NPP Containment Vent Protection
an Examination of the Effects and Mitigation Strategies
to Manage Decay Heat Deposition on Dry Filtration Vent Systems

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World Class Filtration Solutions
Purpose Of The Paper And Presentation

To give focus to the particular aspect of decay heat deposition on dry filtration solutions in containment venting applications.

- To continue the debate
- To familiarise the industry with this particular aspect of the FCVS application
- To review the implications decay heat loading on mechanical equipment
- To illustrate the current somewhat different models for the consequences of LOCA specifically relating to decay heat
Mitigating a LOCA

A LOCA presents a complex problem which appears not to be fully understood.

It is reasonable to simplify FCVS applications in the following terms:

- An arduous set of process conditions (often in conflict with one another, for seemingly similar sites)

- A range of different operating philosophies
Establishing An Accurate Source Term

In order to begin to understand and indeed design a filtration system to deal with the consequences of a LOCA, an accurate source term must be derived, as it appears there is a range of different and sometimes conflicting requirements.

With a specific focus to decay heat we have a seen several different values quoted for this individual variable, which would have a significant effect on the overall size of otherwise similar equipment.
The effects of decay heat

• Total burdens experienced to date in the several applications we have been asked to look at have ranged from 2 kW to some hundreds of kW

• Must be distributed across the filter elements to a sustainable figure per unit area (preventing loss of the system) or be removed by another means

• Decay heat loading must be managed such that filter media/element integrity is maintained

• The potential presence of caesium hydroxide (which melts at 273 Celsius)
Effects of Heat Loading on Media Integrity

- High active surface area
- Small diameter fibres (1-30 microns)
- Relies upon sinter bonds for structural integrity
- Currently understood continuous operating temperature 370 °C maximum in oxidising environment
- Higher in reducing environment depending on gas constituents
Tensile Test 1 (Ambient Calibration Test)

Test conditions

• Temperature: 20°C (68°F)
• Pressure: Ambient
• Samples tested: 4
Tensile Test 2 (Post Heat Soak)

Test conditions

- Soak temperature: 500°C (932°F)
- Soak time: 72 hours
- Pressure: Ambient
- Test furnace fluid: Air
- Samples tested: 4
Tensile Test Results

![Graph showing tensile test results]
Efficiency Test 1 (Calibration Test)

Test conditions

- Temperature: 20°C (68°F)
- Pressure: ambient
- Face velocity: 3 cm/s
- Challenge: 0.3µm Ondina oil (DOP)
Efficiency Test 2 (Post Heat Soak Test)

**Test conditions**

- Temperature: 20°C (68°F)
- Pre test heat soak: 500°C (932°F)
- Pressure: ambient
- Face velocity: 3 cm/s
- Challenge: 0.3µm Ondina oil
Efficiency Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Filtration Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Calibration test ambient</td>
<td>99.9924% at 0.3 µm</td>
</tr>
<tr>
<td>2 post heat soak test</td>
<td>99.9916% at 0.3 µm</td>
</tr>
</tbody>
</table>

• In both tests efficiencies of greater than 99.97% at 0.3µm were achieved

• No appreciable loss in efficiency was observed after the heat soak test (DF at 0.3 µm >10^4 in both cases)
Filter Assembly Heat Testing

• 7 off filter elements were provided for the test program

• Heating rods inserted provide a variable power input (Watts) for a fixed unit area

• Pitched in a circular array with adjustable spacing

• Vertical and horizontal tests performed with and without a covering shroud

• A stabilised temperature plateau was reached for a fixed heat input
Filter Cores and Their Purpose

- Key structural component of a filter element
- Relatively open structure ranging from typically 40 to 70%
- To enable custom filtration solution to be produced without imposing high ΔP penalty
- A key factor influencing filter element selection
- Primarily two failure mechanisms
Why Is Core Collapse Important?

- CV
- SRV
- Process Filters
- AGR BPBD Filters
- Metallic Radial Flow HEPA Filters
## Original Calculated Core Collapse Values

<table>
<thead>
<tr>
<th>Core Collapse Failure Mode</th>
<th>Core Collapse Pressure Psig (Barg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumferential Collapse</td>
<td>605 (41.7)</td>
</tr>
<tr>
<td>Buckling</td>
<td>1582 (109.1)</td>
</tr>
</tbody>
</table>

## Test Sample 1

<table>
<thead>
<tr>
<th>Core Number</th>
<th>Core Collapse Pressure Psig (Barg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>440 (30.3)</td>
</tr>
<tr>
<td>2</td>
<td>400 (27.6)</td>
</tr>
<tr>
<td>3</td>
<td>420 (29)</td>
</tr>
</tbody>
</table>
Core Collapse Values

- Core Collapse Values
- Minimum Calculated Circumferential Collapse Value

Graph showing the variation of collapse pressure in PSI against core number.
Observations

• Both efficiency and structural integrity were not significantly affected when a filter was exposed to elevated temperature for a fixed time period

• It appears that an additional factor of safety must be incorporated into the routine methodology for calculating core collapse

• Filter elements in systems where core collapse in extreme conditions is a concern, should also be supported by tested data to validate a “true” core collapse value
On-going Work

- We aim to complete additional heat soak efficiency and media tensile testing, at greater elevated temperatures

- Our test work continues with a view to determine a more reliable method of determining a filter cores true collapse value.

- We have a completed a phase of core collapse test at elevated temperature

- We are looking at performing further test programs on different configurations of cores and elevated temperatures
# Table of HT Collapse Results

<table>
<thead>
<tr>
<th>Core Number</th>
<th>Core Collapse Pressure Psig (Barg)</th>
<th>Out of Round Distinguishing Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>405 (27.9)</td>
<td>Bottom half out of tolerance</td>
</tr>
<tr>
<td>8</td>
<td>407 (28.1)</td>
<td>All sections in tolerance</td>
</tr>
<tr>
<td>A</td>
<td>376 (25.9)</td>
<td>Top quarter in tolerance</td>
</tr>
<tr>
<td>B</td>
<td>440 (30.3)</td>
<td>Middle third out of tolerance</td>
</tr>
<tr>
<td>C</td>
<td>407 (28.1)</td>
<td>All sectors in tolerance</td>
</tr>
<tr>
<td>D</td>
<td>464 (32) no collapse</td>
<td>All sections in tolerance</td>
</tr>
</tbody>
</table>
Conclusions

- Decay heat is clearly a fundamental issue and not an after thought.

- One potential worst case outcome of uncontrolled decay heat loading, is a huge temperature rise which may possibly be sufficient to cause the steel filters to melt.

- At the very least temperature rises (to a much lower degree than mentioned above) could give rise to reductions in available tensile and yield strength, potentially resulting in collapse of filter elements/plates or rupture of the filter medium.

- In addition to the other points raised in my presentation we hope that our joint presentations have cast a light on the importance of establishing a true and verifiable source term to enable filter companies to offer fully competent solutions to the filtration aspects of containment venting.
Thank you for your time
are there any questions?