Cycle Isolation
Prioritization and Organization

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 Agenda

- Introduction
- Prioritization – Value of leaking valves
- Organization – Process for developing a Cycle Isolation Program
- Case study
True North Consulting

- Power Services
- Plant Thermal Performance
- Engineering Programs
- Engineering Support Services
- Software Solutions
True North – Thermal Performance
What do we do?

Testing Services
- Turbine Testing
- Cooling Tower Testing
- Feed water heater testing
- PTC- 46 turnkey testing
- PTC – 6 Testing
- Heat Exchanger Testing

Customized Software
- TSM – Thermal System Monitor
- CIM – Cycle Isolation Monitor
- TP-Steam – Steam Tables
- Thermal Power Monitor

Plant Analysis
- Turbine Retrofit Evaluations
- Plant Uprate Evaluations
- Thermal Performance Program Assessment
Introduction

- Generating plants often suffer from power losses due to leakages through valves that are faulty and/or do not seat correctly.
- Often these losses are significant and have been difficult to quantify.
Introduction

All organizations have finite resources and need to apply those resources intelligently to get the most out of them. All power plants have leaking valves, but there may not always be a business case for repairing them.
Cycle Isolation Monitoring

- Monitor high energy valve leakage
- High energy valve leakage leads to:
  - Increased heat rate
  - Reduced plant efficiency
  - Potential valve damage
  - LOST MW!
Cost of a Leaking Valve

How Much is 1 MW of electricity worth?

● Revenue
  ● If the plant CAN’t make it, they can’t sell it
  ● $400,000 per year

● (Fossil) Fuel Cost?
  ● If the plant CAN make it, they need to overcome the loss
  ● $250,000 per year, depending on fuel type and efficiency
Cost of a Leaking Valve

Data Source:
US Energy Information Administration
http://www.eia.gov/
Cost of Leaking Valves

Typically plants have between 2-6 MW of lost generation from leaking valves

- For a plant that can not make up this loss, this represents $800,000 - $2,400,000 annual lost revenue.
- For a plant that can make it up, it represents additional fuel costs of $500,000-$1,500,000
  - + Additional Costs
Relative Impact of Leaks Around the Power Plant
Relative Impact of Leaks Around the Power Plant

<table>
<thead>
<tr>
<th>Location of Leakage in Cycle</th>
<th>Heat Rate Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throttle</td>
<td>0.83%</td>
</tr>
<tr>
<td>HP Turbine Exhaust</td>
<td>0.53%</td>
</tr>
<tr>
<td>Ahead of Intercept Valve</td>
<td>0.69%</td>
</tr>
<tr>
<td>Cross-Over</td>
<td>0.44%</td>
</tr>
</tbody>
</table>

Source: Evaluating Steam Turbine Performance by K.C. Cotton
Causes of Leakage

- Leakage due to tank level control problems
- Leakage due to AOV valve setting issues
- Leakage due to MOV thermal expansion
- Relief valve drifting
- Steam cutting of valves
- Improper valve alignment
- Leakage resulting from maintenance on the system
- Leakage due to foreign material in the valve
- Leakage from startup valves being left open
Prioritization of Leakage

- Valve leakage should be frequently identified and tracked
- Prioritization basis
  - Energy level of liquid or vapor upstream of the valve
  - Thermodynamic Impact on cycle
  - Extent of the valve leakage
- Large valves are expensive to repair so make sure the benefit is there
- Also include additional checks that confirm the valve is leaking

One thing to remember - the size of the leak today will not be the size of the leak tomorrow
Prioritization of Leakage-Determining Effect on the Cycle

- Build a thermodynamic model of the cycle. Most plants already have this.
- Run the model at normal conditions and record the generation.
- Simulate the leak by pulling a small amount of flow (1%) to the sink.
- Run the model with the simulated leak and record the generation with the leak active.
Prioritization of Leakage-Determining Effect on the Cycle

- Calculate the power in the leaking fluid
  \[ P = \dot{m} \cdot h = \text{flow} \times \text{enthalpy} \]

- Divide the lost generation by the power from the leak
  \[ \text{LossFactor} = \frac{P_{\text{GenerationLoss}}}{P_{\text{LeakageLoss}}} \]

- Use this loss factor to determine effect on electric generation from each leak
Process for Implementing Cycle Isolation Program

1. Identify Valves to Monitor
2. Walkdown Units
3. Update List of Valves to Monitor
4. Valves Leaking?
   - Yes: Continue Monitoring
   - No: Create Work Order
5. Close/Repair Valve(s)
6. Verify Repair
Identify Valves to Monitor

- Review Plant Information
  - Thermal Kits
  - Thermodynamic Models
  - P&ID’s
  - Isometrics
- Normally Closed valves that if open, dump high energy fluid to a sink (condenser, blowdown tank, etc.)
What Valves Should Be Monitored?

- Feedwater heater dump valves
- Main steam line drain valves
- Gland seal unloader valve
- Turbine bypass valves
- Feedwater heater vent valves
- Gland steam isolation valves

- Extraction steam line drain valves
- Heater bypass valves
- Feed pump recirc valves
- Before and after seat drain valves
- Steam drain line orifices (and orifice bypass valves)
Identifying Valves

Combined Cycle HP Governor Valve Seat Drain
Identifying Valves

Coal Cogeneration Plant Feedwater Heater Drain and Vent P&ID
Identifying Valves

Coal Cogeneration Plant Boiler Blowdown System
Walkdown the Unit

- Verify Location of Valves
- Determine measurement locations
- Verify piping configurations
- Establish the walkdown order
- Document, document, document
- Record initial temperature measurements
Measure temperature approximately 10 diameters downstream of the valve. Be careful of conduction across the valve and piping.

- If using infrared ensure it will be in the line of site from a safe location, but getting the device as close as possible to the pipe. Make sure the pipe is not “shiny” and that the hole in the insulation is adequate.

- Know the drawings; look for other paths that could be a source of heat into the location you are measuring.
Walkdown the Unit

- Verify Location of Valves
- Determine measurement locations
  - Approximately 10 diameters downstream of valve
  - Measure pipe temperature, not insulation temperature
- Measure distance to sink
- Verify piping configurations
  - Look for sources of error
    - Environmental conditions
    - Other heat sources
- Establish the walkdown order
- Document, document, document
- Record initial temperature measurements
Update List of Valves

- Collect data on valves discovered during walkdown
- Update valve information
  - Upstream conditions
  - Valve type, size
  - Pipe size, schedule
  - Distance to condenser
- Record initial temperatures
Determine if Valve Is Leaking

- Determine nominal temperatures for non-leaking valves
- Establish threshold for identifying leaking valve
  - What temperature is indicative of a leak?
  - Avoid false positives
- Verify leakage with alternate source (Acoustic)
- Calculate Leakage
  - Infer pressure inside pipe from temperature
  - Use piping configuration and sink conditions to calculate flow
  - Calculate value of fluid (high energy, high value)
  - Convert flow to generation or heat rate loss.
Prioritize

- If more than 1 valve is leaking, determine which valve is worth more
  - Effect on lost generation
  - Cost to repair
- Communicate with maintenance and/or operators to repair/replace valves
  - Isolate if possible
- Large valves are expensive to repair so make sure the benefit is there
- Also include additional checks that confirm the valve is leaking

One thing to remember - the size of the leak today will not be the size of the leak tomorrow.
Collect Valve Information

- Data for each valve is entered into input forms or can be imported from spreadsheets which then produce results from advanced cycle isolation loss calculations which can be graphed and reported to monitor valve degradation over time.

- The goal of a cycle isolation program is to provide the ability for plant personnel to quickly detect and quantify leakage losses in a plant cycle.
Plant Implementation

- Presentation made at EPRI Heatrate Conference 2009
- Interest expressed
- Implemented on two 300 MW units

- Unit #6: 304MW CE, 1814psia/1000F Reheat unit tangential twin furnace - 1978
- Unit #1: 300MW B&W, 1812psia/1000F Reheat unit front and back wall fired - 1992
Plant Implementation

- Identify valves – P&IDs
- Locate valves – walkdown of unit
- Quality of fluids – Thermodynamic models
Plant Implementation

- Site Visit
  - Located all valves
  - Determined proper measurement locations
Plant Implementation

- Site Visit
  - Located all valves
  - Determined proper measurement locations
  - Drilled holes in insulation
Plant Implementation

- Site Visit
  - Located all valves
  - Determined proper measurement locations
  - Drilled holes in insulation
  - Measured upstream and downstream temps
Plant Implementation

Determined final walkdown order & created Worksheet

<table>
<thead>
<tr>
<th>Walkdown Order</th>
<th>Valve ID</th>
<th>Description</th>
<th>Elevation (feet)</th>
<th>Location</th>
<th>Measure</th>
<th>Previous Value</th>
<th>Current Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DR123-V3</td>
<td>Drain from HPH #4 to condenser</td>
<td>0</td>
<td>Basement, southwest of condenser</td>
<td>Downstream Temperature</td>
<td>92.0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DR123-V5</td>
<td>Drain from HPH #4 to condenser (bypass line)</td>
<td>0</td>
<td>Basement, southwest of condenser</td>
<td>Downstream Temperature</td>
<td>93.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>DR108-V2</td>
<td>Drain (Turbine extraction line to HPH #5) (downstream)</td>
<td>0</td>
<td>Basement, SW of condenser</td>
<td>Downstream Temperature</td>
<td>103.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>DR108-V2</td>
<td>Drain (Turbine extraction line to HPH #5) (downstream)</td>
<td>0</td>
<td>Basement, West of condenser</td>
<td>Downstream Temperature</td>
<td>99.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>DR105-V3</td>
<td>Drain (Turbine extraction line to HPH #4) (Bypass)</td>
<td>0</td>
<td>Basement, West of condenser</td>
<td>Downstream Temperature</td>
<td>232.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DR107-V3</td>
<td>Drain (Turbine extraction line to HPH #4) (Bypass)</td>
<td>0</td>
<td>Basement, West of condenser</td>
<td>Downstream Temperature</td>
<td>220.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>DR130-V2</td>
<td>LH#1 HH bypass drain to condenser</td>
<td>0</td>
<td>Basement, near condenser manifold (west)</td>
<td>Downstream Temperature</td>
<td>102.0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>6-CRH-6</td>
<td>CRH pipe drain to condenser HP drain manifold</td>
<td>0</td>
<td>Downstream valve, mezzanine west</td>
<td>Downstream Temperature</td>
<td>408.0</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>DS-10</td>
<td>LH Reheat stop/ interce valve below seat chain</td>
<td>0</td>
<td>Mezzanine, west, To condenser</td>
<td>Downstream Temperature</td>
<td>101.0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>6-MS-1</td>
<td>Main steam pipe drain to blow down tank/Downstream</td>
<td>0</td>
<td>Mezzanine west (near stairs)</td>
<td>Downstream Temperature</td>
<td>263.0</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>DS-12</td>
<td>RH Reheat stop/ interce valve below seat chain</td>
<td>0</td>
<td>Mezzanine, west, To condenser</td>
<td>Downstream Temperature</td>
<td>104.0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>6-BD-14</td>
<td>Water wall blow off connection, lower side west header</td>
<td>0</td>
<td>Basement, west side (boiler north)</td>
<td>Downstream Temperature</td>
<td>88.0</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>6-BD-15</td>
<td>Water wall lower side header, west, to blow down tank</td>
<td>0</td>
<td>Basement, west side (boiler north)</td>
<td>Downstream Temperature</td>
<td>158.0</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>6-BD-16</td>
<td>Water wall lower side header, west, to blow down tank</td>
<td>0</td>
<td>Basement, west side (boiler south)</td>
<td>Downstream Temperature</td>
<td>158.0</td>
<td></td>
</tr>
</tbody>
</table>
Plant Implementation

Valve information sheet

- **Valve ID**: DS-8
- **Description**: 3B stop v/v below sect drain (RHS) to condenser
- **Plant Code**: BD8
- **System**: HP Drains
- **Model**: 
- **P&ID #**: A345775025
- **Valve Type**: Globe
- **Valve Size**: 1
- **Coordinate**: 
- **Elevation**: 30 feet
- **Location**: Mezzanine west
- **Actuator Type**: 
- **Failure Mode**: 
- **Insulation**: 0 inches
- **R-Value**: 
- **Loss Factor**: 0.352
- **Upstream Pressure**: 1014 psia
- **Upstream Temperature**: 1030 deg F
- **Upstream Enthalpy**: 1480.1 Btu/lbm
- **Downstream Temperature**: 
- **Pipe I.D.**: 1 inch
- **Nominal**: 100 deg F
- **Limit**: 140 deg F
- **Distance to**: 42 feet
- **Condenser**: Condenser

**Notes**: Check LF

(Use Ctrl-Tab and/or Ctrl-Enter to format.)
Plant Implementation

- Entered walkdown results
- Planned maintenance on valves

Estimated savings: 50.3 Btu/kWh ≈ $475,000 per year
Plant Implementation

Post-Overhaul Results

Valve Leakage Summary

<table>
<thead>
<tr>
<th>Valve ID</th>
<th>Description</th>
<th>Type</th>
<th>Size (inches)</th>
<th>System Code</th>
<th>Temperature Limit (deg F)</th>
<th>Downstream Temperature (deg F)</th>
<th>Average Leakage (lbm/hr)</th>
<th>Average Loss (MWe)</th>
<th>Average Loss (BTU/kwh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-CRH-6</td>
<td>CRH pipe drain to condenser HP drain manifold</td>
<td>Globe</td>
<td>2</td>
<td>HP Drains</td>
<td>145.0</td>
<td>403.0</td>
<td>12355.9</td>
<td>1.1</td>
<td>23.6</td>
</tr>
</tbody>
</table>

- Closed manual blocking valve
  - (temp now 50 deg F)
- Estimated Savings
  - $275,000
Plant Walkdowns

- Plant personnel take downstream measurements of temperatures using handheld equipment.
  - Some plants install thermocouples to record temperature measurements.
  - Some plants verify temperature measurement with acoustic methods.
- Each measurement is recorded using Walkdown Worksheet forms or can be uploaded from spreadsheets or handheld recording devices.
Verify Repairs

- Always measure temperatures before and after repairs to ensure valve is repaired properly
- Continue monitoring and ensure leaking condition does not return
- Identify problem locations
- Document, document, document
  - What repair was performed?
  - When was it performed?
  - Pictures of damage
Trending of Leakage

![Compose Graph window](image)

<table>
<thead>
<tr>
<th>Measures Available</th>
<th>Valves with Downstream Temperature Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream Temperature</td>
<td>Valve ID</td>
</tr>
<tr>
<td>Upstream Pressure</td>
<td>23MD28*</td>
</tr>
<tr>
<td>Upstream Enthalpy</td>
<td>23MD32</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>23MD34*</td>
</tr>
<tr>
<td>Downstream Temperature</td>
<td>23MD36*</td>
</tr>
<tr>
<td>Condenser Pressure</td>
<td>23MS7</td>
</tr>
</tbody>
</table>

(Select a measure to graph.)

(include MW Loss) ✓

<table>
<thead>
<tr>
<th>Valves in the Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve ID</td>
</tr>
<tr>
<td>21TB20</td>
</tr>
<tr>
<td>21TB30</td>
</tr>
<tr>
<td>21TB40</td>
</tr>
</tbody>
</table>

(Select valves for a one-time graph, or to assign to a graphing group.)

[Add] [Delete] [Graph] [Export] [Close]
Graphing

True North Power Plant - Unit 1

Downstream Temperature with MWe Loss

Degrees Fahrenheit

U1-23RD3
MWe Loss

0.00 0.05 0.10 0.15 0.20 0.25 0.30

19-Sep-06 21-Sep-06 23-Sep-06 25-Sep-06 27-Sep-06 29-Sep-06 01-Oct-06 03-Oct-06 05-Oct-06
# Action Taken Reports

## Demo Plant 4 - Action Taken Summary

<table>
<thead>
<tr>
<th>Valve ID</th>
<th>Description</th>
<th>System Code</th>
<th>System Name</th>
<th>Walkdown ID, Date</th>
<th>Workorder Request</th>
<th>Workorder</th>
<th>Action Taken</th>
<th>Retest Result</th>
<th>Avg. Loss (MWe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21BF32</td>
<td>21 SGFP RECIRC CONTROL VALVE VPI</td>
<td>BF</td>
<td></td>
<td>068: Sunday 06.01.2008 01:38</td>
<td>1234</td>
<td>1A</td>
<td>Repaired</td>
<td>Passed</td>
<td>0.0</td>
</tr>
<tr>
<td>21HD2</td>
<td>26A FV HTI DRN CUR BYPASS DRN TO CNDENSRT AQY VPI</td>
<td>HD</td>
<td></td>
<td>068: Monday 07.01.2008 01:43</td>
<td>1235</td>
<td>1B</td>
<td>Repaired</td>
<td>Passed</td>
<td>0.0</td>
</tr>
<tr>
<td>21HV9</td>
<td>23 FWHY VENT</td>
<td>HV</td>
<td></td>
<td>068: Monday 07.01.2008 01:43</td>
<td>1236</td>
<td>1C</td>
<td>Repaired</td>
<td>Passed</td>
<td>0.0</td>
</tr>
</tbody>
</table>

---

Action Taken Summary 1 of 1 Thursday, 10 January 2008
Combination of Technology

- A leak in one valve will increase the pressure in the entire header
- Acoustics can help pinpoint the leak source
Conclusion

- Prioritize valve leakages
- Program to structure leakage measurement
- Identification of leaking valves can happen very quickly
- Always use good engineering practices and judgment including diverse measurement methods
- Tracking of leaking valves can be very rewarding
  - Estimate flow losses to cycle
  - Estimate lost generation and heat rate impact