The Effects of Particle Size on Filtered Containment Venting Systems

Eric R. Duvekot
Porvair Filtration Group
Ashland, VA USA

Content

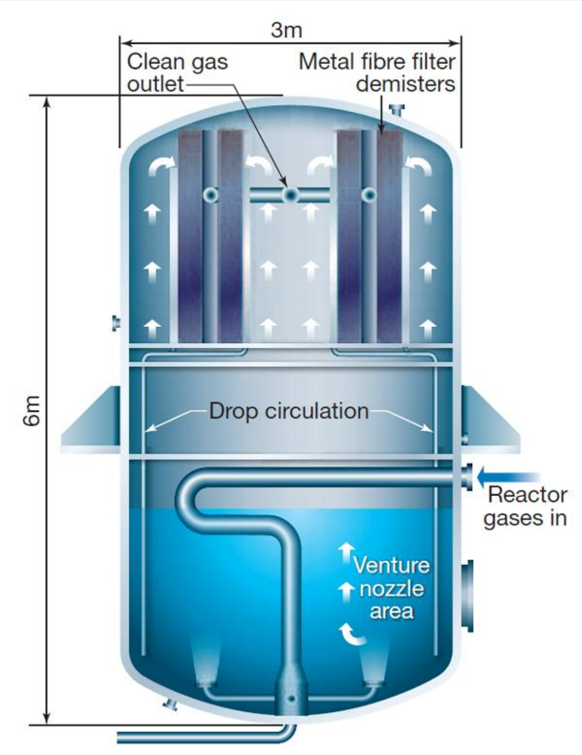
- Filtered Containment Venting Systems
- Design Considerations
- Filtration Principles
- Aerosol Characterization
- Filter Cake Development
- Conclusions

Filtered Containment Venting Systems (FCVS)

- Control containment pressure
- Reduce hydrogen concentration
- Minimize fission product releases
- Limit land contamination

Filtered Containment Venting Systems (FCVS)

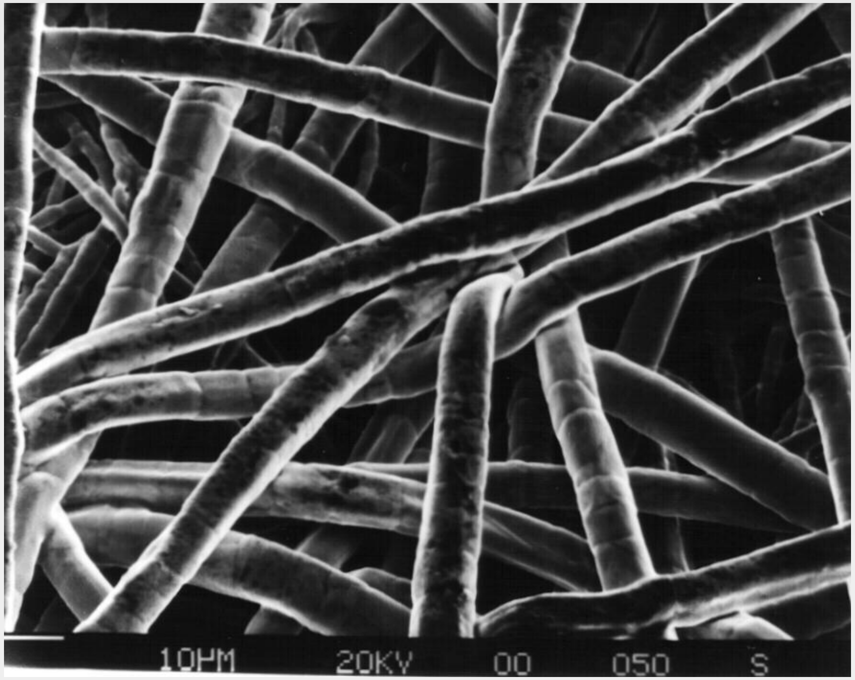
- Wet Filtration
  - pool scrubbing
  - IMI, Westinghouse, Areva
- Dry Filtration
  - gravel/sand bed
  - <u>metal fiber</u>



Goesgen filter tank.
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

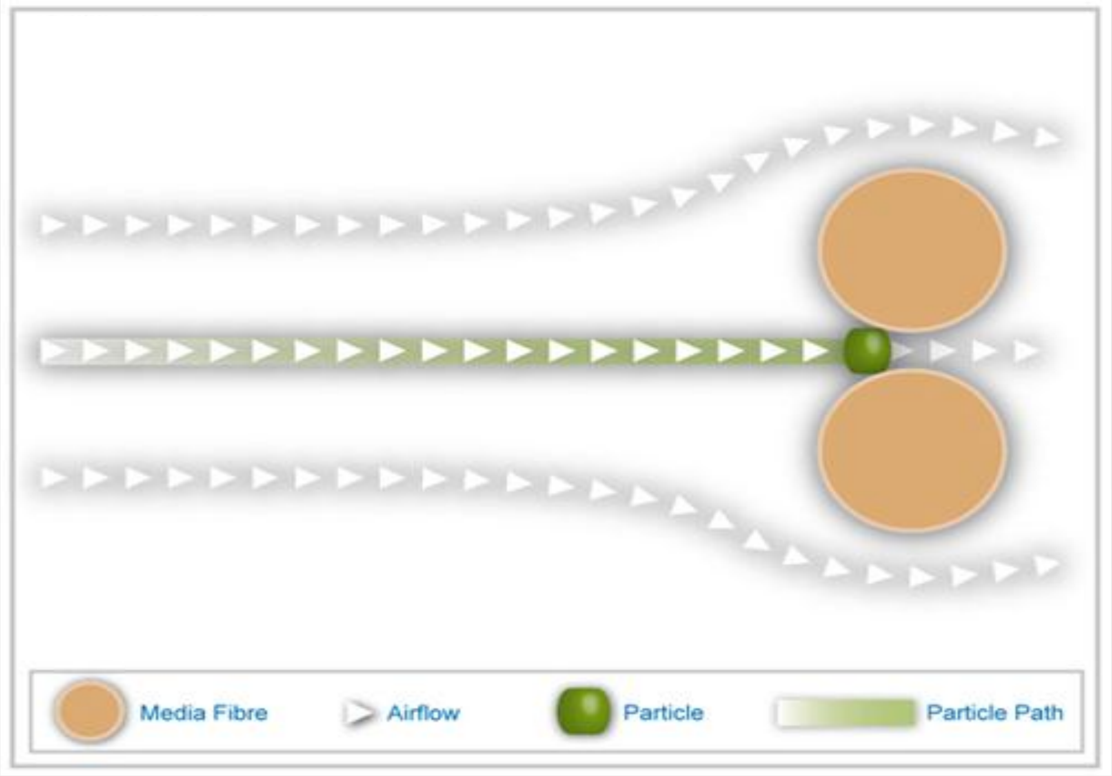
Design Considerations

Particle size distribution

Aerodynamic shape

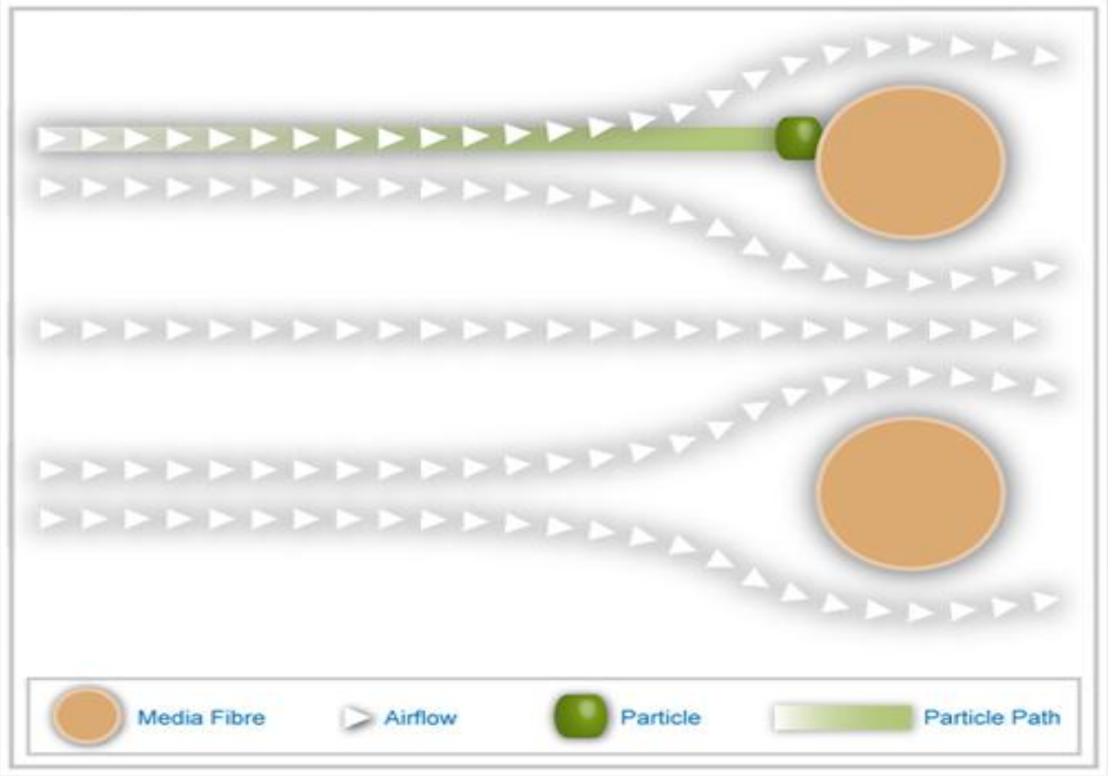
Filtration Principles

- **Direct Interception**
- >5 micron



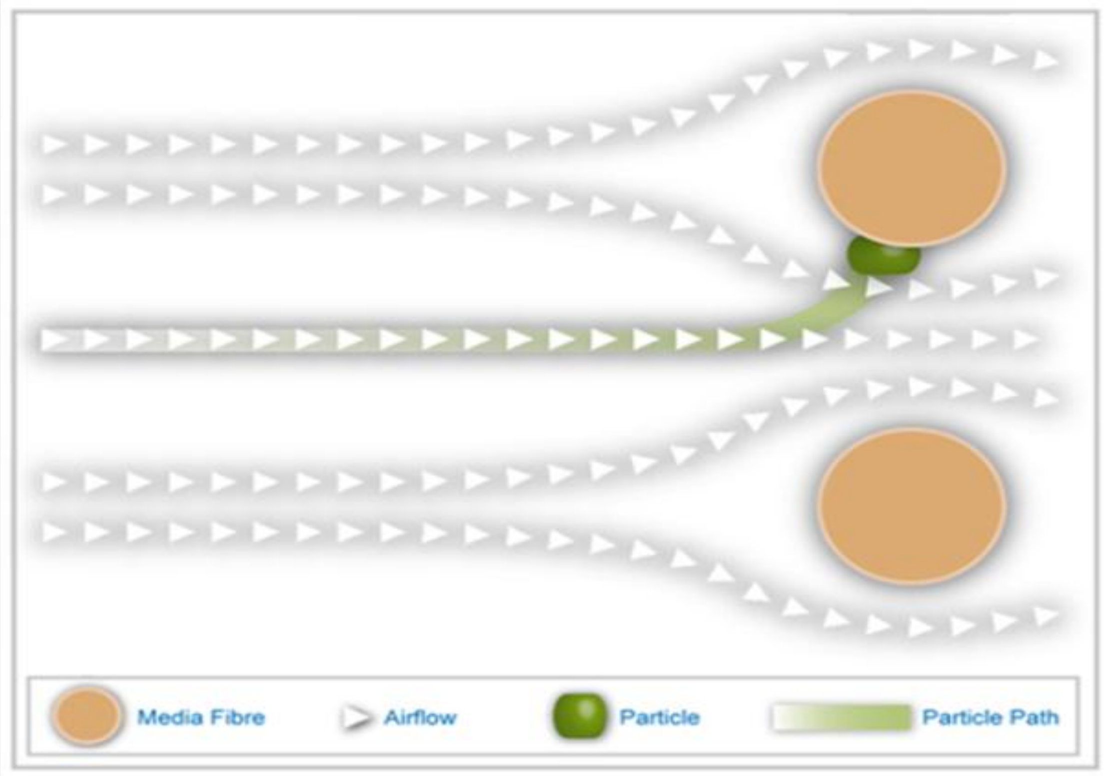
Filtration Principles

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



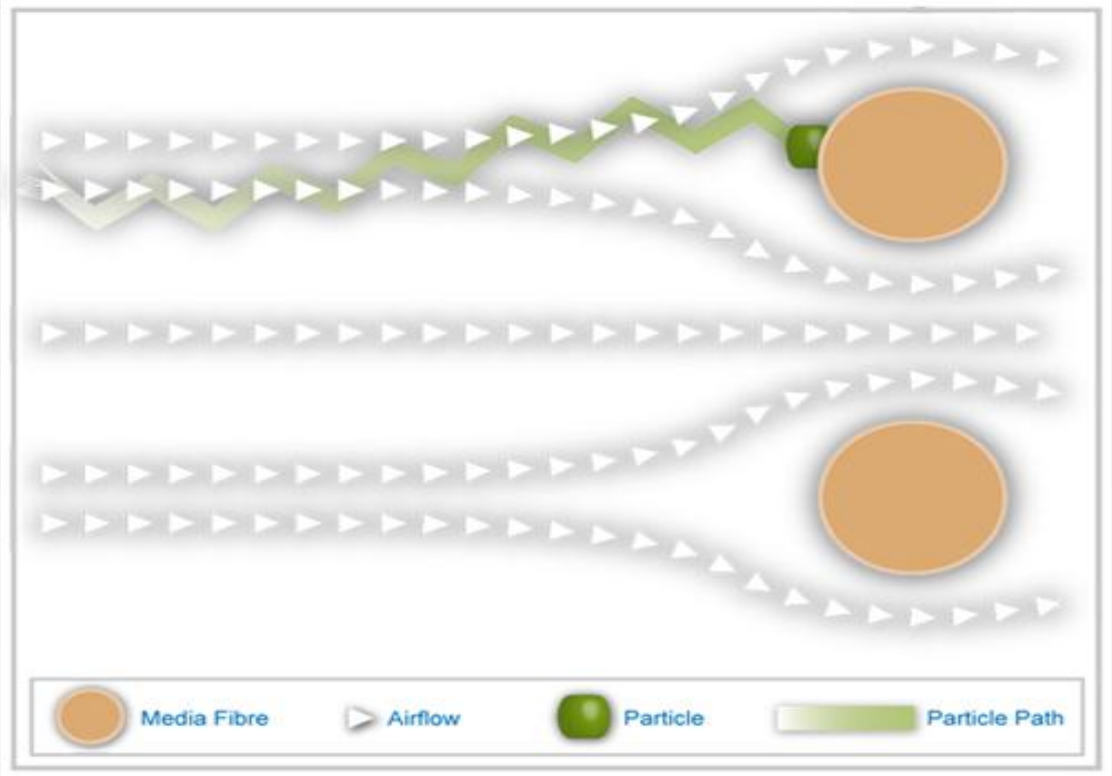
Filtration Principles

- **Inertial Interception**
- 0.1 to 1 micron



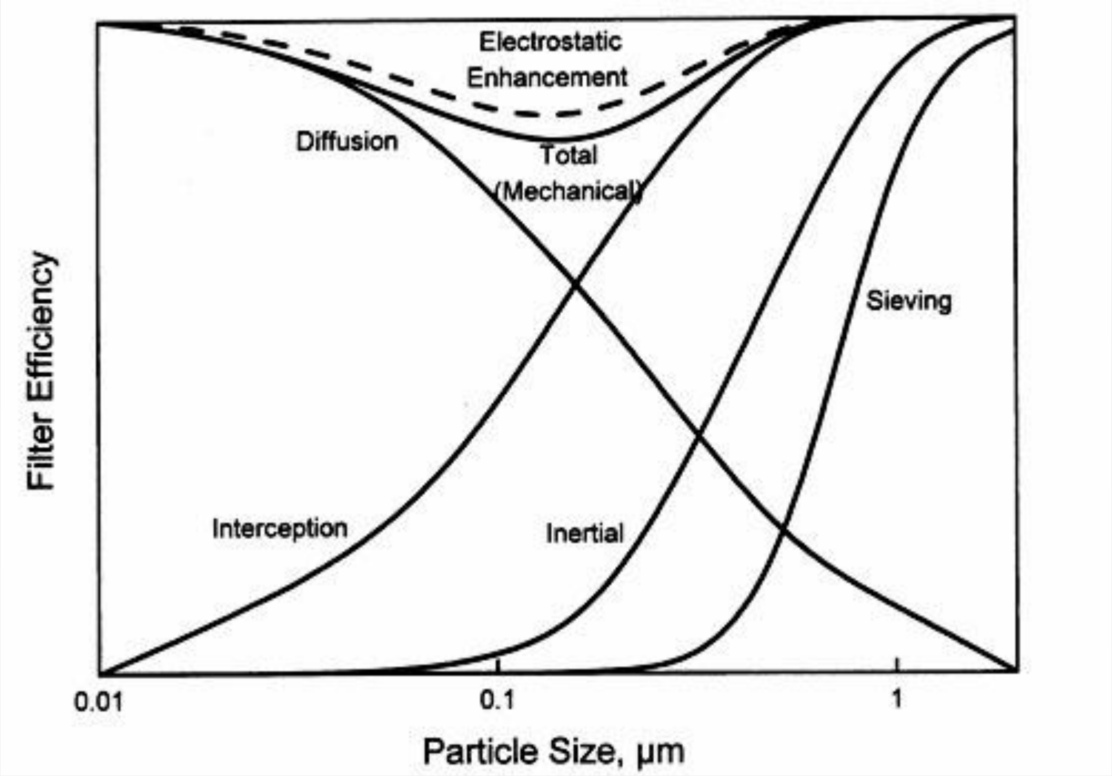
Filtration Principles

- **Brownian or Diffusional Interception**
- <0.5 micron



Filtration Principles

- **The recognized <u>Filtration Gap</u>**
- 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

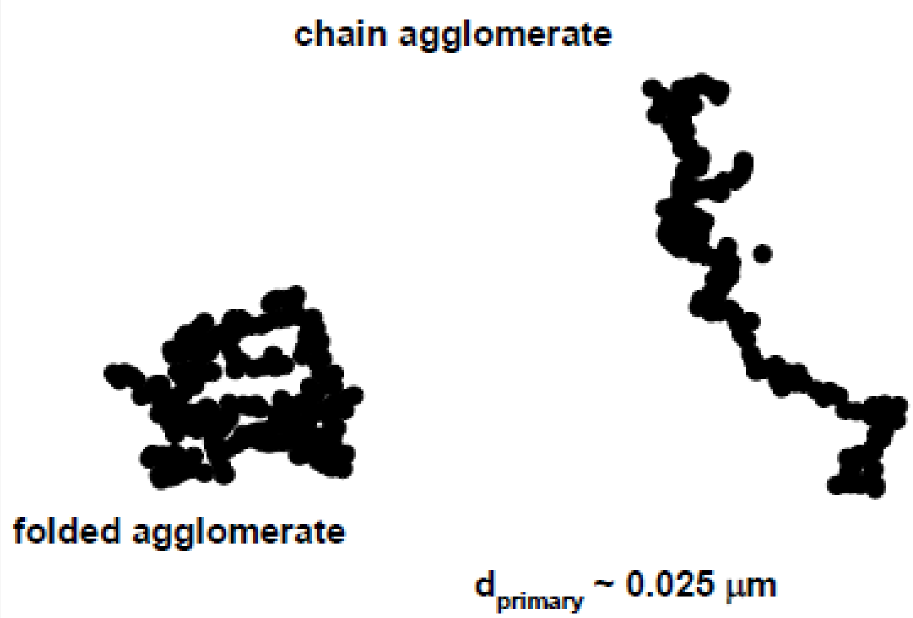
Aerosol Characterization

- A spherical particle assumption is ***<u>invalid</u>***

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

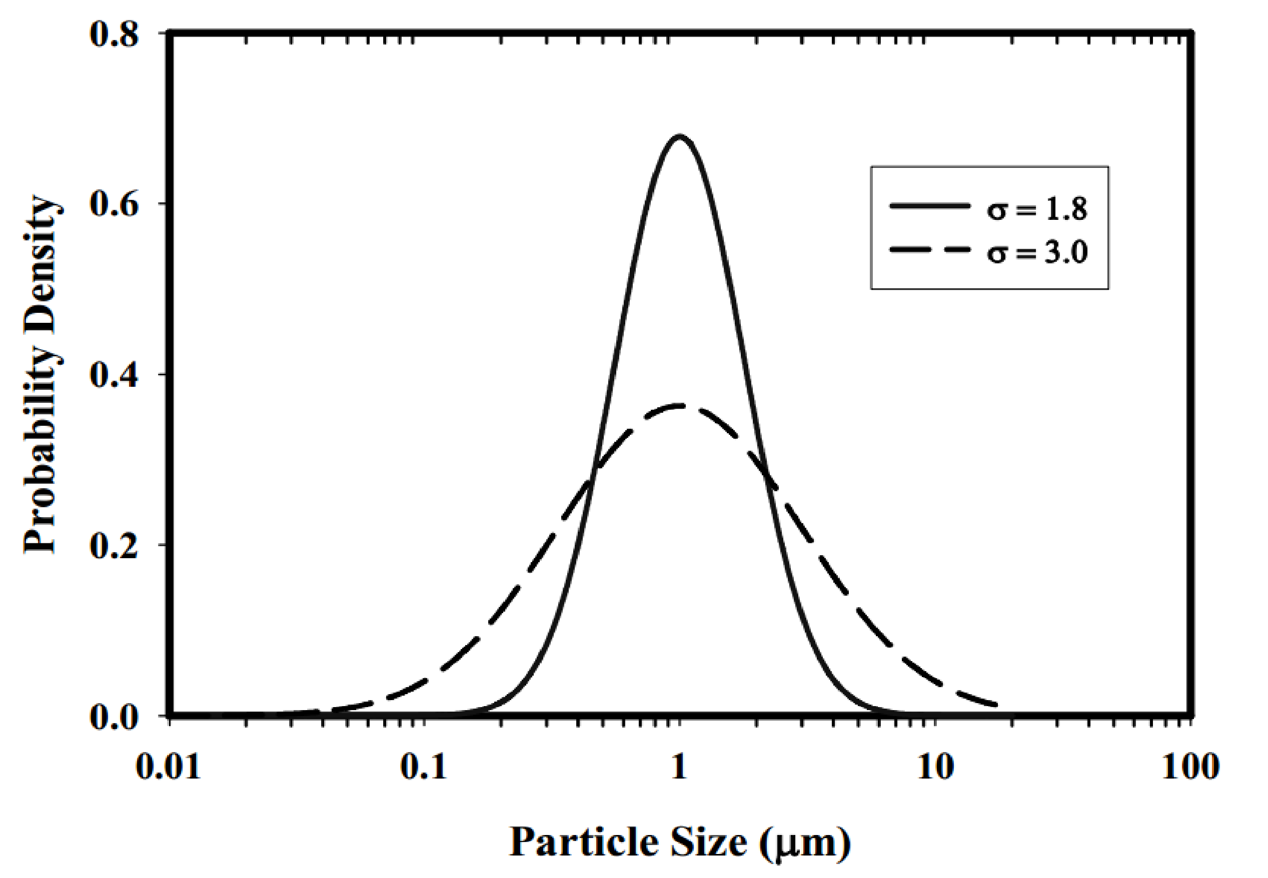


Examples of folded and chain agglomerates [1]

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

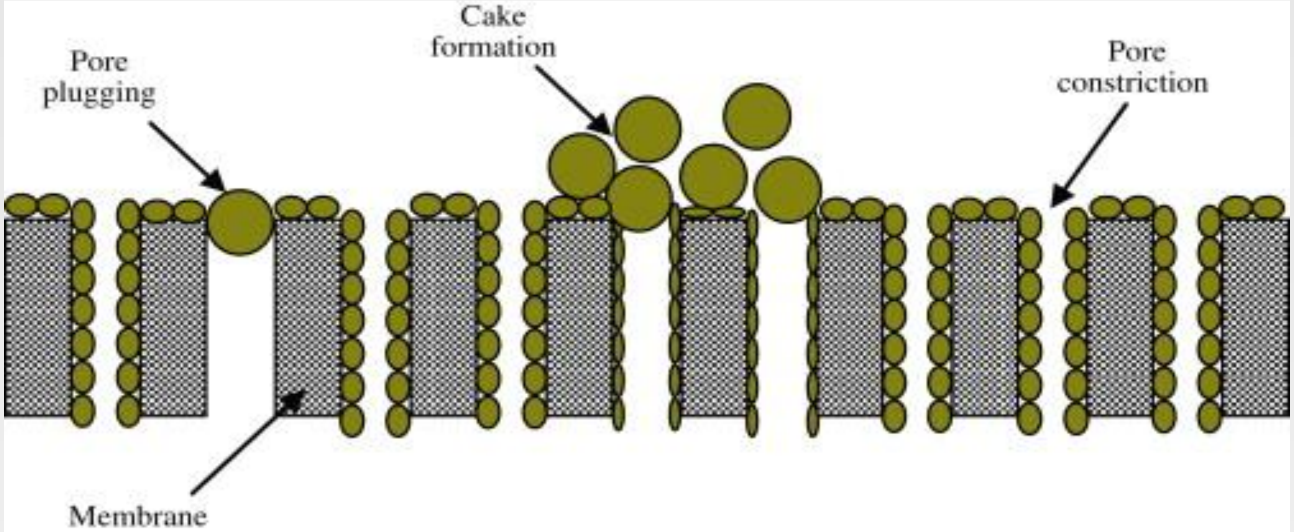


Example of lognormal particle size distribution [1]

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

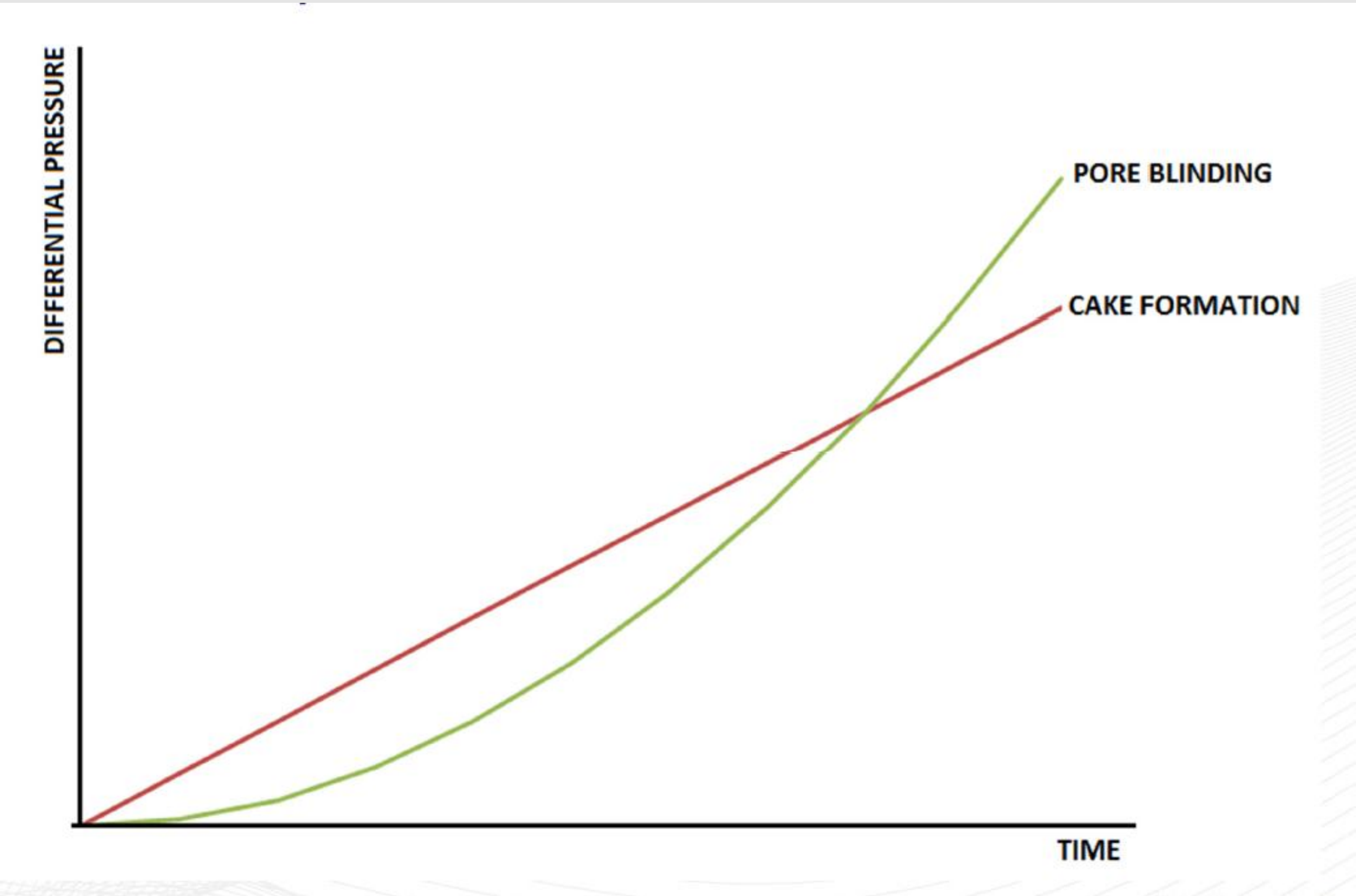
- **0.2 micron** MPPS has been assumed

- 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



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

[1] NEA/CSNI Group of Experts on Nuclear Aerosols in Reactor Safety, State-of-the-Art Report on Nuclear Aerosols, December 2009.

[2] H. Hoshi, M. Hirano, "Severe Accident Analyses of Fukushima-Daiichi Units 1 to 3," Japan Nuclear Energy Safety Organization (JNES), Presentation, 17 September, 2012.

[3] A. Bevis, "Filtration Training Programme," Presentation, August 2013.

[4] A. Wolski, "Worley Parsons – Global Nuclear" IAEA Regional Workshop on Advanced Level 2 Probabilistic Safety Analysis, July 2013.

[5] R.J. Wakeman and E.S. Tarleton, Solid/Liquid Separation: Principles of Industrial Filtration, Elsevier, 2005 (ISBN 1 8561 74190)