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# Challenges of Severe Accident Management at Ukrainian NPPs

**SSTC NRS**

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- General overview
- SAMG
- FCVS
- Hydrogen removal
- Conclusions

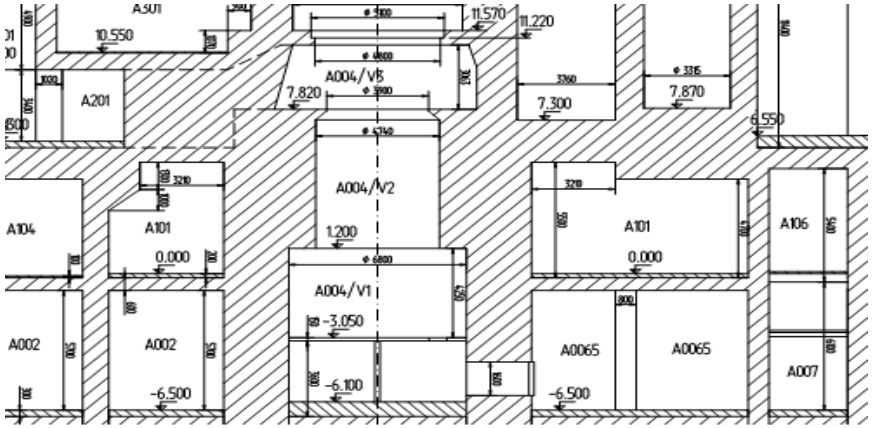
# Severe Accident Management Guidelines

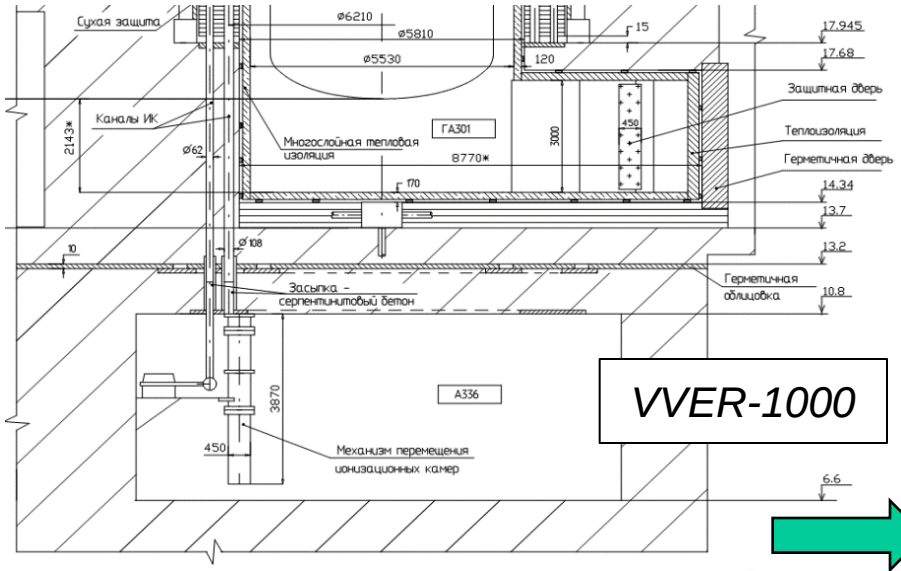
- Status of the development
- SAMG documentation package
- Symptom-oriented approach used for SAMG development
- Analytical justification analyses conducted by Utility using MELCOR and RELAP5/SCDAP computer codes

# SAMG Review Findings (1/5)

- Large difference in results of MELCOR and RELAP/ SCDAP calculations
- VVER vulnerabilities under ex-vessel phase
- High hydrogen concentration in the VVER-1000 containment is possible, even if the hydrogen removal system is implemented

*VVER-440*




*VVER-1000*

# SAMG Review Findings (2/5)

- UKTS-43 outcomes:
  - Independent verifying calculations (including GRS and IRSN codes)
  - On-going upgrades (PARs, FCVS) should be considered properly
  - Nodalization scheme and concrete chemical composition should be verified
  - Interference and combination of strategies
  - Decreasing of the uncertainties (melt re-flooding, corium cooling)

# SAMG Review Findings (3/5)

- Vessel failure can be avoided if water injection starts at any time before the melt hits the core lower plate
- Water injection is not effective when failure of the bottom of internal reactor cavity occurs
- It is necessary to recover power supply for water injection to reactor
- In-depth investigation for a number of SA phenomena is required

# SAMG Review Findings (4/5)

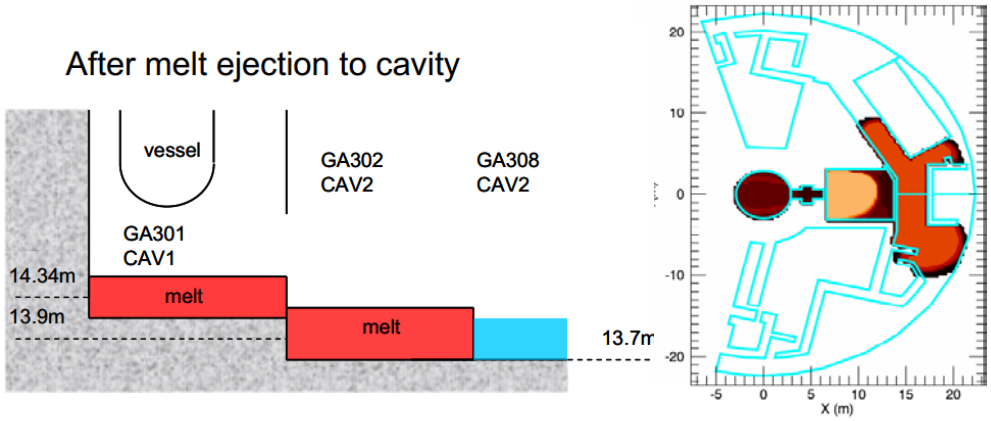
- IVR strategy with cavity cooling could be effective for VVER-440
- EVC strategy with cavity cooling could be effective for VVER-1000 and is not effective for VVER-440

- Extra measures are needed for VVER-1000 ex-vessel melt cooling

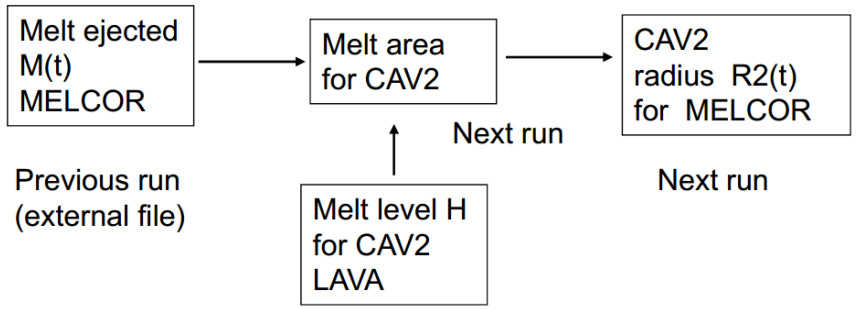
# SAMG Review Findings (5/5)

- **Problems/limitations:**
  - ✓ Melting of ionization chamber channels
  - ✓ MELCOR limitations in corium spreading (distribution) in containment compartments
  - ✓ Concrete properties

***VVER-1000***




- **Solutions:**
  - ✓ Sealing of channels with infusible pipes
  - ✓ Use of coupled MELCOR-LAVA *(LAVA transfer and training of SSTC NRS staff under bilateral cooperation with GRS)* for modelling corium spreading and cooling
  - ✓ Evaluation of original properties of concrete for each NPP



## SAMG Follow-up Activities

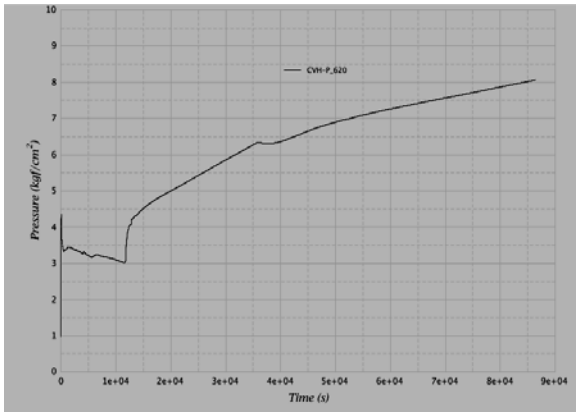
- Comparative validation of severe accident models
- Corium formation and relocation in the vessel lower head
- Corium stratification and vessel thermal loading (focusing effect issue)
- Fuel-coolant interaction: leading to core melt fragmentation upon contact with water, steam production, dynamic loading of structures in case of steam explosion
- Re-criticality of molten core
- Corium spreading and cooling during ex-vessel phase
- Extra measures for post-accident management of hydrogen

# Containment Filtered Venting System (1/2)

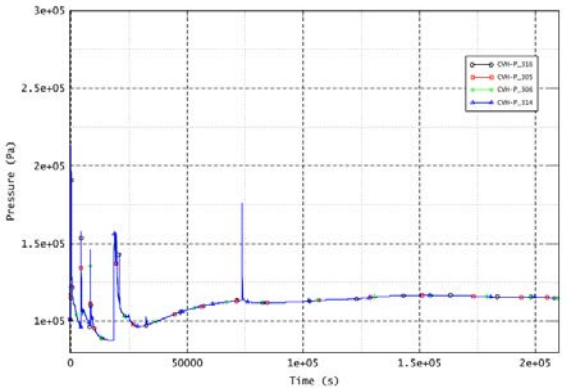
- 1st stage - containment venting through the existing ventilation system using the available filters
- 2nd stage – installation of filters

# Containment Filtered Venting System (2/2)

- Different accidents were considered under FCVS analyses
- MELCOR 1.8.5 was used for justifications
- Results show the possibility of containment failure due to reaching the containment pressure limit for VVER-1000
- FCVS with dump pipelines of less than 100 mm in VVER-1000 did not prevent increase containment pressure;
- Results for VVER-440 do not show containment failure




***VVER-1000***



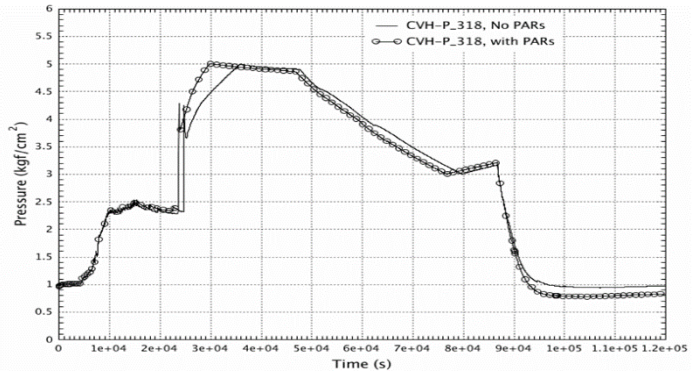

***VVER-440***

# Findings of the FCVS Review (1/2)

- The additional calculations (benchmarks) were conducted;

**Comment**

- Justification of setpoint of FCVS venting stop (3 kgf/cm$^2$)
- FCVS justifications were performed without taking into account PARs
- MELCOR analysis of spray actuation and PARs accounting was conducted

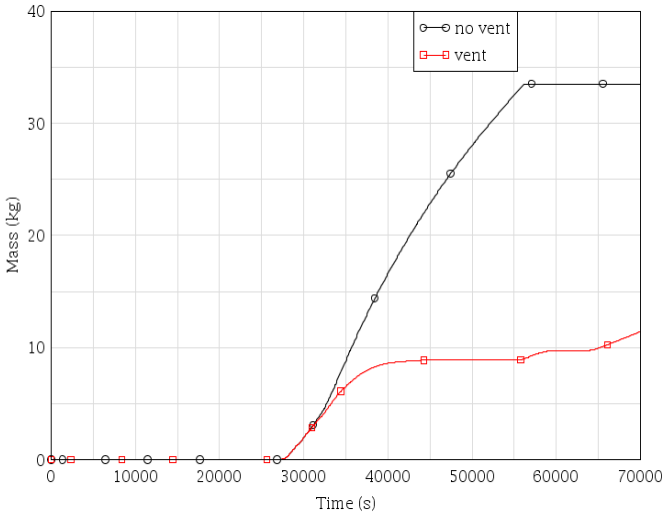



**Resolution**

- PSAR should support the setpoints for the FCVS design
- PSAR has accounted the updated justifications
- Venting pipe diameter increased to 125 mm (previous 100 mm)

# Findings of the FCVS Review (2/2)

- FCVS for VVER-1000 concept was reviewed in the framework of UKTS 43 project
- Independent COCOSYS calculations were conducted
- Concept for VVER-440/213 did not take into account features, containment design and high containment leakage
- It is reasonable to investigate the possibility of VVER-440 FCVS usage for reducing radioactive releases




***VVER-440***

*Radioactive release into environment with FCVS and without FCVS*

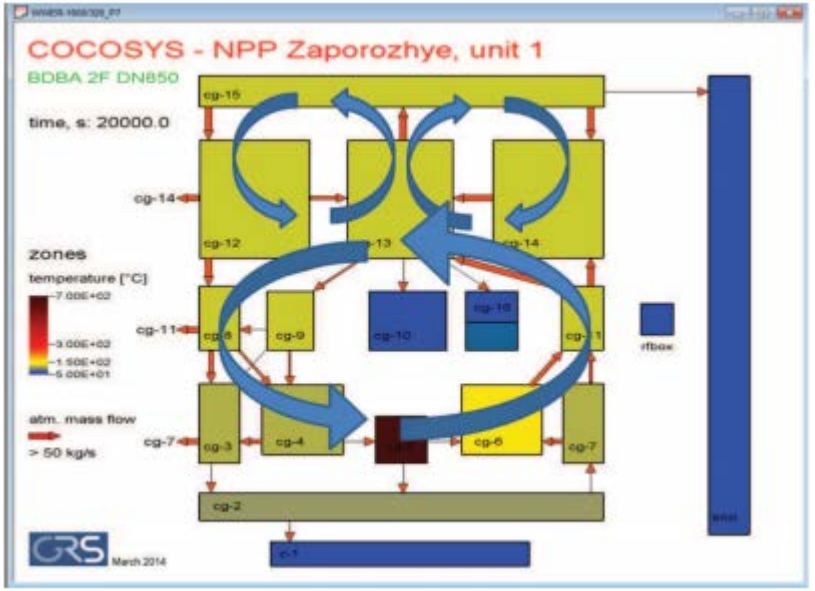
# Hydrogen removal system

- PARs were selected as solution
- RVK-1000 and NIS-PAR Westinghouse were used
- In cooperation with GRS assessment of PARs properties; identification of uncertain features of PARs suggested for implementation in VVER-1000
- Justification calculations were performed to select number and location of PARs
- PARs for hydrogen generated during DBA earlier implemented at KhNPP-2, RNPP-4 (ALSTOM PAR) and RNPP-1,2 (FRAMATOM)
- PARs justifications for KhNPP-2, RNPP-4 are being reviewed

***NIS PAR***

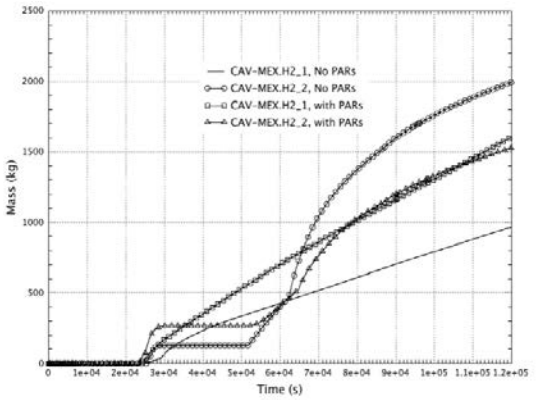
# Findings of the PARs Justifications Review (1/2)

- Outcomes of UKTS-43 project:
  - Independent COCOSYS calculations
  - Safety criteria (pressure and temperature peaks, flame propagation analysis)
  - Different design approach for the determination of PARs capacity
  - Risks outside the reactor containment
  - Local effect of hydrogen deflagration

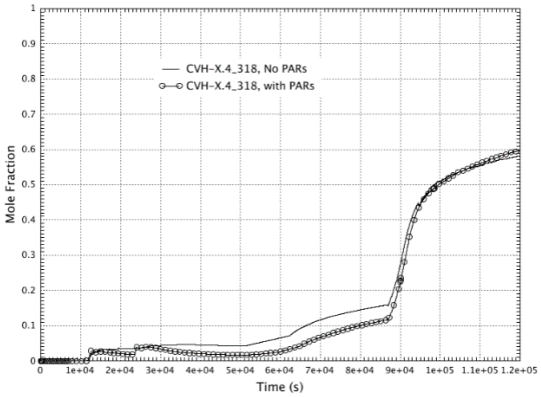


# Findings of the PARs Justifications Review (2/2)

- In-depth investigations of spray system operation affects the hydrogen concentration in the containment is necessary
- Accounting of both sources (reactor and SFP) for VVER-1000
- Accounting of specific concrete content for each NPP
- Limited capabilities of MELCOR 1.8.5 in SFP modelling ⟹ *Using other codes (e.g. MELCOR 1.8.6 or ATHLET-CD)*
- Limitation of MELCOR 1.8.5 in modelling of corium spreading ⟹ *Investigation with LAVA*
- Need of extra measures for post-accident hydrogen management




***VVER-1000***
*Hydrogen generation during ex-vessel phase*




***VVER-1000***
*Hydrogen concentration in containment*

# Conclusions

- “Program of Activities on Analysis of Severe Accident Phenomena” has been developed:
  - Update the existing version of computer codes or buy new codes
  - In-depth study of the selected phenomena
  - Development of recommendations for modelling of selected phenomena
  - Improvement of the existing computer models for severe accident analysis
  - Training of NPP staff for new codes and new approaches to severe accident investigations
- Several SAM measures are being implemented:
  - IVRM for VVER-440
  - Ex-vessel corium cooling for VVER-1000
  - Second stage of FCVS


Thank you for attention!