The Effects of Particle Size on Filtered Containment Venting Systems

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Filtered Containment Venting Systems (FCVS)

- Control containment pressure
- Reduce hydrogen concentration
- Minimize fission product releases
- Limit land contamination
Filtered Containment Venting Systems (FCVS)

- **Wet Filtration**
  - pool scrubbing
  - IMI, Westinghouse, Areva

- **Dry Filtration**
  - gravel/sand bed
  - metal fiber

Source: neimagazine.com
Filtered Containment Venting Systems (FCVS)

- Random Laid (Non Woven) Matrix
- Metal Fibers 1-30um
- Sinter-bonded
- No Binders
- Pleatable
- High Porosity 60-80%
Design Considerations

- Water vapor and other condensates
- High and variable gas flow rates
- High and variable solids burden
- Dissipation of decay heat
- High operating pressure and temperature
- Extended design and shelf life
- Seismic and other physical design criteria
Design Considerations

Particle size distribution

Aerodynamic shape
Filtration Principles

- Direct Interception
- >5 micron
Filtration Principles

- **Inertial Impaction**
- 0.5 to 8 micron
Filtration Principles

- Inertial Interception
- 0.1 to 1 micron
Filtration Principles

- Brownian or Diffusional Interception
- <0.5 micron
Filtration Principles

- The recognized Filtration Gap
- Most Penetrating Particle Size (MPPS)
- .13 - .18 micron
Aerosol Characterization

Particle size distribution

Aerodynamic shape
Aerosol Characterization

- Severe Accident Progression Modeling (MELCOR, ASTEC, CONTAIN, etc.)
- Laboratory/Experimental Data
- Accident Data (TMI and Fukushima)
Aerosol Characterization

- Spherical particle assumption and/or
- Consistent aerodynamic shape
- Discreet, regular solids
- Mono-dispersed sizing
- 0.2 micron mean diameter
Aerosol Characterization

• A spherical particle assumption is invalid

Models describing aerosol dynamics generally assume spherical, fully dense particles but nuclear aerosols are often neither, particularly those originating from core melt sequences, or accident scenarios in which large parts of containment have low humidity. [1] NEA-CSNI Report
Aerosol Characterization

- Aerodynamic shape is **not** consistent

Examples of folded and chain agglomerates [1]
Aerosol Characterization

- Containment aerosols are rarely mono-dispersed
- Yet, a lognormal distribution is commonly accepted to be a suitable representation of particle size within containment [1]
Aerosol Characterization

Example of lognormal particle size distribution [1]
Aerosol Characterization

- **Agglomeration of multi-component aerosols over time** given varying environmental conditions within containment.
- **Re-suspension of particles** due to seismic activity, hydrogen combustion and breach of containment.
- Pool scrubbing, hydrogen recombination, and containment spraying.
- Releases associated with a **molten corium concrete interaction (MCCI)** – these releases would include some concrete-based aerosols.
- **Fires within containment** (can cause the mixing of fire aerosols with nuclear aerosols, thus changing the nature of the particle challenge).
- It can be noted, that at Fukushima Dai-ichi, seismic activity, hydrogen combustion, MCCI, and numerous other factors played a part in the releases of radionuclides from containment [2].
Filter Cake Development
Filter Cake Development

- **0.2 micron** MPPS has been assumed

- Using a normal sized filter element and standard test dust data and a mean particle size of **5 microns** gives a DP of 130 mbar and a cake thickness of 0.5 mm, retaining **470 grams per element**

- Using the same conditions as the above but changing the mean particle size to **0.2 microns** reaches 130 mbar DP with a cake thickness of 0.8 microns retaining **0.7 grams per element**

- These sizes suggest some form of blinding mechanism and not dust cake evolution
Filter Cake Development

![Graph showing differential pressure over time with lines indicating cake formation and pore blinding.](chart.png)
Conclusions

The details of particle shape and size distribution in reactor containment during severe accident scenarios need to be better characterized for effective filter system design.

Porvair Filtration Group has identified several specific topics for further investigation:

- Aerosol particle **size distribution** (specific to given accident scenarios and plant designs)
- Aerodynamic **particle shape** and associated shape factor
- Aerosol **variation over time** during accident progression
- Bulk density and void fraction of filter cake
Questions?
References


