IMI Critical Engineering

Engineering GREAT together
DRAG® Technology and Heater Drain

FSRUG Conference 2016
Critical applications

Process Control Valves and Actuation

IMI CCI provides a wide range of severe and general service control valves with a proven history of meeting the most demanding high-differential pressure and thermal conditions in today’s power industry. We have qualified the nuclear valve product range per QME-1, and qualified the nuclear actuator product range per IEEE-323,344, and 382.

- BOP Control Valves
- CCI ABJ Control Valves
- DRAG® Severe Service Control Valves
- Piston and Spring Diaphragm Actuators
- QuickTrak® Digital Controllers

Isolation and Relief Valves

High energy isolation valves provide a tight shut-off with each cycle, preventing local leak rate test (LLRT) failures and related schedule delays. Our system medium operators eliminate any dependence upon troublesome air supply, nitrogen gas, and hydraulic fluid or mechanical springs. We have qualified the nuclear valve product range per QME-1, and qualified the nuclear actuator product range per IEEE-323,344, and 382.

- Check Valves, damped and un-damped
- Pilot Operated Safety Relief Valves
- Solenoid Operated Valves
- System Medium Actuated Gate Valves

Mechanical Systems

Specialized nuclear technologies for ECCS Suction strainers, vent resistor silencers, Containment venting and other applications Contributing to plant productivity and safety.

- Atmospheric Resistor Silencers
- ECCS Pocket Cassette Sump Strainers
- Filtered Containment Venting Systems
DRAG®

CCI designed, built and patented the first DRAG® control valves in 1967, answering the need for a valve capable of handling high-pressure liquids and gases such as water, oil, steam, natural gas, petroleum products and chemicals. DRAG® technology is considered one of the landmark innovations in the history of the severe service control valve industry.

QuickTrak®

For process control problems caused by inadequate positioner and accessory performance, the introduction of the CCI QuickTrak® electronic valve controller marked a new performance milestone for highly accurate rapid valve positioning in the control mode without auxiliary boosters or quick exhaust valves. With remote mounting, self-diagnostic capabilities and compatible protocols, the QuickTrak® is the standard in speed, accuracy and reliability.

System Medium Actuation

The PPS valve was designed for safety-related applications, where the valves must close safely and surely under the most critical conditions, including pipe ruptures. These include main steam and main feed water isolation applications on both PWR and BWR of the present day type.

Aftermarket services

Unlike many valve companies, IMI CCI has a full aftermarket service division, which provides field service, parts, repair, upgrades and long-term service agreements for our customers. Employing highly trained field service technicians and dedicated repair centers around the globe, our aftermarket team is always ready to meet customer needs. Using the original factory drawing and specifications, IMI CCI’s field service technicians are capable of conducting critical dimension analysis (CDA) to ensure your process is functioning safely and at optimal efficiency.
IMI CCI addresses severe control

- Cavitation potential exists (Kc>0.6)
- Flashing service
- High vibration or noise expected
- High pressure ratio: $\Delta P/P_1>0.5$
- History of problems
- Needs continuous maintenance

Common symptoms

- Lost Production
- System Shutdown
- Poor Control
- Noise

- Trim & Body Wear
- Pipe Vibration
- Downstream Pipe Erosion
- High Maintenance
Valve trim designs and limits

- Valve suppliers use different styles of valve trim to provide protection against erosion, cavitation, flashing, vibration.
- Valve trim velocities and velocity head (dynamic pressure) can be calculated directly from the Darcy equation and valve trim loss coefficient, K.
Failure due to improper velocity / kinetic energy control
Determining valve trim loss coefficients

- The loss coefficients of control valves can be calculated using the piping system methods from Crane 410.

- Loss coefficients can be summed in series. The summation must include the effect of changes in area. This can be done using the area expansion coefficient, Ec.

\[
K_T = K_{entry} + \sum_n \frac{K_i}{E_{ci}^2} + K_{exit}
\]

\[
E_c = \frac{A_1}{A_2}
\]
Typical loss coefficients for control valves

- Single-stage cage has $K = 1.5$.
- Three-stage cage with $Ec = 2$ has $K = 1.97$
- A series of right angle turns with $Ec = 1.072$ have an average loss coefficient of $K = 1.32$ (determined experimentally).
- Four right angle turns with $Ec = 1.072$ have $K = 6.7$.
- Discharge velocity can be found using Darcy equation, pressure drop, density, and loss coefficient.

\[ V = \sqrt{\frac{2g\Delta P_{net}144}{K\rho}} \]
Key Critical Service Elements

Process Insight
- Understanding of the applications

Reliability
- Control of Fluid Velocity/ Kinetic Energy
- Material of Construction
- Robust Design
- Multi Stage Pressure Reduction
- Discrete Flow Passages

Control Resolution
- Actuator/Positioner
- Trim Design
## Velocity / Kinetic Energy Control

### Service conditions

<table>
<thead>
<tr>
<th>Continuous service, single phase fluids</th>
<th>Steam [psi]</th>
<th>Steam [Kpa]</th>
<th>Water [ft/s]</th>
<th>Water [m/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70</td>
<td>480</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>Cavitating &amp; multi-phase fluid outlet</td>
<td>40</td>
<td>275</td>
<td>75</td>
<td>23</td>
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<tr>
<td>Vibration sensitive system</td>
<td>11</td>
<td>75</td>
<td>40</td>
<td>12</td>
</tr>
<tr>
<td>Intermittent duty, 5% or less valve use</td>
<td>150</td>
<td>1030</td>
<td>-----</td>
<td>-----</td>
</tr>
</tbody>
</table>

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...consisting of a specific number of right-angle turns that form a tortuous path.

**MULTI-STAGE PRESSURE DROP**
The Value of DRAG®

Fluid Velocity / Kinetic Energy Control
- Lower Noise
- Controlled Vibration

Trim Characterization
- Control Resolution
- Rangeability
- Matched to “system”
Actuator/Positioner Design

Construction / Features

- Positioner & System Design
- High force levels
- Inherent stiffness
- Minimum air volumes for fast response

Performance Specifications

Stability

- Overshoot
- Oscillation

Thrust/Power Performance

- Stroking Time
- Small Signal Response
Control Valve Hierarchy

- **Butterfly**
- **Ball**
- **Globe**

Severity ➔ Performance ➔ Severe service
Heater Drains System
DRAG® Valve Applications in Nuclear (not all!)

CCI CONTROL VALVES IN A TYPICAL
BOILING WATER REACTOR
Energy diagram of typical feedwater system
Idealized BWR Cycle (no heater)

- Line drawing and Carnot Efficiency
BWR with heater

- Condensate heating not shown:
Two Stage Regenerative Rankine Cycle (PWR)
T-S diagram of Rankine Cycle
System Description

- Remove heat from convenient points in the turbine and use it to heat the feedwater system
- The Heaters are shell type heat exchangers
- Each heater is provided with a drain valve
  - Control valve (Globe) or
  - Rotary control valve
- Each heater is also provided with an emergency drain valve to the condenser
  - Butterfly
  - Rotary Globe
BWR Heater System

- More complicated, with two stages, and bypass
Level controller on a feedwater heat exchanger.

From this...  to this... in minutes
Heater Drains Flow
Condensate System Flow

- Before main feedpump
Typical Heater Drain Valve arrangement
System Valve Requirements

- Dealing with saturated steam and condensate
- Saturated condensate tends to flash
- Challenge in material selection, trim life and control
- Excessive leakage can affect MW
- Emergency Steam Dump valves should have MSS-SP-61 shutoff specified
System Valve Requirements

- Flows cascade from one heater to the next so flows add up and the valve sizes increase
- Pressure downstream of upstream heater can be assumed as inlet to next heater for preliminary sizing purposes
- Chrome-Moly bodies for flashing service
- Angle valves should be considered for new construction
Valve Design, Material Selection - Key

- Flow over the plug
- New Construction – KISS principle, 5 dia.
- Use Chrome Moly C5, F11/F22 bodies, 316 best
- 20% to 45% is most erosive – try to reduce by backpressure devices
What is flashing?

The difference in inlet and outlet enthalpy divided by the enthalpy of formation.

\[
\% \text{ Flash} = \frac{h_{f1} - h_{f2}}{h_{fg2}}
\]

\( h_{f1} = \text{Enthalpy of Saturated Water, Inlet (temperature)} \)

\( h_{f2} = \text{Enthalpy of Saturated Water, Outlet (pressure)} \)

\( h_{fg2} = \text{Latent heat of saturated steam, Outlet (pressure)} \)
Flashing in Valve

- Outlet pressure at or below vapor pressure.
- Example: 20% flashing, 20% vapor in fluid.
Figure 1. Downstream Orifice
Issues to Consider

1. Add bottom base to casting pattern.
2. Add sacrificial material.
3. Add blind flange.
4. Add studs and nuts.
5. Modify hydro-test procedure.

Diaper Style

Plug Style
Issues to Consider
1. Add metal to "top plate" and "bottom plate" of casting.
2. Extra machining for weld prep.
3. Extra machining on top plate.
4. One size bigger casting.
5. Design basket.
Sacrificial Target – Basket, same size body

Issues to Consider
1. Special undercut in crotch area.
2. Design basket.

Large Hole Pattern

Single Wide Slot
Case Study: PWR Heater Drain Application

- Cascade Type Heater Drain
- Unstable operation
  - *Internal waveforms not being filtered out.*
  - *Control Valve Cycling >1M per refueling outage*
- Hardware:
  - *First Generation digital Level Transmitter*
  - *DCS controller*
  - *Digital positioner*
  - *Globe Valve*
Case Study: PWR Heater Drain Application (Cont.)

Solution:

- Digital level controller with “local loop”
- 4-20 ma output on digital level controller
- Power Supply for Local Loop Control
- First order filtering and autotune features
- Lesson learned: digital solution may be independent of hardware.
Latest Generation Digital Level Transmitters
Guided Wave Radar Level and Interface Transmitter

A reflection is developed off the liquid surface.

Air $\varepsilon_r = 1$

Media $\varepsilon_r > 1.4$

A small amount of energy continues down the probe in a low dielectric fluid, e.g. hydrocarbon.

24 VDC, 4-20 mA Loop Powered
Latest Generation Digital Level Transmitters

Retrofit existing cages by removing displacer.

From this... to this... in minutes
Heater Drain Valve Solutions

Regardless of digital technology, the hardware must be addressed.

BWR Heater Drain with through body leakage, addressed with seat diffuser.
Conventional valves in heater drain
Expensive Solution: Wiring is a hidden cost.
Local Loop Control Option

- Level controller also PID controller.
- Output 4-20 ma signal to valve positioner.
- Similar to local loop pneumatic control.
High cycling

- Address digitally:
  - Reduce sampling rate of digital level controller.
  - Reduce aggressive tuning parameters of digital positioner (PWR).
- Address mechanically:
  - Live load packing.
  - Low friction packing (Teflon, PWR)
  - Piston actuator with STI features like bearing surfaces, piston guiding, lifetime lubrication.
- High cycling is an issue in PWR’s
  - Uneven number of heaters cascading
  - Surface turbulence, cycling in the 1M count
Premium Actuator Features

- STI actuator features
  - Lifetime lubrication
  - Stem guiding O-ring surfaces
  - Piston guide rings
Digital Upgrades, BWR’s

- Heater bays are inhospitable for digital positioners
  - *Background radiation*
  - *High temperature*
- Solution: Remote mount.
<table>
<thead>
<tr>
<th>QTY</th>
<th>Plant</th>
<th>Construction</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Cofrentes (Spain)</td>
<td>BWR</td>
<td>Heater Drain Valve</td>
</tr>
</tbody>
</table>

Features: Remote Mount Control Panel
Longest distance remote mount in the industry (>130 ft)
Heater Drain Solutions, BWR’s

- Valve body erosion due to flashing.
- Difficulty using digital positioners due to environment.

Solutions:
  - *Seat diffuser with pilot trim.*
  - *Remote mount digital positioners.*
Heater Drain Solutions, PWR’s

- High cycle count
- Controller issue
- Solutions:
  - *STI Actuator technology for long life, high cycles*
  - *Digital tuning for reduced cycle count.*
  - *Pilot trim for tight shutoff.*
Efficiency

- Plant efficiency is tied to thermal efficiency.
  - *Thermal efficiency is a function of heater drain performance.*
  - *The performance of heater drains directly impacts plant efficiency.*
- *Applications that move the needle:*
  - CSDV, Turbine bypass (steam side)
  - Heater Drain (Condensate and Feedwater Side)
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Engineering GREAT Solutions