

Design and Operation of European Containment Filtered Venting Systems

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WorleyParsons

37,000 people in 165 offices throughout 43 countries



FY04 – \$ 0.5 B

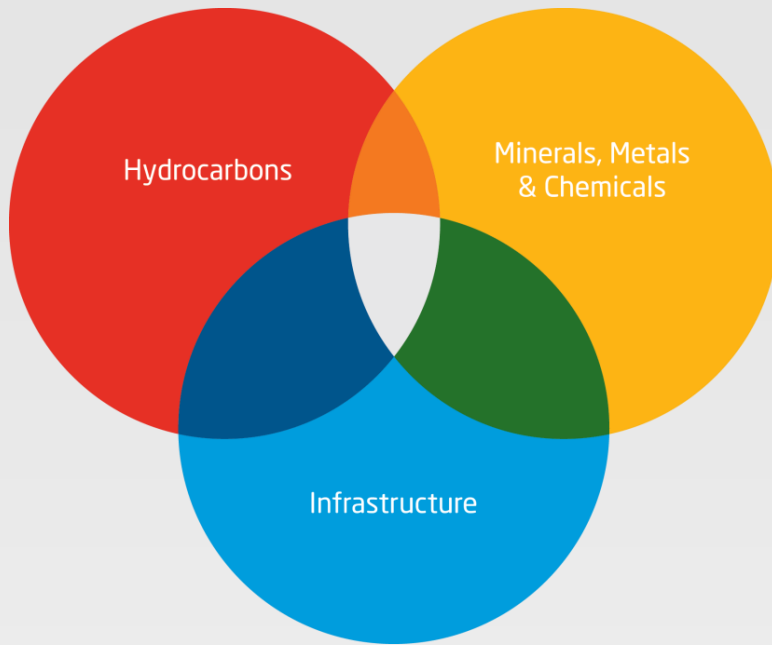
FY13 – \$ 7.6 B

>140 Legacy
Companies

WorleyParsons was ranked **No. 1** in ENR's Top 200
Engineering Firms in 2013



WorleyParsons



- Sofia, Bulgaria
- Reading, PA
- Toronto, ON

- Nuclear Engineering since Shippingport (1954-57)
- Engineer on Record for 18 units in US, Asia, Europe
- Support full lifecycle of the nuclear asset
- “Market-leader” in New-build support world-wide
- Strong focus on safety upgrades and uprates

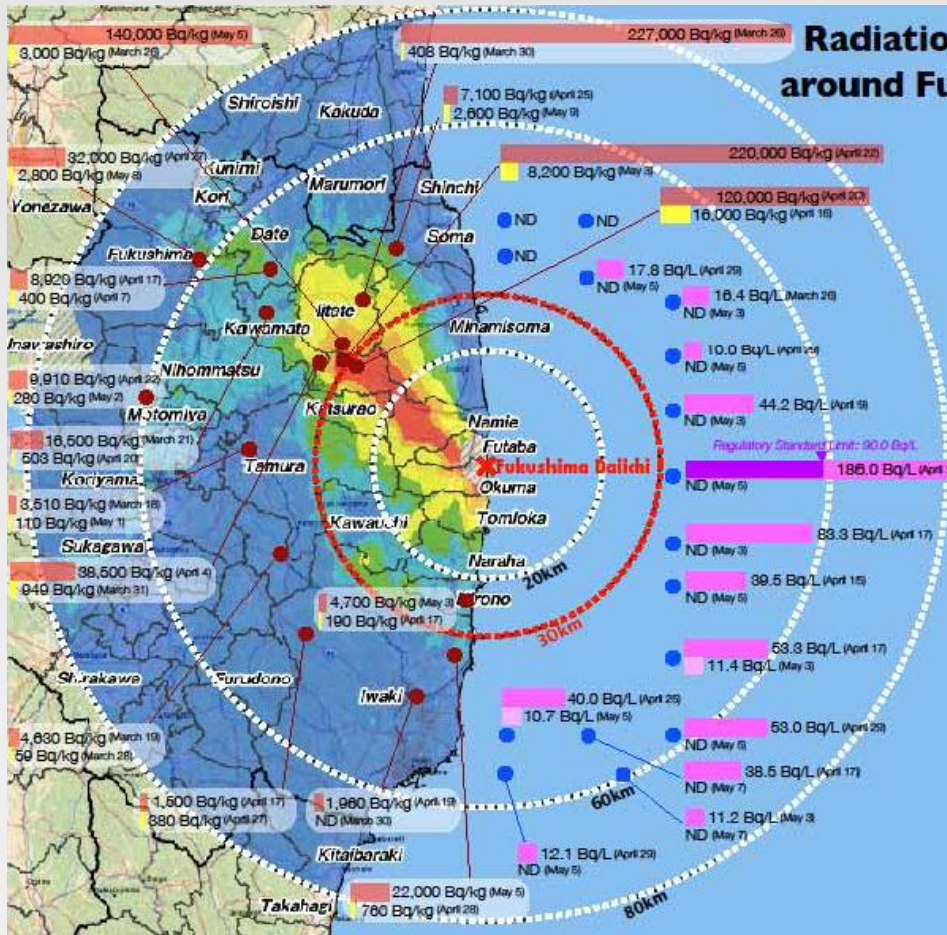


CFVS “What” and “Why”

- Severe Accidents (SA) in NPP may lead to melting of the fuel and destruction of the Reactor Vessel.
- The residual heat of the radioactive isotopes combined with complex reactions between the melt and the concrete continue to increase pressure and temperature for an extended period.
- The reactor containment may lose its structural integrity due to over-pressurization leading to uncontrolled radioactive releases in the environment.
- Controlled Containment Venting avoids containment failure and releases energy.



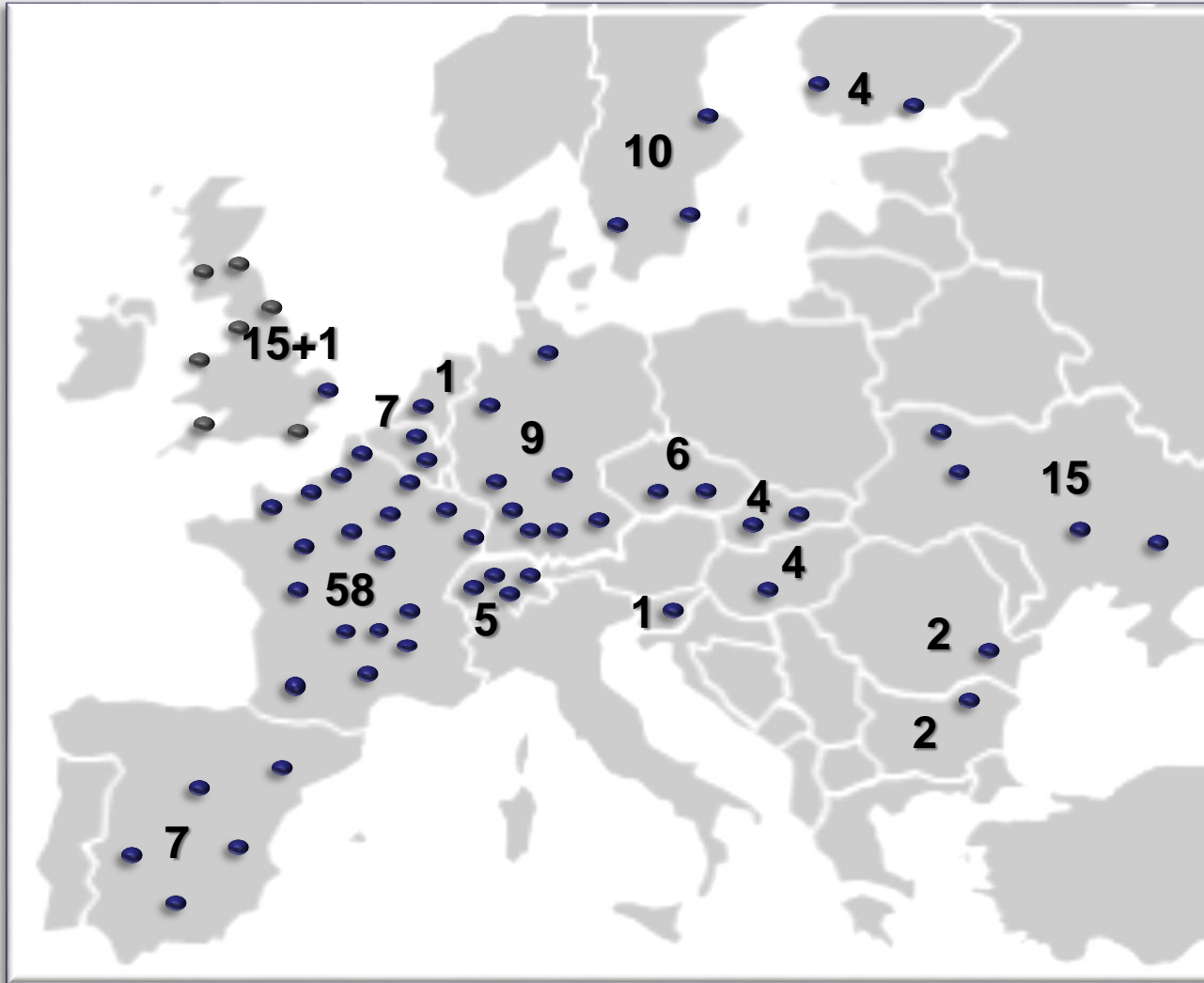
CFVS “What” and “Why”



- High performance particle filters in the vent lines avoid extensive land contamination.
- Specialised iodine filters mitigate immediate radiological impact.
- Controlled release through stack mitigates radiological impact of gaseous nuclides.



CFVS Status in Europe



Nuclear Power

EU+CH+UA

16 Countries

64 Sites

151 Reactors

136 PWR/BWR



CFVS “First Wave” in Europe

- Active consideration started with TMI (1979-03-28)
- Chernobyl (1986-04-29) intensified the activities significantly.
- Germany as one example:
 - Atomic Act(1959) requires “state of science and technology” for prevention of damages as condition for operation.
 - Extreme events (multi-unit, explosions, airplanes, ATWS) included.
 - Reactor Safety Commission (RSK) tasked to investigate more hypothetical accident scenarios and combinations thereof.
 - 1985/86 RSK recommends measures for depressurization of the containment vessel via high-efficiency particulate filters.
 - 1986 all German utilities commit to implement the RSK recommendations.
 - 1992 all 20 operating commercial power reactors have CFVS
 - 1994 Revision of Atomic Act makes CFVS mandatory for new facilities.

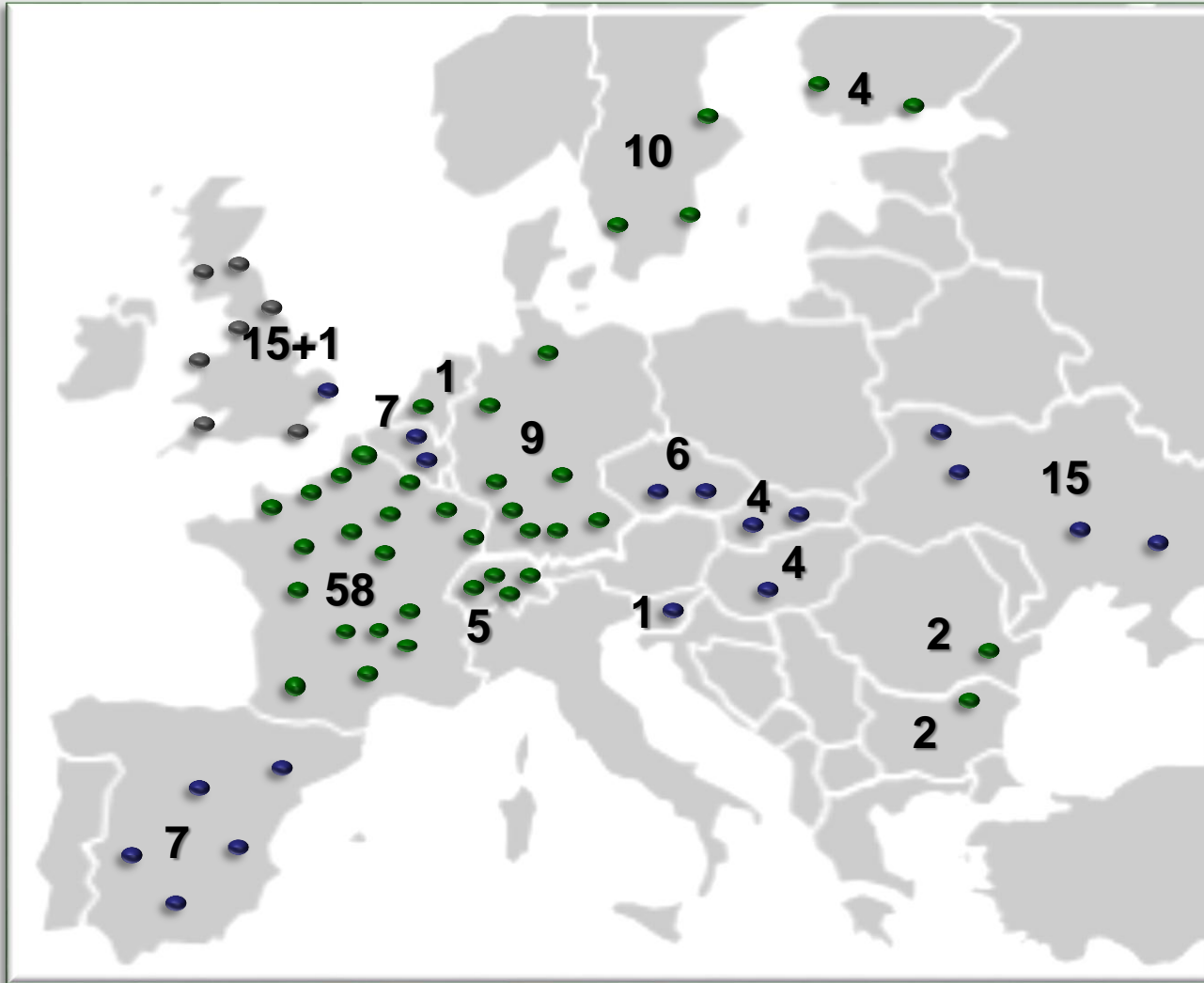


CFVS “First Wave” in Europe

- Multiple European Countries mandated the implementation of CFVS after the Chernobyl accident
- The implementation took place on a national level by formulation of regulations and/or inclusion in the respective Nuclear Legislation.
- No consistent set of technical requirements was established across the European countries.
- Typical efficiency requirements are:
 - $DF > 1000$ for aerosols
 - $DF > 100$ for molecular iodine
 - $DF > 10$ for organic iodine



CFVS Status in Europe



CFVS before
2011-03-11
EU+CH+UA

8 Countries
91 PWR/BWR



CFVS – Post-Fukushima

- EC (ENSREG) deployed “Targeted Reassessments of safety margins” for all European reactors (“stress tests”) coming to the following conclusions:
 - (1) The Fukushima disaster highlighted once again the importance of the containment function, [...] as the last barrier to protect the people and the environment [...]***
 - (2) Containment Venting must be considered via filters designed for severe accident conditions.***
- All European Countries – based on the results of their national stress tests – submitted by the end of 2012 binding action plans to increase the robustness of their nuclear plants against extreme events.



CFVS – Post-Fukushima

- Some countries decided on upgrades of the installed CFVS with respect to seismic resistance and efficiency.
- All countries without installed CFVS addressed the issue.
- Belgium, Slovenia, Spain, Ukraine and the UK mandated the installation of CFVS within timeframes ranging from end of 2014 until end of 2018.
- For the 440 MW Russian type PWRs retrofitting an external pressure vessel cooling system has been demonstrated feasible and would avoid destruction of the vessel. The benefit of a CFVS in this case has to be investigated (Czech Republic, Slovakia, Hungary).



CFVS – System Designs

- **Wet System Designs**

- Scrubbing of the steam/gas through water retains particles.
- Chemicals for simultaneous retention of iodine.
- Predictable behaviour towards residual heat.
- Need control and operator intervention.

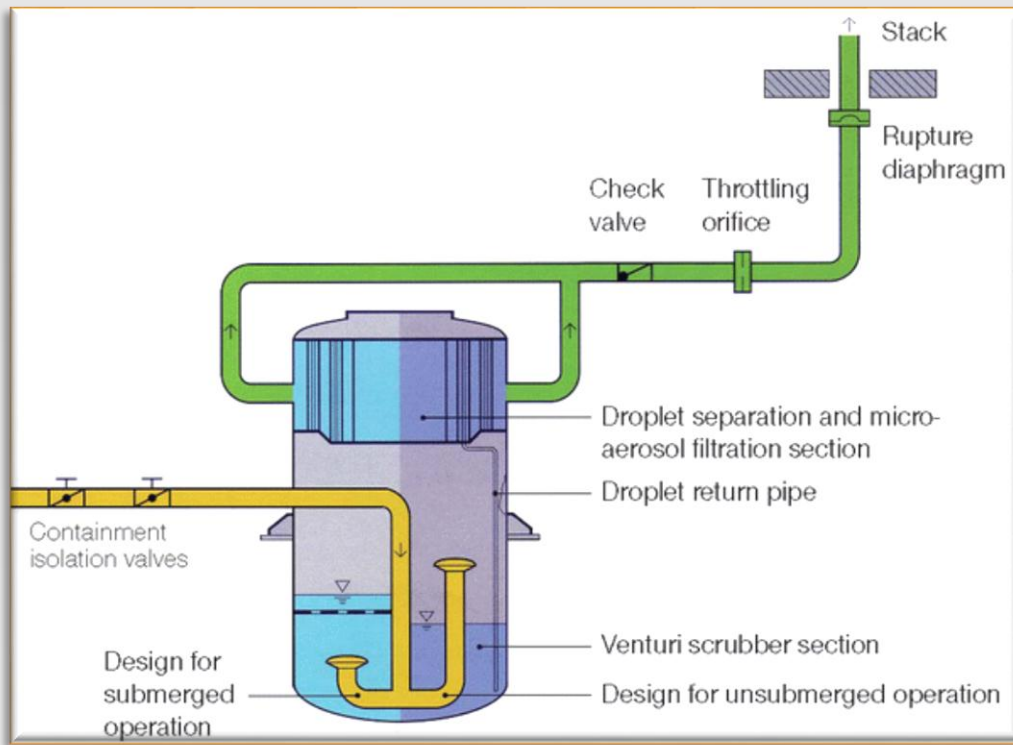
- **Dry System Designs**

- Use either sand beds or stainless steel fibre filters.
- Use separate stage for iodine filtration, if required by regulator.
- Can achieve high efficiency for particle retention.
- Require special consideration for heat dissipation.



Wet Filters (1) - AREVA

High Speed Sliding Pressure Venting (Plus)

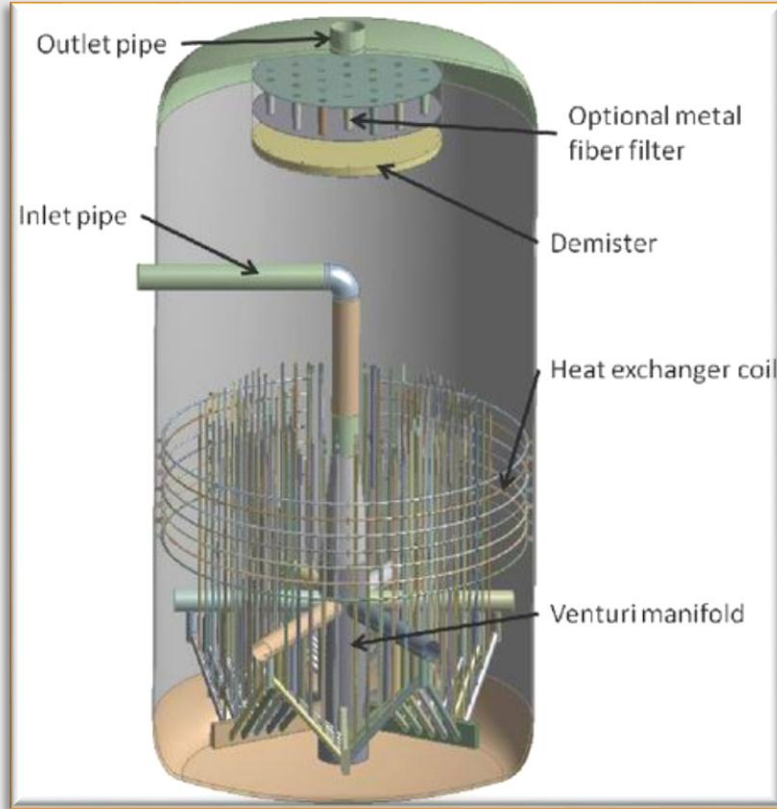


- Short venturi nozzles
- Droplet separator
- pH- control plus thiosulfate addition
- Flow-choking venturis combined with orifice maintain constant volume flow.
- Inside or outside of the containment.



Wet Filters (2) - Westinghouse

Filtra-Multi-Venturi-Scrubber



- Based on 1st Generation ABB Atom design
- Long venturi nozzles for higher pressure drop (efficiency)
- Geometrical control of engaged venturis
- Outside of the containment.



Wet Filters (3) – IMI Nuclear

Filtered Containment Venting System

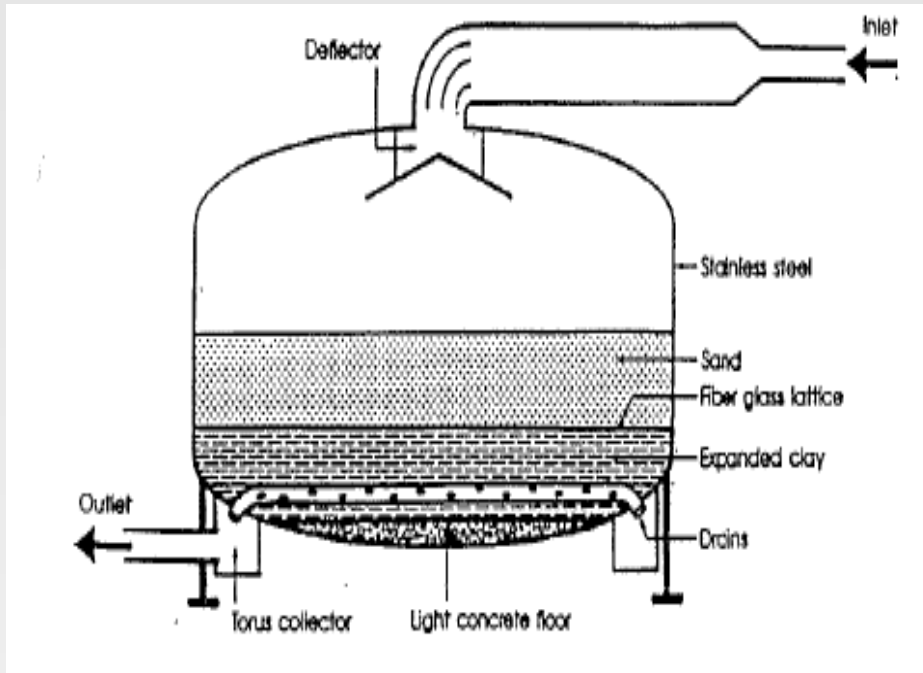


- Based on 1st Generation Sulzer / CCI design
- Nozzles with bubble breaking baffles
- Section with mixing elements
- Improved chemistry for excellent iodine retention
- Outside of the containment.



Dry Filters (1) – EdF

EdF Sand-Bed Filters

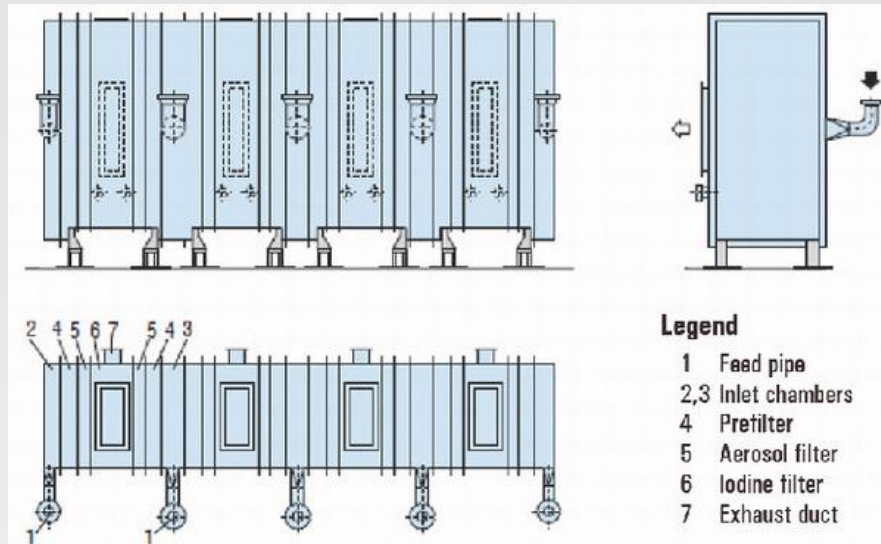


- Sand bed vessel outside containment
- Steel pre-filter inside containment
- One vessel for each twin-unit



Dry Filters (2) – Westinghouse

Dry Filtration System (DFM)

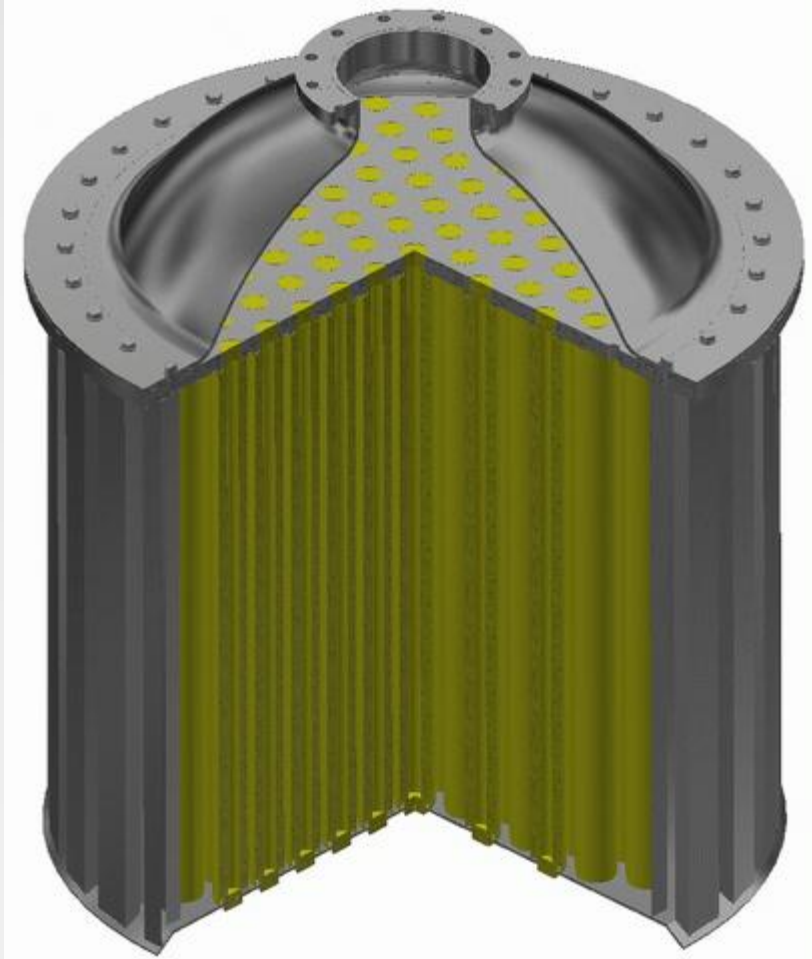


- Based on 1st Generation German design.
- Modular multi-stage metal fibre bed filters inside containment.
- Improved design for heat dissipation.
- Separate iodine filter based on zeolites
- Recently commissioned in Slovenia



Dry Filters (3) – WorleyParsons

Dry Filtration System (DFM)



- New design based on industry proven filters.
- Cartridges with pleated sintered SS316 fibres.
- Proven HEPA quality and heat dissipation.
- Extreme flexible geometry.
- Separate iodine filter based on new generation zeolites.
- Inside containment.



Filter Designs – Summary

	AREVA	MVSS	IMI	EdF	DFM	WP
Aerosols	>10,000	>1000 >10,000 ^{a)}	> 10,000	>1000	>10,000	>20,000 ^{c)}
I₂	>500 >1000 ^{a)b)}	>10,000	>1000	>10	<1000	>>2000
I₂ (org.)	>50 ^{a)b)}	>5	>1000	N.D.	<40	>2000

Tolerance against source term uncertainties	Ease of installation (additional civil structures)	Qualification against high seismic loads
Catastrophic failure scenarios	Additional support systems	Licensing efforts
Efficiency for small particles (<0.5 µm)	Additional consumables	Operating Experience
Ability for long-term and multiple operation	System maintenance effort	Hydrogen risk
Total Lifecycle Cost		



Europe – Current Trends

- Design Owners continue improving 2nd generation of CFVS.
- New designs based on state-of-the-art components emerged.
- EU restarts funding of the research for enhancing this area (Passive and Active Systems for SA Mitigation - PASSAM)
 - Experimental verification of 2nd generation CFVS
 - Experimental verification of new approaches
 - Experimental data collection for existing solutions

