In the wake of a core melt accident, the reactor containment might suffer damage resulting from overpressure caused by the decay heat generated inside the containment over a long period. A core melt accident causes strong activity to be released into the containment. There, the release of steam, gases like H₂ and, in case of ex-vessel situations, CO, CO₂ etc. causes the pressure to rise. The challenge is keeping the containment tight and preventing significant off-site long-term dose issues.

It is therefore necessary to
- Limit the excessive pressure build-up inside the containment
- Protect the structural integrity of the ultimate fission product barrier
- Retain the airborne activity of the vented gas efficiently
- Return the accumulated activity to the containment
- Establish a slight sub-atmospheric pressure inside the containment for certain containment designs

**Design of the High Speed Sliding Pressure Retention Process**

To meet this challenge, AREVA offers the Filtered Containment Venting System (FCVS). Its process is double-staged and uses the advantages of a high speed venturi scrubber technology combined with highly efficient fibre filter features. All components are installed in the pressure vessel and operate under sliding pressure conditions.

**Stage 1: High Speed Venturi Section**

The venturi scrubber unit is operated at pressures close to the prevailing containment pressure. The venting flow entering the scrubber is injected into a pool of water via a small number of venturi nozzles. The ratio of the diameter of the aerosols and the venturi throat precludes any clogging.

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**>> Key Features**

**Reliable damage prevention**
- Prevention of excessive containment pressure
- Safe release of hydrogen
- Control of captured fission product decay heat
- Reliable retention of activity in short and long term venting operation

**Highly efficient**
- Reliable mid- and long-term operation thanks to the combined benefits of the high speed wet scrubbing technology and the most efficient dry metal fibre filter features
- Maximum retention rate of aerosols > 99.99 % and iodine > 99.5 %
- Large excess storage capacity for aerosols and iodine
- Complete process verification, even under elevated sliding pressure and temperature conditions with different types and sizes of aerosols and iodine
- Recirculation of the activity to the containment

**Optimum flexibility**
- Passive operation and operator-initiated startup
- Passive high speed control of the venturi section
- Operates over a wide range of flow rates
- System-inherent high overload capacities in throughput, aerosol capacities, etc.
- Seismic qualification
- Most compact design due to sliding pressure operation
- Easy to retrofit and maintain
This essential high speed control of the venturi section is realized fully passively in combination with down stream critical throttling devices reaching velocities of up to mach 1.

As the vent gas passes through the throat of the venturi nozzle, the incoming gas flow develops a suction that causes scrubbing water to be entrained with it. On account of the large difference between the velocity of the scrubbing water particles and that of the incoming vent flow, more than 99.5% of the aerosols are removed. At the same time, the particles of the entrained scrubbing water provide large mass transfer surfaces inside the throat of the nozzle, permitting effective sorption of iodine.

Conditioning the water with caustic soda and other additives leads to optimum iodine retention in the water pool inside the scrubber. This way, permanently most aerosol and iodine particles are in fact already separated inside the pool section, thus creating optimum operating conditions and enabling reliable long-term operation.

**Stage 2: Metal Fibre Filter Section**

In the second cleaning stage, the micro-aerosol filter combination additionally equipped with metal fibres down to 2 μm helps avoiding significant long term re-entrainment. The gas exiting from the pool venturi section contains small amounts of penetrating aerosols as well as small scrubbing water droplets. Both are removed from the gas by means of a high-efficiency droplet separation unit and a micro-aerosol filter stage downstream. In the first part of the filter unit, the water droplets are agglomerated and removed. The second part of the filter unit retains the aerosol particles that are usually too small for retention by any scrubber and droplet separator devices.

**Further System Features**

**Activity Recirculation**

During the venting process, iodine and aerosol are quantitatively separated inside the nozzle throats and stored in the venturi pool. The purpose of this recirculation of pool liquid is to store the activity inside the containment instead of keeping it outside the containment, e.g. in the venting system. The expected range of activity recirculation to the containment is 95 - 99 %.

**Integrated Auxiliary System Function**

In addition, the system includes provisions for inertization with nitrogen or steam, filling, conditioning, draining, and in-situ measuring of thermohydraulic properties. When not in operation, the system is kept inerted.

**Modular and Compact**

Thanks to their modular, compact design, the AREVA FCVS is easy to backfit into existing buildings at low cost. The scrubber and filter easily adapt to any reactor type, unit size, type of containment, or other design parameters without loss of efficiency or the need for requalification. If there are height restrictions, the scrubbing unit can be split, dividing the venturi section and the filter section into two horizontal vessels.
**Operation of the System**

The combined scrubber-filter system is connected to the containment either by two isolation valves or an isolation valve with a rupture disc and a venting line. The filtered vent gas is routed to a stack via a discharge line that is normally closed by a rupture disc but opens at a small overpressure of app. 0.5 bar.

Containment venting is initiated manually in accordance with the written emergency procedures by opening the containment isolation valves. Those may be operated either by independent batteries or manual remote. After this initiating action, the system works in an entirely passive mode.

The venting pressure of the system can range from approx. 0.2 bar to 10 bar gage and may drop during venting without any loss of removal efficiency. To terminate venting when desired pressure is reached, one or both isolation valves are closed.

The sliding pressure operation could provide important system-inherent additional venting mass flow capacities, e.g. in case of delayed venting more than 50% of design venting mass flow rate is possible.

<table>
<thead>
<tr>
<th>Typical System Data</th>
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<tbody>
<tr>
<td>Design Pressure</td>
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<tr>
<td>Design Temperature</td>
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<tr>
<td>Operating Pressure</td>
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<tr>
<td>Mass Flow Rate</td>
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<td>Decay Heat</td>
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**Qualification of Retention Process and Components**

AREVA consequently performed national and international qualification, including third party testing, to fulfill the international qualification standards.

**International Qualification Standard**

**High Speed Sliding Pressure Process Qualification**
- All components were tested at a full-scale mockup facility under simulated operating conditions
- Qualification tests covered the full range of sliding pressure operation, e.g.
  - 1 up to > 10 bars
  - pool temperature up to 150 °C
  - retention of iodine and different aerosols under pressure and more

**Enveloping Process Qualification**
- under participation of various international experts and authorities
- consequent testing in external test centers (US)
- third party confirmation of high retention and reliable operating results
- represents the latest international qualification standard
- finalized the venting process qualification successfully

**Passive Venting & Forced Flow Filtered Leakage Control**

For long term containment leakage control, e.g. of single shell containments, etc., the system can be equipped with a forced flow leakage control module. This module is again operated under high speed venturi conditions and equipped with additional filter stages, e.g. like metal fibre filters and molecular sieves.

This technology enables efficient long term containment leakage control for post severe accident situations of e.g. > weeks or - months - and very high aerosol and iodine retention (elemental & organic) of up to 99.9%.

**Licensing / Standard Compliance**

Applicable to all kinds of nuclear power plants

**References**

More than 50 applications in PWR, BWR, CANDU and VVER reactors worldwide (e.g. Germany, Switzerland, Finland, P. R. China, Canada, Korea, Rumania, Japan)

**Patent Rights Reserved**
Benefits at a Glance

• Prevention of excessive containment pressure
• Protect the structural integrity of the ultimate fission product barrier
• Excellent purification levels of gas discharges, even in long-term operation
• Unique high-speed sliding pressure process resulting in a very compact, easy-to-retrofit design
• Control of captured fission product decay heat
• Flexible process design enables sub-atmospheric containment leakage control by adding a forced module installation within existing plants

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