Comprehensive and systematic validation of independent safety analysis tools (COVA)

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Background of the project

- Apros is a system-scale safety analysis tool developed at VTT in cooperation with Fortum since 1986
- When the call for SAFIR2018 opened the validation span of Apros was already nearly three decades long. Assessment of the validation was seen as a priority. This assessment would reveal possible gaps and weaker points in the code's validation that could later be corrected.
- Other interest included continuation of networking through international programs and new validation analyses. Education of new experts would be needed.
- SAFIR2018 COVA project was founded on these ideas

Assessment of Apros' validation against OECD/NEA validation matrices

- As OECD/NEA had published validation matrices for both separate effect tests and containment code validation, these were used as the basis of the assessment.
- No major gaps were found from the validation. In some cases the validation of the phenomenon was covered with only a single experiment or the calculation was performed with out-dated version Apros.
- Recommendations were given for further validation.

Assessment of Apros' validation against OECD/NEA validation matrices (2)

Examples of validation matrix phenomena classification:

Separate effect test matrix for thermal-hydraulic code validation

0. Basic Phenomena	1. Evaporation due to Depressurisation 2. Evaporation due to Heat Input 3. Condensation due to Pressurisation 4. Condensation due to Heat Removal 5. Interfacial Friction in Vertical Flow 6. Interfacial Friction in Horizontal Flow 7. Wall to Fluid Friction 8. Pressure Drop at Geometric Discontinuities 9. Pressure Wave Propagation
1. Critical Flow	1. Breaks 2. Valves 3. Pipes
2. Phase Separation / Vertical Flow with and without Mixture Level	1. Pipes / Plena 2. Core 3. Downcomer

Containment code validation matrix

Phenomena Number and Title	Significance		Experiments Exhibiting this Phenomenon
	DBA	SA/BDBA	
P1-1 - Stratification	Major	Major	E1-3 - LSGMF GMBT001 E1-4 - LSGMF GMUS001 E1-6 - FIPLOC F2 E1-7 - VANAM M3 (ISP-37) E1-15 - HDR E11.2 (ISP-29) E1-24 - PANDA ISP-42, Phase A E1-27 - PANDA ISP-42, Phase F E1-28 - PANDA BC4 E1-31 - THAI TH2 E1-32 - THAI TH7 E1-33 - THAI TH10 E1-34 - THAI TH13 (ISP-47) E1-35 - THAI HM2

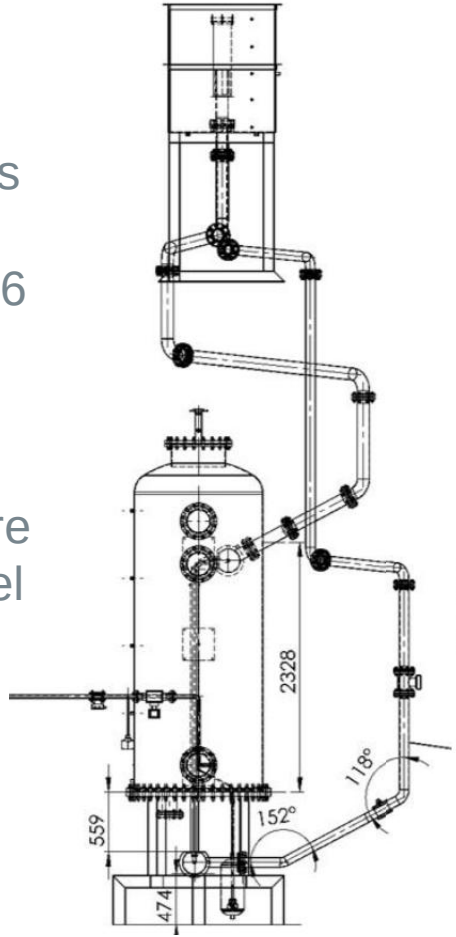
The subsequent validation analyses

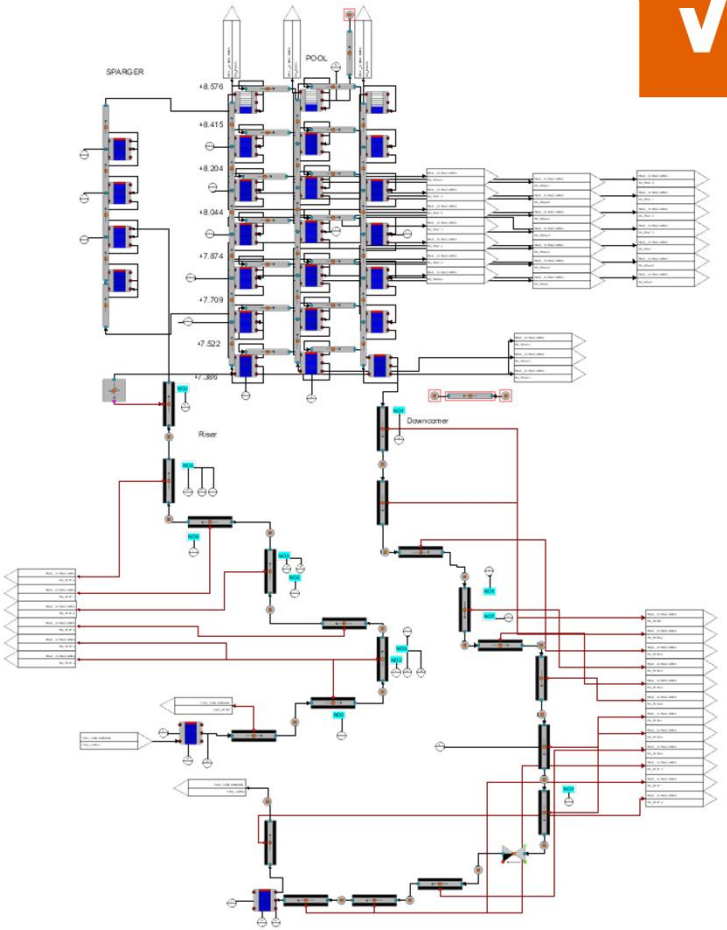
Experiment or case	Phenomenon or scenario	Used code
19-rod bundle experiments	bundle heat transfer and friction	Apros
ACHILLES ISP-25	core reflood	Apros
Becker burnout experiments	critical heat flux	Apros
ERSEC ISP-7	core reflood	Apros
FLECHT SEASET test 31302 FLECHT SEASET test 32013	core reflood	Apros
LOTUS	friction and phase separation in annular flow	Apros
RBHT reflooding experiments 937, 945 and 1143	core reflood	Apros
NEPTUN experiments 5050 and 5052	core reflood	TRACE
HYMERES/PANDA natural circulation test HP6_1	natural circulation, stratification	Apros containment
TOSQAN ISP-47	wall condensation	Apros containment
TOSQAN spray test 101	spray	Apros containment
TOSQAN test T201	wall condensation, sump evaporation	Apros containment

New analyses and benchmarks

Experiment or case	Used code
ATLAS A5.1 benchmark	Apros
ATLAS A5.1 post-test calculation	Apros
ATLAS A5.2 pre-test calculation	Apros
BNL critical flow experiments	Apros
Boivin critical flow experiments	Apros
FONESYS critical flow benchmark	Apros
FONESYS extended critical flow benchmark	Apros
PKL IIIi NC-flowmap test	Apros
PKL4 i2.2 run3 benchmark	Apros
HYMERES HM 2-1 and 3-2 calculations	Apros containment
HYMERES HP6 scoping calculations	Apros containment
PASI characterizing experiments	Apros & Apros containment

- In 2018 an Apros model was created of the LUT's PASI facility which represents the AES-2006 PHRS-C passive containment heat removal system
- Characterizing tests were calculated and the model is ready for the experiments that are scheduled to be performed in 2020





International cooperation

- International cooperation has been a significant part of COVA project. In years 2015-2018 the following international cooperation programs have been participated:

- OECD/NEA ATLAS (Advanced Thermal-hydraulic test Loop for Accident Simulation)
- OECD/NEA HYMERES (Hydrogen Mitigation Experiments for Reactor Safety)
- OECD/NEA HYMERES-2
- OECD/NEA PKL-3 (Primary Coolant Loop Test Facility)
- OECD/NEA PKL-4
- OECD/NEA WGAMA (Working Group on Analysis and Management of Accidents)
- U.S. NRC CAMP (Code Application and Maintenance Program)
- FONESYS network (Forum & Network of System Thermal-Hydraulics Codes in Nuclear Reactor Thermal-Hydraulics)

Final words

§ The main achievements of COVA project can be summed up as:

- Better understanding of the current state of Apros' validation
- Improvement of the validation
- A vision forward
- Training of new experts to the field
- Continued international networking