Enhancement of Safety Evaluation tools (ESA)

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

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<tr>
<th>Experiment or source</th>
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<tr>
<td>GEKO</td>
<td>Building condenser efficiency</td>
<td>Apros containment</td>
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<td>CONAN</td>
<td>Wall condensation under forced convection conditions</td>
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<td>Areva RECO data</td>
<td>Efficiency of passive auto-catalytic recombiner (PAR)</td>
<td>Apros containment</td>
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<td>SARNET generic containment benchmark</td>
<td>Pressurization, H2 concentration and operation of PAR system in a large dry containment</td>
<td>Apros containment</td>
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<td>SARNET elementary spray benchmark</td>
<td>Heat and mass transfer of single droplet</td>
<td>Apros containment, Fluent</td>
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<td>PANDA ST4.1</td>
<td>Containment cooler experiment</td>
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<td>ThAI test TH24</td>
<td>Break up of stratified steam/air layer</td>
<td>Apros containment, Fluent</td>
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<td>ThAI test HM-2</td>
<td>Stratification of hydrogen</td>
<td>Apros containment, Apros 6eq</td>
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<tr>
<td>OECD CFD benchmark</td>
<td>Gas stratification in PANDA test facility</td>
<td>Fluent</td>
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<tr>
<td>MISTRA HM2-1</td>
<td>Gas mixture stratification and mixing with a PAR system</td>
<td>Apros containment</td>
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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.

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