TECHNOLOGY FOR BUSINESS

Enhancement of Safety Evaluation tools (ESA)

Ismo Karppinen • Seppo Hillberg • Risto Huhtanen • Jarno Kolehmainen
Joona Kurki • Sampsa Lauerma • Ari Silde • Pekka Urhonen
VTT Technical Research Centre of Finland Ltd

Introduction

System analysis codes are used in safety evaluation of nuclear power plants. New power plant concepts have passive and active components. Especially in the passive systems the driving forces are weak and therefore evaluation of their performance with computational methods requires models that are validated for these conditions.

Validation of system analysis codes

A systematic and thorough validation of codes is a prerequisite for their use in safety analysis. Calculation of the validation cases and analysis of the results is also an effective means to educate young experts. The thermal hydraulic system analysis codes Apros and TRACE have been validated with experimental data from Lappeenranta University, EU and OECD research programs (Table 1).

Table 1. System code validation with LUT, EU and OECD experiments.

Experiment or case	Phenomena or scenario	Code
NOKO EU series	passive horizontal condenser	Apros
PANDA PCC	passive vertical condenser	Apros
PACTEL NCg experiments	Horizontal SG with non-condensable gas	Apros
ROCOM tests 2.1, 2.2	Fluid mixing in reactor vessel downcomer	TRACE
ROSA-2 test 3	Hot leg SBLOCA (1.5%)	Apros, TRACE
ROSA-2 test 2 and 7	Cold leg intermediate size LOCA	Apros, TRACE
PWR PACTEL benchmark	Blind SBLOCA	Apros
AER DYN-006 benchmark	Steam line break	TRACE/PARCS
LUT PCC	Condensation efficiency of passive containment condenser system	Apros
FLECHT-SEASET	Reflooding	Apros, TRACE
PWR PACTEL CNC-01, CNC-02	Cool down with natural circulation with isolated steam generator	Apros
PKL3 test G7.1	Hot leg SBLOCA	Apros
PKL3 test H2.1	Station black out	Apros
PWR PACTEL SBO-02	Station black out, supplement to PKL3 H2.1	Apros
FONESYS benchmark 1	Boiling in a channel	Apros
FONESYS benchmark 2	Critical flow	Apros
ABWR plant model	Integrated plant model with isolation condenser and passive containment cooler.	Apros

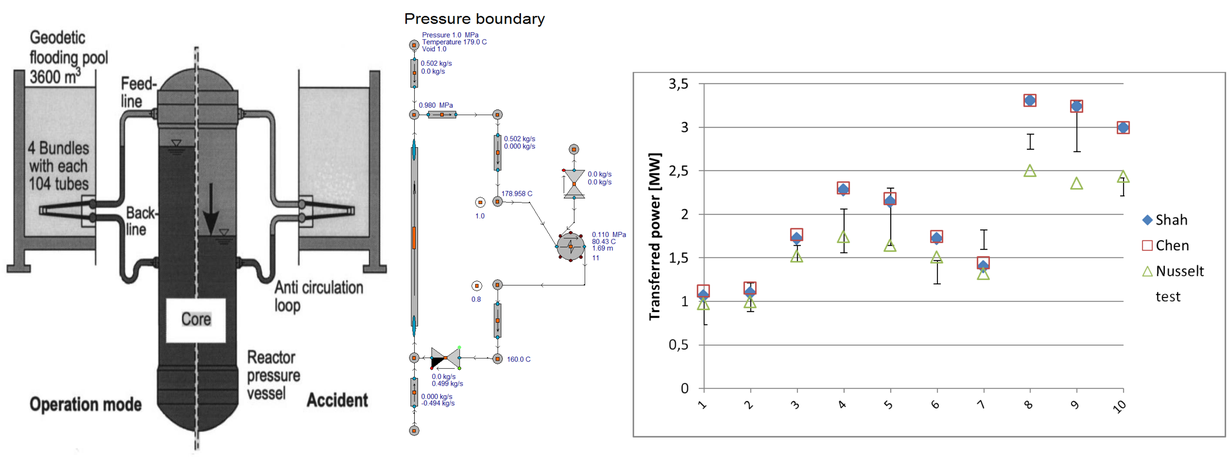

Figure 1. Principle of the emergency condenser, Apros model of the NOKO experiment and calculated heat transfer rate in all the 10 test cases with three different interfacial heat transfer correlations.

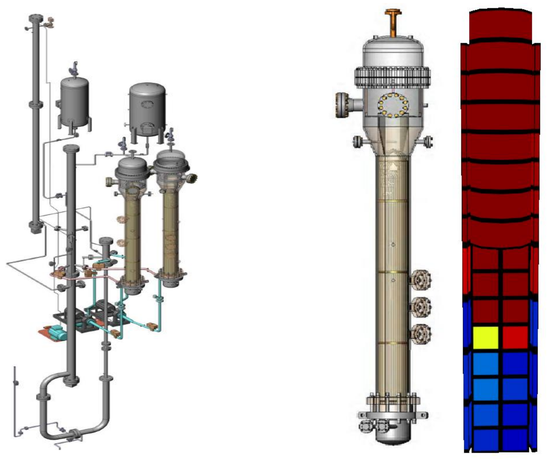

Figure 2. PWR PACTEL facility, vertical steam generator and visualization of calculated void fraction in the steam generator secondary side model.

Validation of containment analysis methods

Apros lumped parameter (LP) containment code was validated both with separate effect and integral tests. Models utilized in CFD analysis were tested with separate effect tests like SARNET spray benchmark and finally simulation capabilities were benchmarked in the OECD CFD exercise (Table 2).

Table 2. Containment code verification and validation cases

Experiment or source	Phenomena or Scenario	Code
GEKO	Building condenser efficiency	Apros containment
CONAN	Wall condensation under forced convection conditions	Apros containment
Areva RECO data	Efficiency of passive auto-catalytic recombiner (PAR)	Apros containment
SARNET generic containment benchmark	Pressurization, H_2 concentration and operation of PAR system in a large dry containment	Apros containment
SARNET elementary spray benchmark	Heat and mass transfer of single droplet	Apros containment, Fluent
PANDA ST4.1	Containment cooler experiment	Fluent
THAI test TH24	Break up of stratified steam/air layer	Apros containment, Fluent
THAI test HM-2	Stratification of hydrogen	Apros containment, Apros 6eq
OECD CFD benchmark	Gas stratification in PANDA test facility	Fluent
MISTRA HM2-1	Gas mixture stratification and mixing with a PAR system	Apros containment

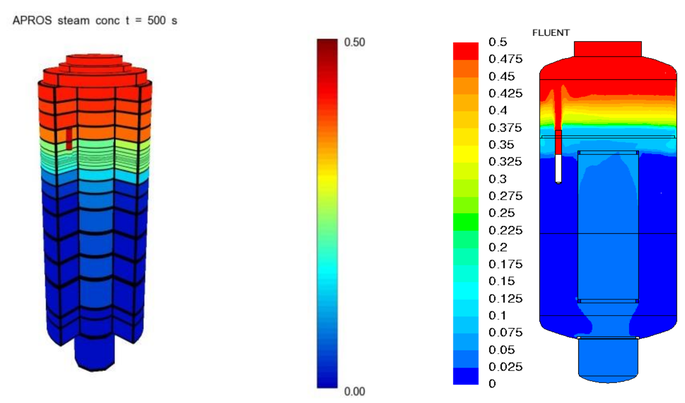

Figure 3. Steam molar fraction at t = 500 s calculated with Apros (left) and Fluent (right) in the THAI TH24 experiment.

Conclusions

Both system analysis codes (Apros and TRACE) and containment analysis methods (Apros LP and Fluent CFD) were validated in large range of experiments from separate effect tests to full-scale power plant models. The multi-node LP nodalization of Apros containment was used successfully to simulate gas stratification in the MISTRA and THAI containment experiments.

Contacts

Ismo Karppinen
Tel. +358 40 593 8649
ismo.karpinen@vtt.fi