Safety of New Reactor Technologies – GENXFIN

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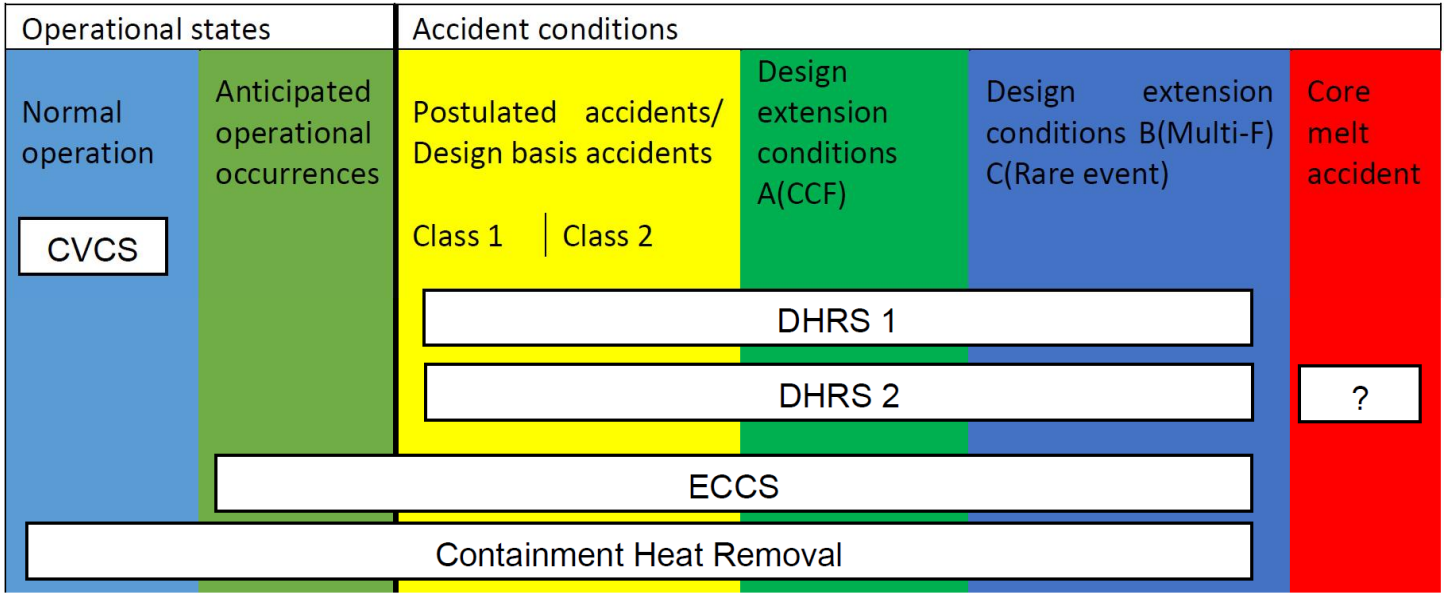
GENXFIN project

- Investigated safety issues of advanced reactor concepts, mainly SMRs
- Coordinated participation in international forums and working groups
- Disseminated information to Finnish stakeholders
- In addition to the normal VYR and VTT funding, TVO and Fennovoima directly funded the project
- Fortum shared reports of its own SMR research to the SAFIR reference group

Licensability of NuScale SMR cooling systems in Finland

- Co-operation of VTT and Fortum
- Investigated independency of defense-in-depth levels and severe accident management systems
- Systems engineering approaches:
  - ADLAS (Advanced Licensing and Safety Engineering), developed by Fortum
  - ORSAC (Overall Safety Conceptual Framework), developed by LUT
- Based on publicly available documents

NuScale heat removal systems and defense-in-depth



Emergency preparedness zones required for SMRs

- District heating reactors need to be located close to a city
- Current regulations:
  - The plant is not placed in a densely populated area (YVL A.2)
  - Precautionary action zone: **5 km** (STUK Y/2/2018)
    - Shall not contain facilities inhabited or visited by a considerable number of people (YVL A.2)
  - Emergency planning zone: **20 km** (STUK Y/2/2018)
    - Shall be covered by a detailed rescue plan
- Small reactor → Less fission products, passive safety
  → Smaller emergency zone?

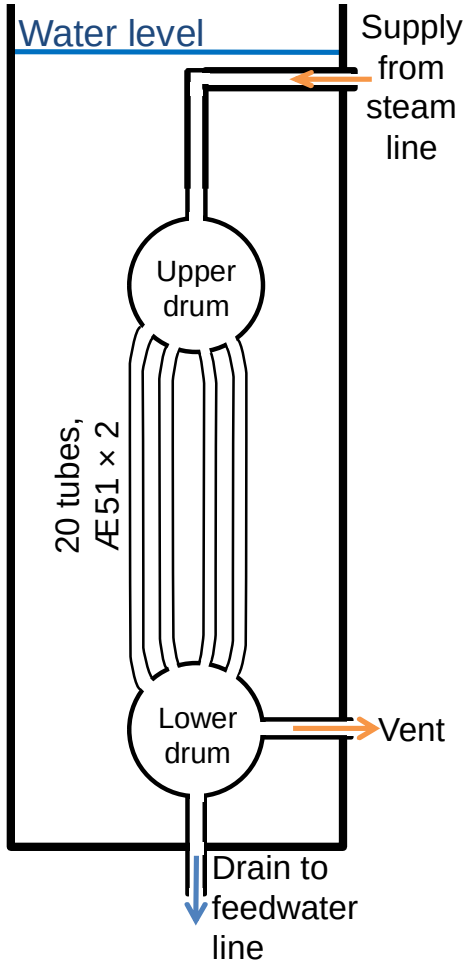
Hypothetical accident in NuScale SMR

- Statistical dose analysis with one-year weather data
- Assumed the same fission product release fraction that would cause 100 TBq Cs-137 release from a 1 600 MW_e reactor
  - Smaller fission product inventory was taken into account
  - Possibly smaller release fraction or smaller accident probability was not considered
- Conservative results:
  - Sheltering could be needed within 5–12 km
  - Evacuation could be needed within 2–8 km

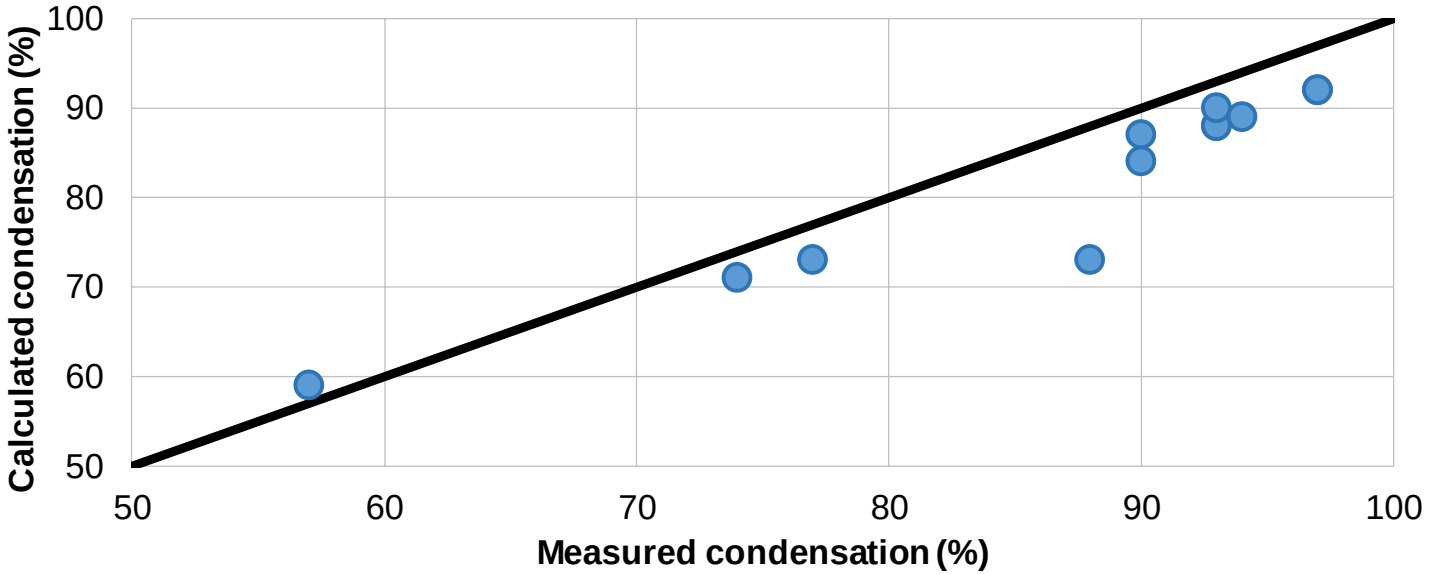
Modeling of passive safety systems

- § Decay Heat Removal System in NuScale
- § Passive Residual Heat Removal System in SMART
- § Steam Generator Passive Heat Removal System in AES-2006
- Ø Condensation in vertical tubes

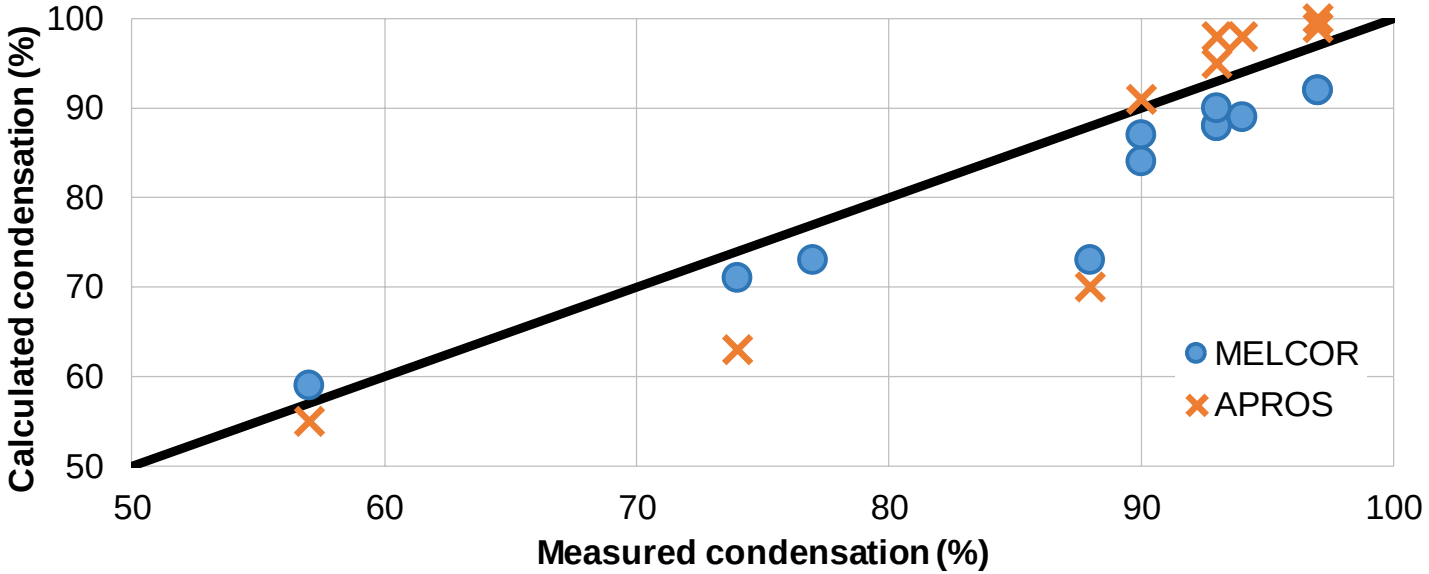
- § PANDA Isolation Condenser experiments, conducted by PSI in Switzerland, modeled with MELCOR code in GENXFIN project



MELCOR results of PANDA Isolation Condenser experiments



MELCOR results compared with earlier APROS results by Seppo Hillberg



Modeling of NuScale and Yanlong reactors with APROS

- Fortum's in-kind contribution to the project
- NuScale model of two 160 MW_{th} reactors connected to a single turbine and district heating network
  - Full power operation modeled well
  - Some challenges with helical coil steam generators
- Chinese Yanlong (DHR-400) district heating reactor
  - Very simple reactor in a 25 m deep water pool
  - Model tested at full power operation, connected to a district heating network

International forums

- Participated various forums and working groups
- Topics:
  - Small modular reactors
  - Supercritical water reactors
  - District heating reactors
  - Accident tolerant fuels
  - Emergency preparedness and response
- Disseminated information to the SAFIR reference group by travel reports and presentations

Organized a national SMR seminar

- 24 people participated
- Presentations by VTT, STUK, Fortum, and LUT
- Picks from the discussions:
  - STUK participates SMR Regulators' Forum
    - The forum has published reports about defense-in-depth and emergency planning zones of SMRs
  - LUT: District heating reactors should be unmanned and remotely operated, to reduce operating costs