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

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## Introduction / background

Apros is a system-scale safety analysis tool developed at VTT in cooperation with Fortum since 1986. Apros is used for safety analyses of light water reactors, and thanks to addition of new advanced features in the recent years, it can also be utilized in analyzing generation IV nuclear reactors.

The overall objective of the COVA project is to improve the state of Apros' validation through a systematic and rigorous approach to the validation process. The process enhances the expertise in thermal hydraulic area of Generation II and III LWR reactors and includes as an essential part training of new experts to this relevant area of reactor safety. While the main effort is being carried out using Apros, as it has higher national interest as a self-developed independent and versatile safety analysis tool, U.S. NRC's TRACE is also used in analyses of new experiments and in code-to-code comparisons with Apros.

## Systematic assessment of Apros' validation

The project started in 2015 with an assessment of Apros' thermal-hydraulic and containment models' validation by compiling databases of the calculated validation cases and then by classifying them according to OECD/NEA's separate effect test 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.

Both 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 and recommendations were given for further validation.

Apros' thermal-hydraulic validation of separate effect phenomena was found to be quite comprehensive even though the validation base was recommended to be extended with tests of wide parameter ranges and of different facilities.

The assessment of containment validation showed that Apros containment is capable of calculating the general containment behavior in design based accidents. The assessment did not reveal any severe deficiencies.

*Table 1. Analyses calculated based on the Apros validation assessment reports.*

| Experiment or case | Phenomena or scenario | Used code |
|---|---|---|
| 19-rod bundle experiment | bundle heat transfer and friction | Apros |
| ACHILLES ISP-2 | core reflood | Apros |
| ERSEC ISP-7 | core reflood | Apros |
| FLECHT SEASET test 31302<br>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 |

## Analyses of new experiments

An integral part of COVA are the analyses of new experiments and benchmark exercises. Such cases calculated in years 2015 and 2016 are listed below.

*Table 2. New analyses calculated in 2015-2016.*

| Experiment or case | Used code |
|---|---|
| ATLAS A5.1 pre-test benchmark | Apros |
| ATLAS A5.1 post-test calculation | Apros |
| ATLAS A5.2 pre-test calculation | Apros |
| FONESYS critical flow benchmark | Apros |
| FONESYS extended critical flow benchmark | Apros |
| HYMERES HM 2-1 and 3-2 calculations | Apros containment |
| HYMERES HP6 scoping calculations | Apros containment |

Two of the calculation cases were the analyses of MISTRA HM2-1 and HM3-2 experiments where a more radiation detailed heat transfer was implemented inside the facility compartments of an existing model. As a result the model was able to predict changes in temperature profiles significantly better.

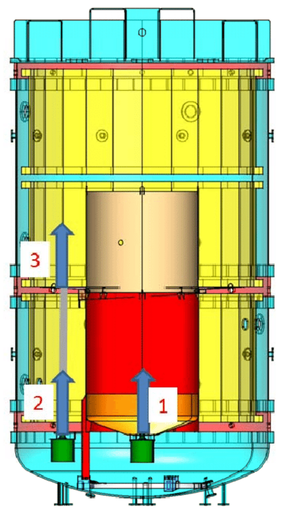


*Figure 1. MISTRA facility*

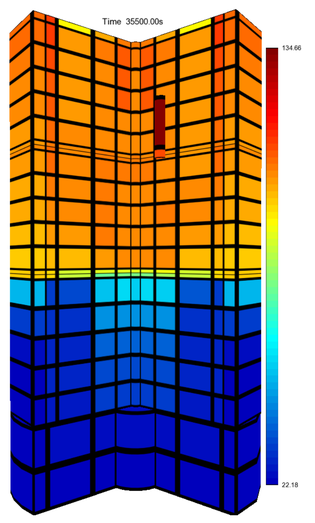


*Figure 2. Temperature near the end of HM2-1 calculation*

## International cooperation

Participation in international research projects related to nuclear safety in the field of thermal hydraulics forms an essential part of the project. Several programs are being followed and some of the participation fees are being channeled through COVA. In 2015-2016 the following programs have been participated:

- ✓ OECD/NEA PKL Phase 3 (Primary coolant loop test facility)
- ✓ OECD/NEA HYMERES (Hydrogen Mitigation Experiments for Reactor Safety)
- ✓ OECD/NEA ATLAS (Advanced Thermal-hydraulic test Loop for Accident Simulation)
- ✓ OECD/NEA CSNI 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)

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