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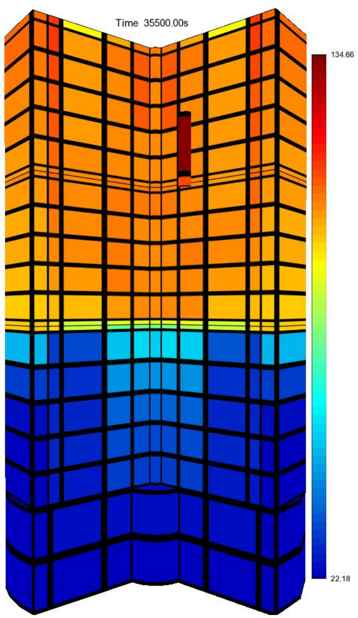

Comprehensive and systematic validation of independent safety analysis tools (COVA)

SAFIR2018 interim seminar, 23.-24.3.2017

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Critical assessment of thermal-hydraulic and containment models' validation

- One the overall objectives of the COVA project is to improve the state of Apros' validation.

- The project started in 2015 with an assessment of Apros's thermal-hydraulic and containment models' validation by compiling databases of the calculated validation cases and then by comparing them to the OECD/NEA's separate effects and containment validation test matrices. This work formed a foundation on which much of the work done in COVA during its four-year period is based.

What are OECD/NEA's validation matrices?

An internationally agreed separate effect test (SET) Validation Matrix for thermal-hydraulic system codes has been established by a sub-group on Task Group Thermal Hydraulic System Behaviour, as requested by the OECD/NEA Committee on Safety of Nuclear Installations (CSNI) Principal Working Group No. 2 on Coolant System Behaviour. ***The construction of such a matrix is an attempt to collect together in a systematic way the best sets of openly available test data for code validation, assessment and improvement, including quantitative assessment of uncertainties in the modelling of individual phenomena by the codes.***

The Committee on the Safety of Nuclear Installations (CSNI) formed the CCVM (Containment Code Validation Matrix) task group in 2002. ***The objective of this group was to define a basic set of available experiments for code validation, covering the range of containment (ex-vessel) phenomena expected in the course of light and heavy water reactor design basis accidents and beyond design basis accidents/severe accidents.*** *It was to consider phenomena relevant to pressurised heavy water reactor (PHWR), pressurized water reactor (PWR) and boiling water reactor (BWR) designs of Western origin as well as of Eastern European VVER types.*

Assessment against the test matrices

Both validation assessment works began by gathering lists of all validation cases calculated with Apros and Apros containment throughout its development history, including information on what code version was used for each analysis and what kind of results was obtained. An assessment was then made against the validation matrices.

0 Basic Phenomena	
0.1 Evaporation due to Depressurisation	Edward's pipe, horizontal blowdown [9] Battelle top blowdown (ISP-6) [9] MIT pressurizer experiments [17]
0.2 Evaporation due to Heat Input	FRIGG BWR fuel element [14, 15] Christensen experiment [16]
0.3 Condensation due to Pressurisation	PACTEL ATWS experiments [17] MIT pressurizer experiments [17] NEPTUNUS pressurizer experiments [17]
0.4 Condensation due to Heat Removal	NOKO [18] PANDA isolation condenser [19, 20] PANTHERS full scale condenser [20] Choi's DCC experiment [23] LUT PCC-06 [25]
0.5 Interfacial Friction in Vertical Flow	FRIGG BWR fuel element [14] LOTUS annular flow experiment [26]
0.6 Interfacial Friction in Horizontal Flow	UPTF loop seal experiments [27] IVO full scale loop seal experiments [27]
0.7 Wall to Fluid Friction	FRIGG BWR fuel element [14]
0.8 Pressure Drop at Geometric Discontinuities	
0.9 Pressure Wave Propagation	Fujii and Akagawa water hammer tests [29] HDR blowdown experiment [30]
1. Critical Flow	
1.1 Breaks	Battelle top blowdown (ISP-6) [9] Marviken critical flow test MXC-17 and 23 [9]
1.2 Valves	
1.3 Pipes	Marviken critical flow test MXC-17 [9]
2 Phase Separation / Vertical Flow with and without Mixture Level	
2.1 Pipes / Plena	LOTUS annular flow experiment [26]
2.2 Core	FRIGG BWR fuel element [14]
2.3 Downcomer	
3 Stratification in Horizontal Flow	
3.1 Pipes	UPTF TRAM A5 loop seal experiments [34,35]
4 Phase Separation at Branches	
4.1 Branches	
5 Entrainment / De-entrainment	
5.1 Core	PERICLE 2D boil-off experiment BO0002 [15] FLECHT SEASET forced flow test 32013 [37]
5.2 Upper Plenum	UPTF test 10A [41, 42] UPTF test 7 [41, 42]

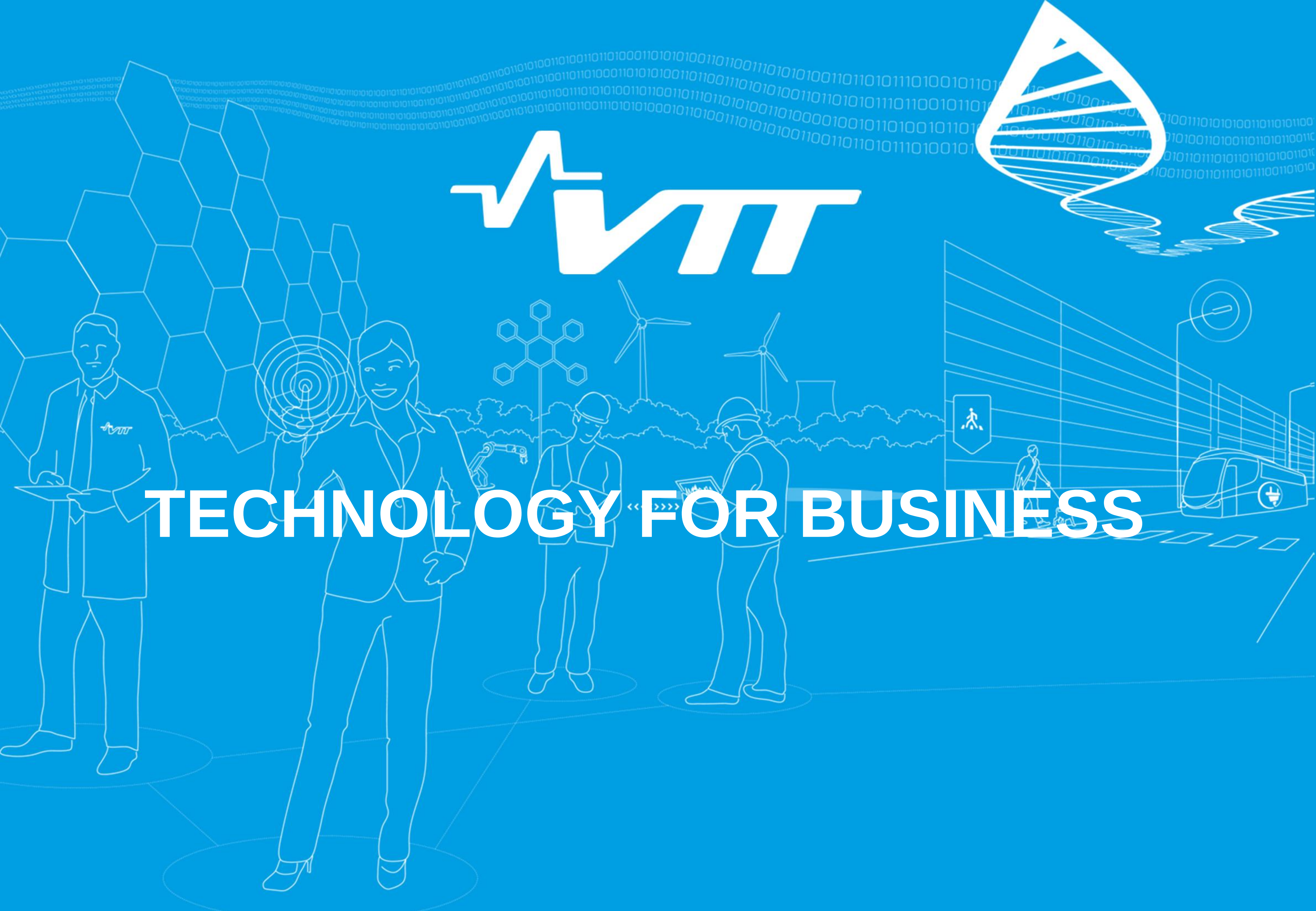
Recommendations were given for further validation

EXPERIMENT	STUDIED PHENOMENON	REMARKS
TOSQAN ISP-47 or TOSQAN condensation tests	- Condensation rate on wall condenser - Pressure - Gas temperatures - Steam and helium concentrations - Stratification	Main focus is on condensation calculation. The gas stratification field should be calculated (adjusted) sufficiently well to enable the validation of condensation calculation.
Some separate effect test for convection heat transfer	- Convection heat transfer	No suitable test found yet.
TOSQAN sump test	- Pool surface evaporation and condensation	
Test on surface pool temperature	- Pool surface temperature in condensation and evaporation cases.	No suitable test found yet.
AECL-SP Dousing test no. 1	- Heat removal by dousing (spray)	

Part of the list of Apros containment recommendations

Cases calculated based on the findings of the validation assessment reports

Experiment or case	Phenomena or scenario	Used code
19-rod bundle experiments	bundle heat transfer and friction	Apros
ACHILLES ISP-25	core reflood	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
TOSQAN test T201	wall condensation, sump evaporation	Apros containment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