Safety through thermal-hydraulic analyses and cooperation (THACO)

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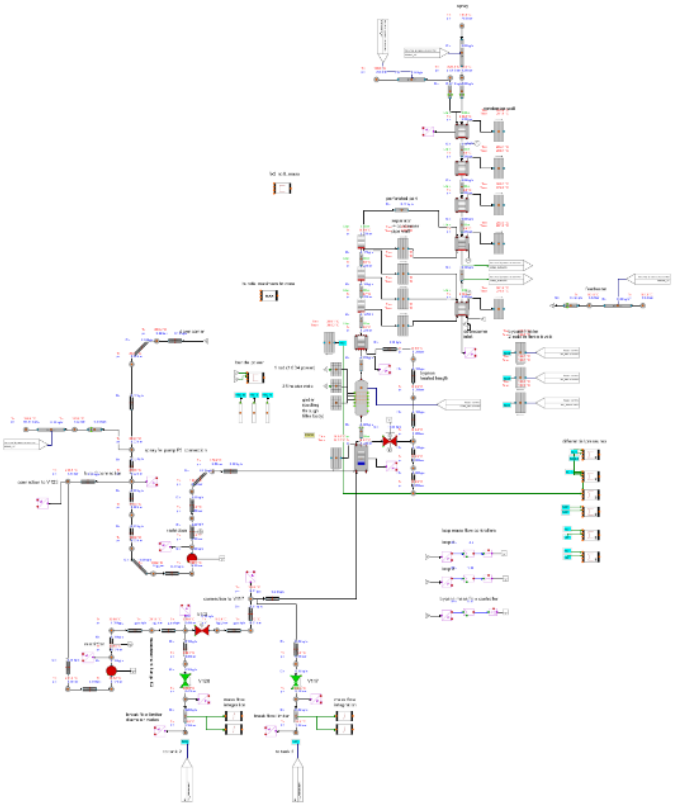
In this presentation

- What is THACO?
- Overview of analysis work in the first two years
- Work on RBHT and PASI test facilities
- International cooperation



Apros

TRACE
TRAC/RELAP
Advanced
Computational Engine

What is THACO?

- Safety through thermal-hydraulic analyses and cooperation, THACO, is a project focusing on improving nuclear safety, mainly by increasing the reliability of thermal-hydraulic deterministic safety analyses.
- Main part of the analysis work is carried out with, and related to, the system-scale safety analysis tool Apros that has been developed in Finland in cooperation between VTT and Fortum.
- Participation in international thermal hydraulics field research projects forms an essential part of the project.

Project personnel in the first two years:

- Tatu Hovi
- Ismo Karppinen
- Joona Kurki
- Joona Leskinen
- Ari Silde
- Marton Szogradi
- Jarno Hiittenkivi
- Robert Airaksinen
- Seppo Hillberg

Analysis work

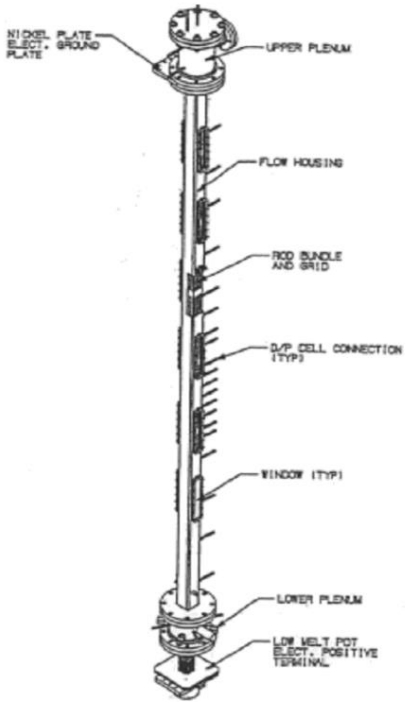
Overview of the analysis work in the first two years

- The first two years of THACO project have been heavily influenced by OECD/NEA's new Rod Bundle Heat Transfer (RBHT) project. Experiments performed in the facility have been calculated with both Apros and U.S. NRC's TRACE codes.
- While RBHT analyses have been the largest part of the project, analysis work has also been done on other integral test facilities. These are LUT's PASI facility, Swedish FIX-II facility, PKL facility and Marviken facility.
- A master's thesis on critical flow Apros modelling has been started in the project.

Rod Bundle Heat Transfer (RBHT) facility

RBHT is located in the Pennsylvania State University. The goal of the project is to conduct experiments in order to:

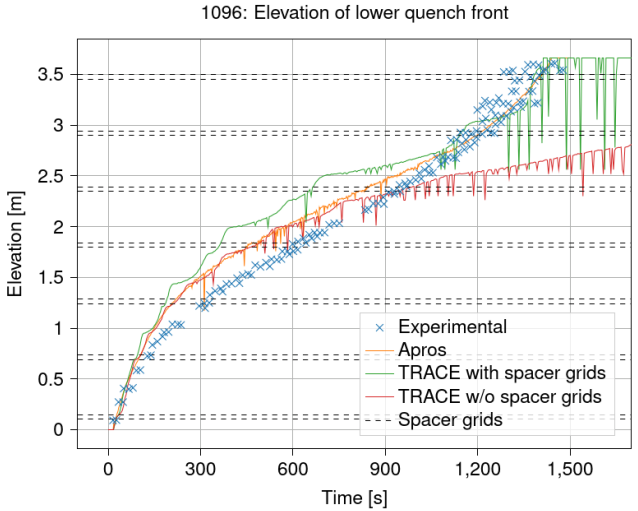
- Simulate reflood scenarios in a prototypical PWR rod bundle section
- Investigate the effect of complex inlet flows (e.g. oscillatory)
- Obtain high-quality data on flow rates, temperature distributions, heat-fluxes and droplet size distributions
- Organise a benchmark exercise to further develop and assess system thermal-hydraulics and sub-channel codes



RBHT test section (image: U.S. NRC)

2019 RBHT analyses

- In 2019, as the new experimental OECD/NEA project data was not yet released, the work started with calculation of older RBHT experiments with both Apros and TRACE
- In total 5 experiments were calculated. In the tests flooding rate, pressure, rod power and inlet subcooling were varied and output parameters like quench front were observed
- Both Apros and TRACE predicted the reflooding phenomena with reasonable accuracy



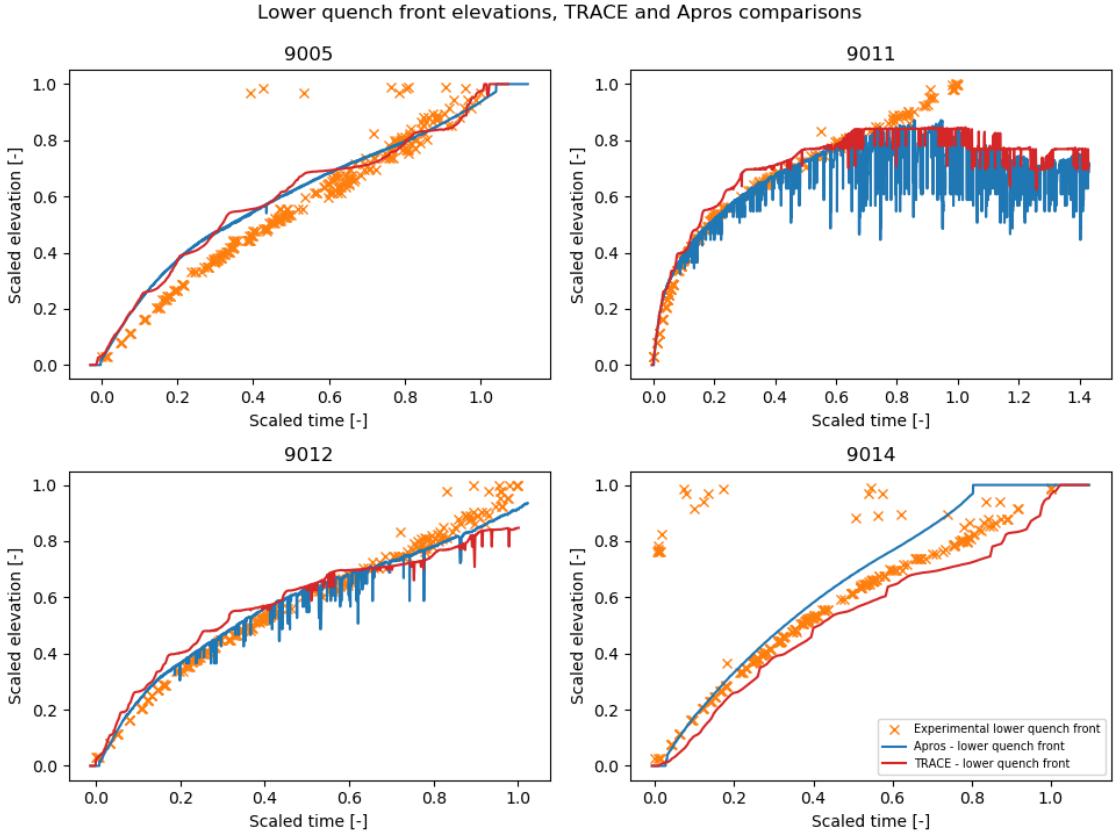
Lower quench front propagation in test 1096. TRACE's spacer grid model leads to improved results.

OECD/NEA RBHT open-phase analyses (2020)

- In 2020, the new RBHT open-phase experiment data was available and it focused on the impact of rod peak power, inlet subcooling and most notably, different reflooding rates and types such as oscillatory reflooding. These cases were calculated with Apros and TRACE.
- The Apros model was prepared for the incoming 2021 blind benchmark. In some of the cases, machine learning and BEPU analysis were used.

OECD/NEA RBHT open-phase analyses (2)

- In total 11 experiments were calculated
- In general, Apros gave better predictions but the TRACE model was not calibrated for these tests
- Both Apros and TRACE performed well



OECD/NEA RBHT open-phase analyses (3)

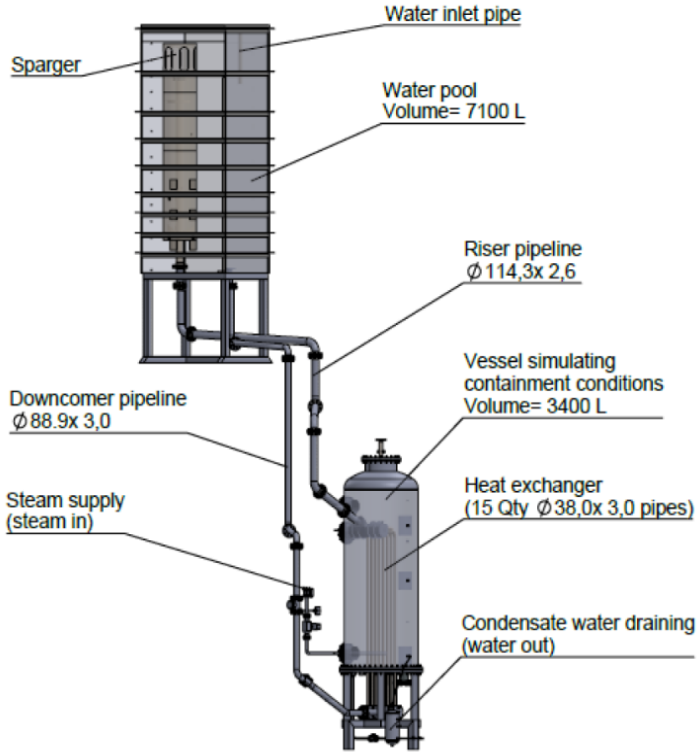
Exp	Apros				TRACE			
	PCT	PCT time	PCT elevation	PCT quench	PCT	PCT time	PCT elevation	PCT quench
9005	1.002	0.401	1.079	1.017	0.982	5.921	1.043	1.042
9011	0.966	1.317	1.074	1.145	1.004	0.944	1.149	N/A
9012	0.953	0.035	1.019	1.043	1.010	0.808	1.015	1.376
9014	1.007	0.780	1.079	0.860	0.982	1.007	1.043	1.183
9015	1.008	0.224	1.019	1.033	0.980	0.537	0.985	1.511
9021	0.963	0.386	1.019	1.063	1.015	0.603	1.015	1.013
9026	0.941	0.698	1.019	0.939	1.003	1.013	1.015	1.001
9027	0.953	0.596	1.019	0.960	1.008	0.975	1.015	1.006
9029	0.971	1.015	1.019	0.958	1.039	1.127	1.007	0.964
9037	1.023	0.488	1.019	0.993	0.989	5.131	0.985	1.019
9043	0.966	0.824	0.982	1.080	0.947	0.976	1.108	1.064

Next: 2021 OECD/NEA RBHT blind benchmark

- The project will next enter the blind benchmark phase. It will likely contain 6 reflooding cases and it will be participated with Apros.

Domestic cooperation with LUT

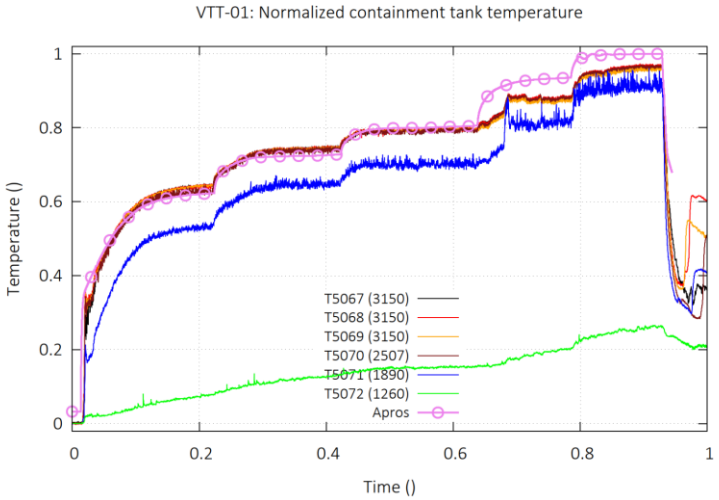
- The LUT PASI facility is a one-loop model of an open passive containment cooling system. The reference system is the passive containment heat removal system of the AES-2006 type pressurized water reactor.
- VTT-01 is one of the two experiments performed in SAFIR2022 PAHE (LUT) for VTT's code validation needs. The experiment is a stepwise steam injection to the containment while the natural circulation loop behaviour is being observed.



↑ PASI facility
(image: LUT)

Domestic cooperation with LUT (2)

- VTT-01 experiment was calculated with Apros in preparation for the following Apros-Fluent coupled calculation that will take place this year in SAFIR2022 CFD4RSA
- In 2022 a publication will be made of this cooperative work between THACO, CFD4RSA and PAHE



Containment temperature was well predicted in the Apros simulation

International cooperation

Representation in international cooperation programs

- Multiple OECD/NEA's and U.S. NRC's programs are being participated
- Crucial validation data is being obtained from these programs and they also contribute to knowledge transfer between organizations
- U.S. NRC codes TRACE, RELAP5, PARCS and SNAP are available through the CAMP participation
- Some of the participation fees are also channelled through the project

Project or program	Type of representation
OECD/NEA RBHT	MB member
OECD/NEA HYMERES-2	PRG member
OECD/NEA PKL-4	PRG member
OECD/NEA WGAMA	country representative
U.S. NRC CAMP	country contact person

beyond
the obvious

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