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APPLICATION OF A LOW PRESSURE CONTAINMENT FILTERED VENTING SYSTEM FOR A LONG-TERM CONTAINMENT COOLING

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Introduction

- Most of the VVER-440 NPPs worldwide have already implemented or are planning to implement in a near term In-Vessel Retention (IVR) of corium as a part of the severe accident management strategy.
- Based on the outcome of the National Action Plans a long-term heat removal is still an open issue that needs to be resolved.
- In some countries as e.g. in Sweden, Containment Filter Venting System (CFVS) can be credited for containment cooling in case it is demonstrated that the system can still fulfill its major task.
- CFVS and especially Dry Filtered Method (DFM) can optimally support long-term containment cooling through Feed & Bleed approach.

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Containment Filtered Venting System

- A Containment Filtered Venting System (CFVS) acts as the last barrier for minimizing the release of radioactive material to the environment when all other safety systems failed.
- The currently installed CFVSs are based on different filtration technologies which can be divided into two categories:
  - wet systems using water as first filtration stage and optional metal fiber filter as second filtration stage
  - dry system based on deep bed filtration (metal fibers) for retention of aerosols and optional iodine filter (silver doped zeolite) for iodine retention
- Usually the efficiency of a CVFS is given by the retention efficiencies of
  - aerosols (e.g. CsI, CsOH),
  - elemental iodine (I_2) and
  - organic iodine (CH_3I, etc.)

Westinghouse has developed both dry and wet filter technology

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Low Pressure Application of DFM

Confinement of VVER-440 is not designed for high over pressures and shows high leak rates at elevated pressures.

- Early venting at low pressure limits leakage and protect the integrity of the confinement. In a same time it assures long-term heat removal.
- DFM filters can operate at a very low pressure without a need for an external power supply (minimum required overpressure is 150 mbars).
- In contrary, wet scrubbers requires electrically power supplied blowers in order to be effective.
- DFM filters are designed to run with low differential pressure across filter media.
- DFM implementation for NPP Darlington proved viability of low pressure operation.

DFM is also effective for very low containment and confinement pressures

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Low Pressure Application of DFM - Main Filter Components

The DFM consists of two major passive filter components:

- Aerosol Filter (deep bed metal fiber filter)
  - removal of solid particles (aerosols) – e.g. CsI, CsOH
  - partial retention of I_2
- Iodine Sorption Filter (molecular sieve with zeolites)
  - High efficiency removal of elemental iodine – I_2
  - High efficiency removal of organic iodine – CH_3I

Two variants are considered for VVER – 440 application:

- Combined aerosol/iodine filter
- Aerosol filter

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Low Pressure Application of DFM - Example Combined Aerosol/Iodine Filter vs. Aerosol Filter

Filter Properties	Combined Aerosol/Iodine Filter	Aerosol Filter
Housing number	1 filter housing	1 filter housing
Housing dimensions (L x H x W)	8.3 m x 3.7 m x 1.8 m	5.8 m x 3.7 m x 1.8 m
Housing weight (tons)	approx. 19	approx. 12
Total aerosol/iodine filter area	24 m^2 (8 filter beds)	24 m^2 (8 filter beds)
Area per filter stage	3 m^2	3 m^2
Bed depth of iodine filter beds:	60 mm*	-
Decay heat load	100 kW aerosol filter and 42 kW Iodine filter	100 kW
Maximum aerosol load	-	36.5 kg (by 400 mbar)
Retention efficiency:		
Aerosols	99.99 %	99.99 %
Elemental iodine (I_2)	99.0 %	80.0 %
Organic iodine (CH_3I)	90.0 %	0.0 %

*It might be reduced (to 40 mm) depending on filter efficiency needed

Filter can be optimized to space constraint application inside containment

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Low Pressure Application of DFM - Combined Aerosol/Iodine Filter (photo)

8.3 m

3.7 m

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Low Pressure Application of DFM - Iodine Retention of Aerosol Filter

Aerosol filter retention efficiency:

- The designed retention efficiency of the aerosol filter is > 99.99 % for aerosols.
- Experimental investigations have demonstrated that also elemental iodine is retained in the metal fiber stages of the aerosol filter. During these tests a retention efficiency up to 95 % has been experimentally measured for elemental iodine.
- Conservatively a retention efficiency of 80 % for elemental iodine can be assumed for the aerosol filter.
- **An integral iodine retention efficiency** in aerosol form (CsI) and gaseous in elemental (I_2) and organic (CH_3I) can be estimated based on the expected vector of iodine species and **is approx. 98.87 %**

Only aerosol filter without iodine filter stage can fulfill integral retention efficiencies

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MELCOR Analysis (1/2)

In order to prove the efficiency of DFM applied to VVER-440, a sample MELCOR calculation was performed assuming following boundary conditions:

- Station Black-Out (SBO) accident scenario
- Only aerosol filter (no iodine) was considered
- The filter was modelled with retention efficiency of 99%
- Iodine is captured by the filter only in aerosol form
- Venting started at the moment when temperature of fuel cladding exceeds 1200°C.
- Accident time was assumed to 72 hours

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MELCOR Analysis (2/2)

Main results of MELCOR calculation:

- **DFM is very efficient** - Radioactive release of main radioactive isotopes is considerably less than release with intact confinement and significantly less than the release due to confinement failure.
- SBO scenario is characterized as low and medium pressure during severe accident progression, which leads to underestimated efficiency of venting system.
- **Calculation is very conservative**:
  - DF for aerosols is about 100 times higher in reality.
  - Gaseous iodine filtration was not considered (in reality metal-fiber aerosol filter has considerable capability for elemental iodine retention, zeolite iodine filter shall provide DF of more than 99%).
- **Two DFM configurations** are considerable: **combined aerosol/iodine filter and single aerosol filter.**

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Dose Calculations (1/2)

Furthermore, in order to prove efficiency of DFM applied to VVER-440 a sample dosis calculations were performed:

- One sever accident scenario at in-vessel phase was assumed.
- MELCOR code calculations were carried out in order to determine the isotope structure and magnitude of emission by key isotopes for four cases:
  - without filtered venting
  - with filtered venting - only aerosol filter
  - with filtered venting - only iodine filter
  - with filtered venting - both aerosol and iodine filters
- Duration of calculation was assumed to 60000 s. Emergency relief of the containment atmosphere environment began after 25000 s into the accident when fuel elements cladding is starting to melt.
- The obtained data on isotope vector and intensity of emission were loaded into the CADO 4.0 and calculations of doses for two weeks are executed under identical boundary conditions of emission.

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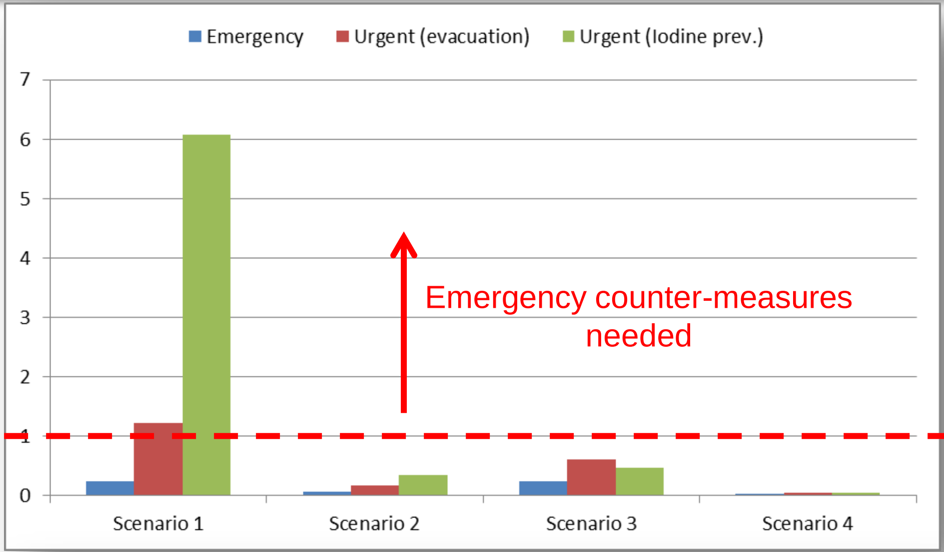
Dose Calculations (2/2)

Main calculation results:

- For each scenario the radiological consequences have been calculated at both onsite and at various distances to the plant.
- A comparison of the radiological consequences to intervention limits has been performed.
- **With no DFM**, criteria on application of the **emergency counter-measures** (urgent, evacuation and iodic prevention) **close to NPP site is reached**.
- Exceedance of criteria on evacuation and iodic prevention is observed at the distance up to 15 km from NPP.
- **By use of DFM**, radiation consequences are such decreased that **no intervention criteria are reached 15 km from the NPP**.



Result, criteria	Scenario 1 (without CFVS)	Scenario 2 (CFVS, aerosol filter)	Scenario 3 (CFVS, iodine filter)	Scenario 4(CFVS, aeros.+iodine filters)
Distance 15 km from the NPP				
Ratio "dose/criteria" for emergency countermeasures (2 days)	0.237	0.064	0.248	0.028
Ratio "dose/criteria" for immediate countermeasures - evacuation (14 days)	1.22	0.174	0.602	0.042
Ratio "dose/criteria" for immediate countermeasures - iodine prevention (14 days)	6.08	0.348	0.464	0.046

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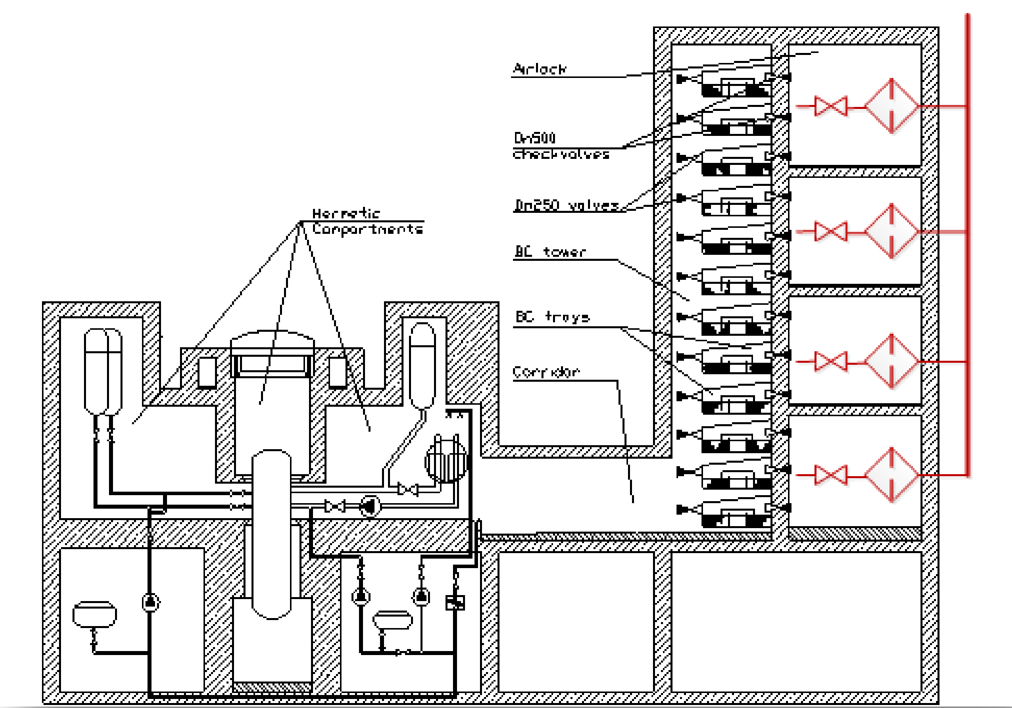
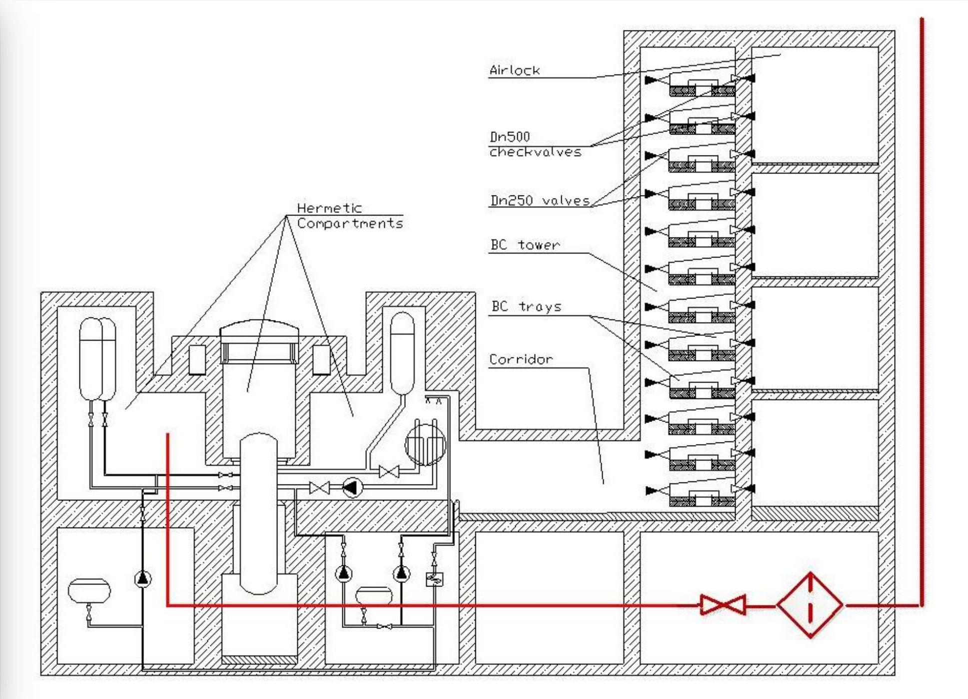
Potential Installation Scheme



Use of BC Tower



Use of Exhaust Ventilation System

The filter can be optimized to space constraint application inside containment

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Summary and Main Advantages

Application of a low pressure CFVS for a long-term containment cooling is confirmed in principle. Main advantages of the DFM application to VVER-440 are:

- Significantly reduced radioactive release and radiation consequences
- Assurance of long term confinement cooling
- Completely passive solution
- Efficient on low overpressures (starting from 150 mbar)
- Proved solution already built in Darlington for containment with 1.5 bar(abs) design pressure
- Technical solution adjustable to specific plant requirements and needs
- Flexible delivery model depending on utility preferences and budget

A plant specific analysis should be performed in order to identify the most optimal filter configuration

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Thank you for your attention!

Questions?

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Dry Filter Method - References

- DFM with aerosol filter **inside** containment:
  - NPP Biblis A and B (delivered in 1990 and installed in 2002)
  - NPP Mülheim-Kärlich (1991)
  - NPP Krško (2013)
  - NPP Ohi 3&4 / Takahama 3&4 (under development)
  - NPP Sizewell B (Design study completed)
- DFM with aerosol filter **outside** containment :
  - NPP Brokdorf (1986 and 2002)
  - NPP Grohnde (1990)
  - NPP Unterweser (1990)
  - NPP Stade (1990)
  - Darlington Nuclear Generating Station (Installation phase)

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