all parameters to perform a heat balance are available including measured flows
- Schedule outage inspection with eddy current and cleaning

**Instrument Issues – less common**

- FW or condensate inlet temperature reading too low
- Heater drain temperature reading too high
DCA Too High

**Air Binding - uncommon**
- Check for proper alignment of start-up and operating vents
- More common after outages or plant transients
- Verify no damage to vent internal flow path

**Drain Cooler Internal Baffle or Shroud Damage**
- Prolonged operation with low level and steam flowing through drain cooler may eventually erode plates and tube support holes.
- Action: Check eddy current inspection results for indication of tube support erosion etc. in the vicinity of the shrouds or baffles.
DCA Too Low

**Instrument Issues**
- FW or condensate inlet temperature reading high
- Heater drain temperature reading low
- Refer to suspicious temperature or pressure readings entries in Table 1, Problem Solving Guide

**Normal Drain Line Isolated – common**
- Check drain line for isolation, obstructions or valve failed closed
- Schedule maintenance work for normal control valve malfunction

**High Heater Level – common**
- Check Heater level controls, setpoints.

**Tube Leak – uncommon**
- Check level, level controls and normal drain valve position.
- If investigation determines tube leakage is possible and removal from service is not warranted perform eddy current testing next
Temperature Rise Too High

**Instrument Issue**
- FW or condensate inlet temperature reading too low, OR,
- Heater outlet temperature indication too high
- Action: Refer to suspicious temperature readings entries in Problem Solving Guide

**Increased heat duty – common**
- Verify if upstream heater is isolated, bypassed, or performance is poor
- Adjust expected temperature rise with condenser pressure and condensate temperature (LP heaters only)
- Action: Ensure power uprate data has been incorporated into expected value
Temperature Rise Too High

**Downstream heater outlet temperature degraded**
- Action: Troubleshoot downstream heater to determine cause of reduction in outlet temperature such as partition plate leakage.
- Action: Verify heater bypass valve is not leaking (if outlet temperature is measured after bypass valve mixes back in).

**Extraction steam bellows failure on upstream heater**
- Abrupt drop in shell pressure
- Banging or roaring in condenser
Temperature Rise Too Low

**Instrument Issues**
- FW or condensate inlet temperature too high
- Heater outlet temperature too low

**Partition Plate Leakage**
- Check for higher than normal TTD, a slight increase in shell pressure, very little or no change in DCA, Normal Level Control valve

**Extraction Steam Bellows Failure**
- Abrupt drop in shell pressure
- Banging or roaring in condenser
Temperature Rise Too Low

**Tube fouling**
- Rule out other causes to determine if fouling is the cause unless all parameters perform a heat balance are available including measured flows.
- Schedule an outage inspection with eddy current testing and cleaning.

**Upstream Heater Performance Improvement**
- Increased shell pressure in upstream heater due to turbine upgrade

**Heater Bypass Valve Leaking Or Partially Open**
- Check for higher than normal TTD, a slight increase in shell pressure, very little or no change in DCA, Normal Level Control valve
Temperature Rise Too Low

- Non-Return Valve (bleeder trip, check valve) failure
- Extraction line isolation valve closed or failed
High Level Dump Open
(AKA Emergency Drain, Alternate Dump)

Steam In The Drain Cooler

- Very common in horizontal heaters with internal short end drain coolers due to shroud erosion or low level
- Check for popping or banging sounds inside heater
- Check control valve position and excessive drain line movement that indicates flashing in drain line
- Review Tube plugging maps for excessive tubes plugged in drain cooler section
- Check for gradual trend over time
- Verify Heater level is normal
- Schedule inspection to identify leakage into drain cooler locations.

Level Control Problem

- Troubleshoot controls - Compare valve control settings to historical settings (eg. 3-15 psi control setting)
- Check for jacked open valve
High Level Dump Open
(AKA Emergency Drain, Alternate Dump)

- Check for moisture in air system
- Check for tight packing on valves
- Check for air leaks in control air around controller and valve diaphragm.
- Inspect components for magnetite or sludge build up
- Verify air operator was not inadvertently left open

Level Control Valves or instruments have sluggish response or Jerky operation

Drain Valve Piping Undersized

- Could be a result of design change for future EPU
## Common Problem Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Symptoms</th>
<th>Possible Follow-up</th>
</tr>
</thead>
</table>
| Tube Fouling (reduction in heater transfer coefficient) | • TTD ↑  
• DCA ↑  
• LCV↓  
• TR ↓  
• Shell Pressure ↑  
• Tube side FW Flow →  
• Shell side Drain Flow ↓ | • Schedule heater for inspection and tube cleaning.  
• Tube fouling is usually a gradual process, check trends to verify. |
# Common Problem Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Symptoms</th>
<th>Possible Follow-up</th>
</tr>
</thead>
</table>
| Excessive Tube Plugging (reduction of heat transfer area) | • TTD ↑ →  
• DC A ↑  
• TR ↓ →  
• Shell Pressure ↑  
• Tube side FW Flow ↓  
• Shell Pressure Drop ↑  
• Heater Tube Side DP ↑ | • TTD increase might show up in a parallel heater  
• Start process to reclaim tubes, replace tube bundle, or replace entire heater  
• Consider drilling holes in partition plate to bypass heater and prevent partition plate failure |
# Common Problem Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Symptoms</th>
<th>Possible Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube Leak</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Drastic increase in shell side drain flow and an increase in condensate flow. | • TTD →  
• DCA ↓  
• LCV ↑  
• Level ↑  
• TR →  
• Shell Pressure →  
• Shell side Drain Flow ↑  
• Tube Side FW ↑  
• Total Condensate Flow ↑ | • Repair of tube leak likely to require short notice outage or power reduction for repair  
• Most common system is high heater level with high level control valve wide open |
## Common Problem Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Symptoms</th>
<th>Possible Follow-up</th>
</tr>
</thead>
</table>
| Drain Cooler Steam Intrusion (reduction of subcooling of drain flow due to steam entering drain cooler due to low level, end plate degradation or drain cooler shroud damage) | • TTD ➔  
• DCA ↑↑  
• LCV↑  
• TR ➔  
• Shell Pressure ➔  
• Tube Side FW Flow ➔  | • Check normal drain valve for full position  
• Check for high level drain valve to be open or cycling open  
• Check for waterhammer or excessive motion of drain line  
• Listen for waterhammer inside of heater near drain cooler region |
# Common Problem Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Symptoms</th>
<th>Possible Follow-up</th>
</tr>
</thead>
</table>
| Air Binding (Shell Side) (reduction of heat transfer area) | • TTD ↑  
• DCA ↑  
• TR ↓  
• Shell Pressure ↑  
• Feedwater Flow → | • Check for normal operating vent valve closed  
• Check for possible damage to air removal piping or duct  
• Design issue with air removal system |
## Common Problem Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Symptoms</th>
<th>Possible Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banging Sound From Heater</td>
<td>• TTD ↑* TTD will be down if leakage is due to low heater level.</td>
<td>• Likely steam leaking into drain cooler</td>
</tr>
<tr>
<td>(waterhammer)</td>
<td>• DCA ↑</td>
<td>• Schedule inspection to look for damage of drain cooler shroud</td>
</tr>
<tr>
<td></td>
<td>• TR →</td>
<td>• Check for proper level during operation</td>
</tr>
<tr>
<td></td>
<td>• Shell Pressure →</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Feedwater Flow →</td>
<td></td>
</tr>
</tbody>
</table>
## Common Problem Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Symptoms</th>
<th>Possible Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Level Control Valve Loss of Air</td>
<td>TTD↑</td>
<td>Troubleshoot and repair air supply and actuator</td>
</tr>
<tr>
<td></td>
<td>DCA↓, Level↑, LCV↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HLD↑</td>
<td></td>
</tr>
<tr>
<td>High Level Control Valve Loss of Air</td>
<td>TTD↓</td>
<td>Troubleshoot and repair air supply and actuator</td>
</tr>
<tr>
<td></td>
<td>DCA↑, Level↓, LCV↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HLD↑↑, Shell Pressure↓</td>
<td></td>
</tr>
</tbody>
</table>
### Common Problem Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Symptoms</th>
<th>Possible Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine Extraction Valve Failure</td>
<td>- TTD ↑</td>
<td>- System reaction is highly dependent on extraction geometry. Typically one heater will be starved for steam and the other heaters will be trying to make up the difference.</td>
</tr>
<tr>
<td></td>
<td>- DCA ↑</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- LCV ↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- TR ↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Shell Pressure ↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Tube side FW Flow →</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Shell side Drain Flow ↓</td>
<td></td>
</tr>
</tbody>
</table>
Scenario: TPE is working in their office on an evaluation for a corrective action report due by 5pm. *The phone rings.*

- Phone call from Control Room Supervisor (CRS)
  - reports a low temperature alarm at the outlet of heater 6S.
  - says he’s not familiar with alarm, may be part of new plant computer modification.
  - I&C says the loop is fine.
  - wants you check it out right away, otherwise it going on the morning status report

- You don’t remember seeing this issue in your trending and monitoring
  - The reality is that you are busy with other work and haven’t done much trending and monitoring.

- What’s The Entry Point: Ops Management Phone Call (Urgent!!)

- Next Step: WHERE DO I START?.........

**Define The Problem**
Troubleshooting Basics

Five Steps Of Troubleshooting

• Define The Problem
• Develop A Plan
• Execute The Plan
• Perform Corrective Actions
• Evaluate The Results

Communication – The Sixth Step?

• An on-going process throughout troubleshooting
Define The Problem(1)

- Is there a thermal efficiency issue?
- What performance parameters have changed?
- Are the indications correct? Does it pass the LOPA test?
- Is the change captured in MWe Accounting?

**Common TPE Practice. Check the “Thermal 5”.

- Is there an impact on the larger plant?
The Thermal 5 (or 6 or 7)

- Corrected Electrical Output
- Turbine First Stage Pressure
- Condenser Pressure
- Circulating Water Temperature
- Feedwater Flow

Others?

These five parameters are always a good place to start troubleshooting as they can quickly lead you to problem areas. Additional parameters can be added based on experience and TPE preference.
Wow! Lots of changes. How did I miss this? Take a look at some parameters to try and define the problem. The go to the applicable chapter in EPRI manual volume 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>6/3/2011 8:00 - 6/6/2011 8:00:00</th>
<th>7/14/2011 8:00:00 - 7/20/2011 8:00:00</th>
<th>Difference</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Generation</td>
<td>MWe</td>
<td>1203.55</td>
<td>1202.04</td>
<td>-1.51</td>
<td>-0.13%</td>
</tr>
<tr>
<td>Thermal Power</td>
<td>MWt</td>
<td>3430.27</td>
<td>3430.02</td>
<td>-0.26</td>
<td>-0.01%</td>
</tr>
<tr>
<td>FW Flow Loop A</td>
<td>lbm/hr</td>
<td>14748753</td>
<td>14684511</td>
<td>-64241</td>
<td>-0.44%</td>
</tr>
<tr>
<td>FW Flow Loop B</td>
<td>lbm/hr</td>
<td>14748753</td>
<td>14684511</td>
<td>-64241</td>
<td>-0.44%</td>
</tr>
<tr>
<td>HP Turbine 1st Stage Pressure</td>
<td>psia</td>
<td>673.38</td>
<td>670.18</td>
<td>-3.20</td>
<td>-0.48%</td>
</tr>
<tr>
<td>Cond N BP</td>
<td>inhga</td>
<td>1.32</td>
<td>1.33</td>
<td>0.02</td>
<td>N/A</td>
</tr>
<tr>
<td>Cond S BP</td>
<td>inhga</td>
<td>1.32</td>
<td>1.33</td>
<td>0.02</td>
<td>N/A</td>
</tr>
<tr>
<td>Circ Water Inlet Temperature</td>
<td>°F</td>
<td>85.13</td>
<td>85.53</td>
<td>0.41</td>
<td>N/A</td>
</tr>
<tr>
<td>Expected Condenser Pressure</td>
<td>inhga</td>
<td>2.67</td>
<td>2.71</td>
<td>0.03</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Define The Problem\textsuperscript{(1)}

- Is there a thermal efficiency issue? (Look at Mwe)
  Apparently there is! How did you miss this?
- What performance parameters have changed?
  Based on phone call check heater 6 outlet temperature.
- Are the indications correct? Does it pass the LOPA test?
  It is a lot lower than normal but outlet temperature is in a valid range.
- Is the change captured in MWe Accounting?
  Don’t know, your MW Accounting needs some adjustments that you are still waiting for the time to take care of it.
Develop A Plan

● What Other Parameters Changed?
  Check other parameters such as
  ● Alternate feedwater temperature measurements
  ● Calculated TTD, does it reflect the change
  ● FW heater inlet temperature
  ● Same temperature on the other train

● Change In Plant Alignment?
  ▪ Checked with Ops and no changes.

● Did A Boundary Condition Change?
  ▪ Boundary conditions are the same

● Has There Been A Seasonal Change?
  Maybe, it is July, but typically HP heater outlet is not affected by seasonal conditions

● Do I Have A Cheat Sheet For This Type Of Problem
  No, I never had this problem before.

● Are Other Resources Available To Help?
  Yes, Contact the process computer folks and see what they know about the alarm.
  Yes, Use Ch 7 “Feedwater Heaters” from TP Manual Vol 3.
Execute The Plan

1. Contact Computer Process Control Group
   Find out more about the alarm

2. Check Other Parameters
   Calculated TTD, does it reflect the change?
   FW heater inlet temperature?
   Same temperature on the other train?

3. Use EPRI Thermal Performance Handbook
   Volume 3 Troubleshooting*
   Chapter 7 Feedwater Heaters

Done. Not helpful.
7.4 Troubleshooting Guide
7.4.1 What’s the problem?

- **TTD Too High!**
  Diagnostic on Page 7-6

- **TTD Too Low!**
  Diagnostic on Page 7-7

- **DCA Too High!**
  Diagnostic on Page 7-8

- **DCA Too Low!**
  Diagnostic on Page 7-9

- **Temperature Rise Too High!**
  Diagnostic on Page 7-9

- **Temperature Rise Too Low!**
  Diagnostic on Page 7-10

- **Emergency Drain Valve Open**
  Diagnostic on Page 7-11
## Pre/Post Event Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>6/3/2011 8:00 - 6/10/2011 8:00</th>
<th>7/14/2011 8:00 - 7/20/2011 8:00</th>
<th>Difference</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>FWH 6N Shell TTD</td>
<td>°F</td>
<td>6.34</td>
<td>12.80</td>
<td>6.46</td>
<td>N/A ↑</td>
</tr>
<tr>
<td>FWH 6N DCA</td>
<td>°F</td>
<td>11.87</td>
<td>11.84</td>
<td>-0.03</td>
<td>N/A</td>
</tr>
<tr>
<td>FWH 6N Temp Rise</td>
<td>°F</td>
<td>43.24</td>
<td>36.80</td>
<td>-6.44</td>
<td>N/A ↓</td>
</tr>
<tr>
<td>FWH 6N Shell Pressure</td>
<td>psia</td>
<td>331.45</td>
<td>331.69</td>
<td>0.24</td>
<td>0.07% ↑</td>
</tr>
<tr>
<td>Level Control Valve</td>
<td>%</td>
<td>45.00</td>
<td>40.00</td>
<td>-5.00</td>
<td>-11.11% ↓</td>
</tr>
</tbody>
</table>
## Common Problem Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Symptoms</th>
<th>Possible Follow-up</th>
</tr>
</thead>
</table>
| Tube Fouling (reduction in heater transfer coefficient) | • TTD ↑  
• DCA ↑ →  
• LCV ↓  
• TR ↓  
• Shell Pressure ↑  
• Tube side FW Flow →  
• Shell side Drain Flow ↓ | • Schedule heater for inspection and tube cleaning.  
• Tube fouling is usually a gradual process, check trends to verify. |

Not the case because of the abrupt nature of the change
# Common Problem Troubleshooting

<table>
<thead>
<tr>
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| Excessive Tube Plugging (reduction of heat transfer area) | • TTD ↑  
• DC A ↑  
• TR ↓  
• Shell Pressure ↑  
• Tube side FW Flow ↓  
• Shell Pressure Drop ↑  
• Heater Tube Side DP ↑ | • TTD increase might show up in a parallel heater  
• Start process to reclaim tubes, replace tube bundle, or replace entire heater  
• Consider drill holes in partition plate to bypass heater and prevent partition plate failure |

<table>
<thead>
<tr>
<th>FWH 6N Shell TTD</th>
<th>↑</th>
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<tbody>
<tr>
<td>FWH 6N DCA</td>
<td>→</td>
</tr>
<tr>
<td>FWH 6N Temp Rise</td>
<td>↓</td>
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<td>Level Control Valve</td>
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<tr>
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</table>
| Tube Leak | - TTD →  
- DCA ↓  
- LCV ↑  
- Level ↑  
- TR →  
- Shell Pressure →  
- Shell side Drain Flow ↑  
- Tube Side FW ↑  
- Total Condensate Flow ↑ | - Repair of tube leak likely to require short notice outage or power reduction for repair  
- Most common system is high heater level with high level control valve wide open |

**FWH 6N Shell TTD**  
**FWH 6N DCA**  
**FWH 6N Temp Rise**  
**FWH 6N Shell Pressure**  
**Level Control Valve**
## Common Problem Troubleshooting

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| Drain Cooler Steam Intrusion (reduction of subcooling of drain flow due to steam entering drain cooler due to low level, end plate degradation or drain cooler shroud damage) | • TTD →  
• DCA ↑↑  
• LCV↑  
• TR →  
• Shell Pressure →  
• Tube Side FW Flow → | • Check normal drain valve for full position  
• Check for high level drain valve to be open or cycling open  
• Check for waterhammer or excessive motion of drain line  
• Listen for waterhammer inside of heater near drain cooler region |

| FWH 6N Shell TTD | ↑  |
| FWH 6N DCA | →  |
| FWH 6N Temp Rise | ↓  |
| FWH 6N Shell Pressure | ↑  |
| Level Control Valve | ↓  |
Common Problem Troubleshooting

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<tr>
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<tbody>
<tr>
<td>Air Binding (Shell Side)</td>
<td>• TTD ↑</td>
<td>• Check for normal operating vent valve closed</td>
</tr>
<tr>
<td>(reduction of heat transfer area)</td>
<td>• DCA ↑ (slightly)</td>
<td>• Check for possible damage to air removal piping or duct</td>
</tr>
<tr>
<td></td>
<td>• TR ↓</td>
<td>• Design issue with air removal system</td>
</tr>
<tr>
<td></td>
<td>• Shell Pressure ↑</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Feedwater Flow →</td>
<td></td>
</tr>
</tbody>
</table>

Not the case because of the abrupt nature of the change

<p>| | |</p>
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<tbody>
<tr>
<td>Foreign Material Blocking Tube Sheet</td>
<td>• TTD ↑</td>
<td>• Schedule opening of heater to remove debris</td>
</tr>
<tr>
<td>(less tube side FW flow)</td>
<td>• DCA ↑* change in DCA will depend on location of blockage and # of tubes blocked</td>
<td>• Check operation history for equipment damage that could have caused foreign material ingress</td>
</tr>
<tr>
<td></td>
<td>• LCV ↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Temp Rise ↑</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Shell Pressure ↑</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Tube-side FW Flow ↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Noise in water box ↑</td>
<td></td>
</tr>
</tbody>
</table>

| FWH 6N Shell TTD   | ↑                                                                                           |                                                                                  |
| FWH 6N DCA         | ➔                                                                                           |                                                                                  |
| FWH 6N Temp Rise   | ➔                                                                                           |                                                                                  |
| FWH 6N Shell Pressure | ↑                                                                                     |                                                                                  |
| Level Control Valve | ➔                                                                                           |                                                                                  |
## Common Problem Troubleshooting

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<tr>
<td>Banging Sound From Heater (waterhammer)</td>
<td>• TTD ↑* TTD will be down if leakage is due to low heater level.</td>
<td>• Likely steam leaking into drain cooler</td>
</tr>
<tr>
<td></td>
<td>• DCA ↑</td>
<td>• Schedule inspection to look for damage of drain cooler shroud</td>
</tr>
<tr>
<td></td>
<td>• TR →</td>
<td>• Check for proper level during operation</td>
</tr>
<tr>
<td></td>
<td>• Shell Pressure →</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Feedwater Flow →</td>
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<tbody>
<tr>
<td>Normal Level Control Valve</td>
<td>● TTD↑</td>
<td>● Troubleshoot and repair air supply and actuator</td>
</tr>
<tr>
<td>Loss of Air</td>
<td>● DCA↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Level↑</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● LCV ↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● HLD↑</td>
<td></td>
</tr>
<tr>
<td>High Level Control Valve</td>
<td>● TTD↓</td>
<td>● Troubleshoot and repair air supply and actuator</td>
</tr>
<tr>
<td>Loss of Air</td>
<td>● DCA↑</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Level↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● LCV ↑</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● HLD↑↑</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Shell Pressure ↓</td>
<td></td>
</tr>
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</table>

FWH 6N Shell TTD ➤
FWH 6N DCA ➔
FWH 6N Temp Rise ➯
FWH 6N Shell Pressure ➤
Level Control Valve ➯
# Common Problem Troubleshooting

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<tr>
<th>Problem</th>
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</table>
| Turbine Extraction Valve Failure | • TTD ↑  
• DCA ↑  
• LCV ↓  
• TR ↓  
• Shell Pressure ↓  
• Tube side FW Flow →  
• Shell side Drain Flow ↓ | • System reaction is highly dependent on extraction geometry. Typically one heater will be starved for steam and the other heaters will be trying to make up the difference. |

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
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<tbody>
<tr>
<td>Partition Plate Leakage (bypass some FW flow around heater)</td>
<td>• TTD ↑&lt;br&gt;• DCA →&lt;br&gt;• LCV↓&lt;br&gt;• Temp Rise ↓&lt;br&gt;• Shell Pressure ↑&lt;br&gt;• Tube Side FW Flow ↓</td>
<td>• Check historical records for similar problem&lt;br&gt;• Review previous work to open heater&lt;br&gt;• Schedule to replace gasket and check for cracked welds</td>
</tr>
</tbody>
</table>

### Table Example

<table>
<thead>
<tr>
<th>Metric</th>
<th>Change</th>
</tr>
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<tbody>
<tr>
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<td>FWH 6N Shell Pressure</td>
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<tr>
<td>Level Control Valve</td>
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References:

QUESTIONS?