Benchmark of in-vessel Loss-Of-Coolant Accident models for an EU DEMO helium-cooled Breeding Blanket: GETTHEM vs. RELAP5-mod3.3

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BACKGROUND

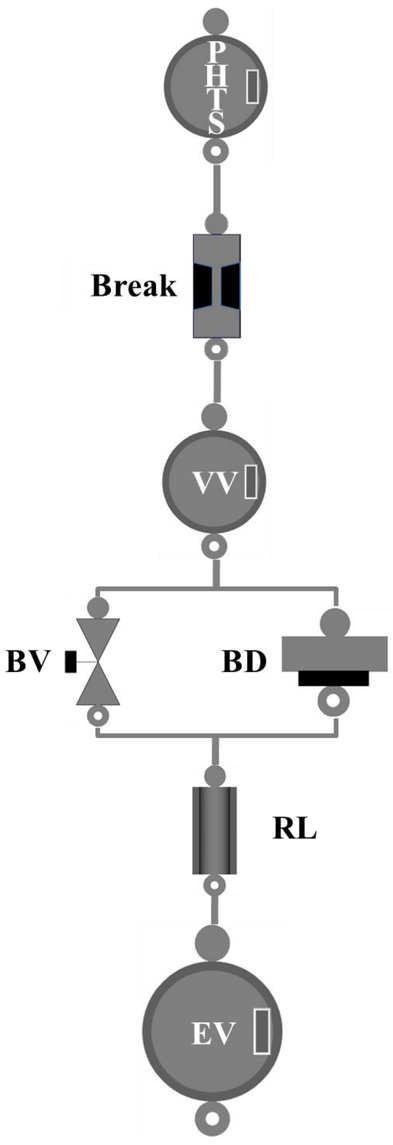
GETTHEM aims to become the first system-level thermal-hydraulic model for tokamak fusion reactors. It enables fast parametric studies through suitable modelling assumptions. As a new tool, it needs verification and validation, which have been partially performed in the past.

AIM OF THE WORK

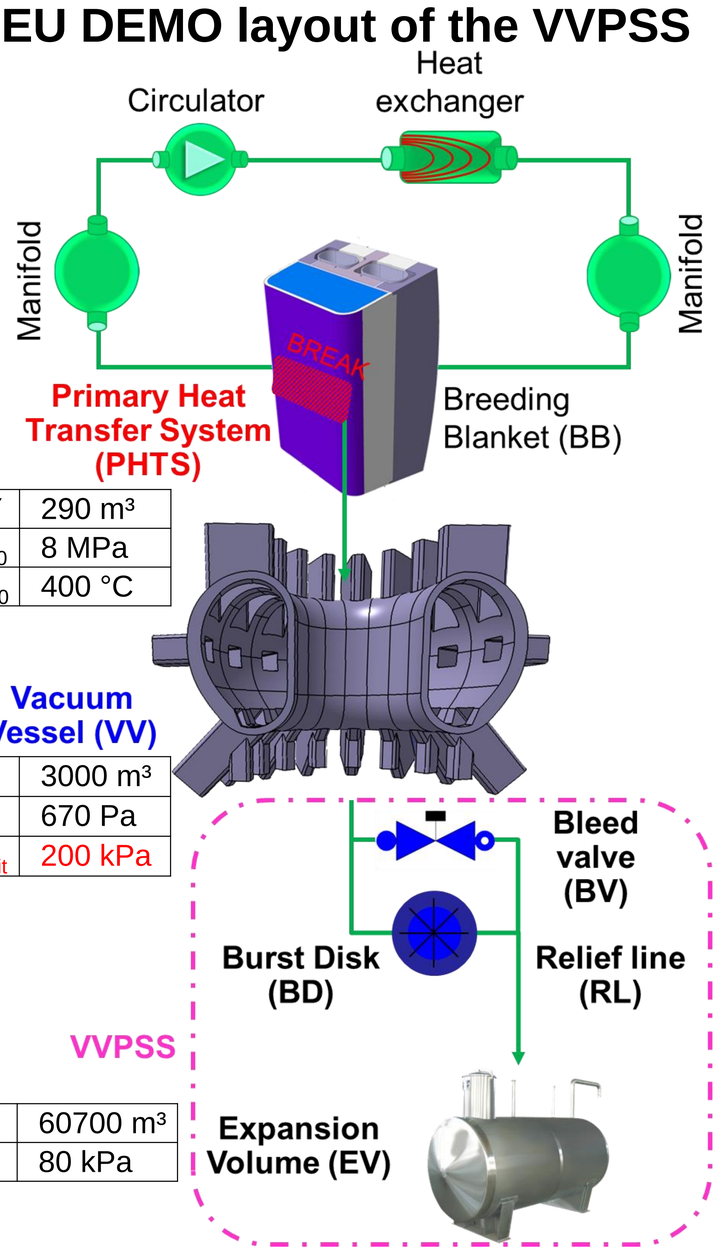
Perform a verification of the GETTHEM in-VV LOCA model (**PHTS**, **VV** and **VVPSS**) for the case of a helium-cooled Breeding Blanket (BB) through a code-to-code comparison against the certified RELAP5-mod3.3 code.

GETTHEM VVPSS model

- 0D mass and energy conservation in all components
  - Additionally, momentum conservation in break, BD, BV and RL
- Helium modelled as ideal gas
- Isentropic gas transformations in PHTS, VV and EV
- Simple choked flow model + discharge coefficient from literature in break, BV and BD



EU DEMO layout of the VVPSS



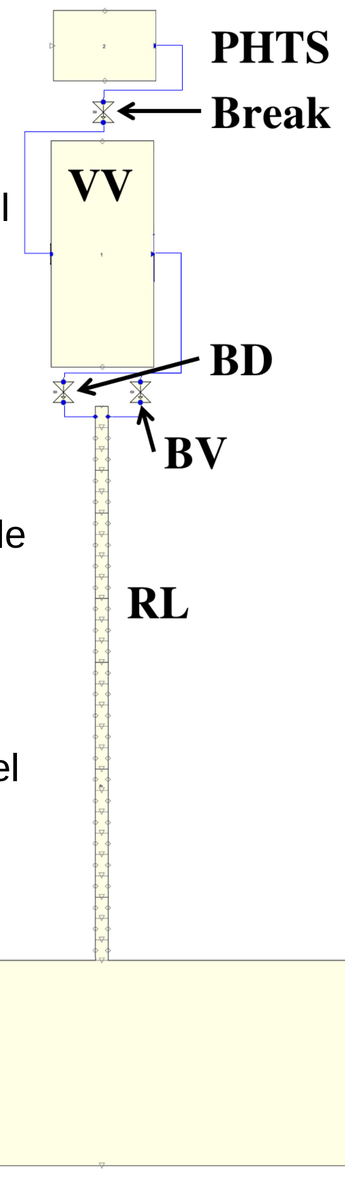
V	290 m³
p_0	8 MPa
T_0	400 °C

V	3000 m³
p_0	670 Pa
p_{limit}	200 kPa

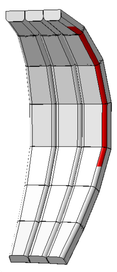
V	60700 m³
p_0	80 kPa

RELAP VVPSS model

- 1D mass, momentum and energy conservation in all components
  - 1 node for PHTS, VV and EV for consistency
- Helium modelled as noncondensable ideal gas
- Polytropic gas transformations (Tangren, 1949)
- Choked flow model from Ransom and Trapp, 1982



Scenarios



Case	FW break size [m²]	Involved inventory [m³]	# channels involved
1	0.01	290	3
2	0.1		21
3	1		210
4	2		418

RESULTS

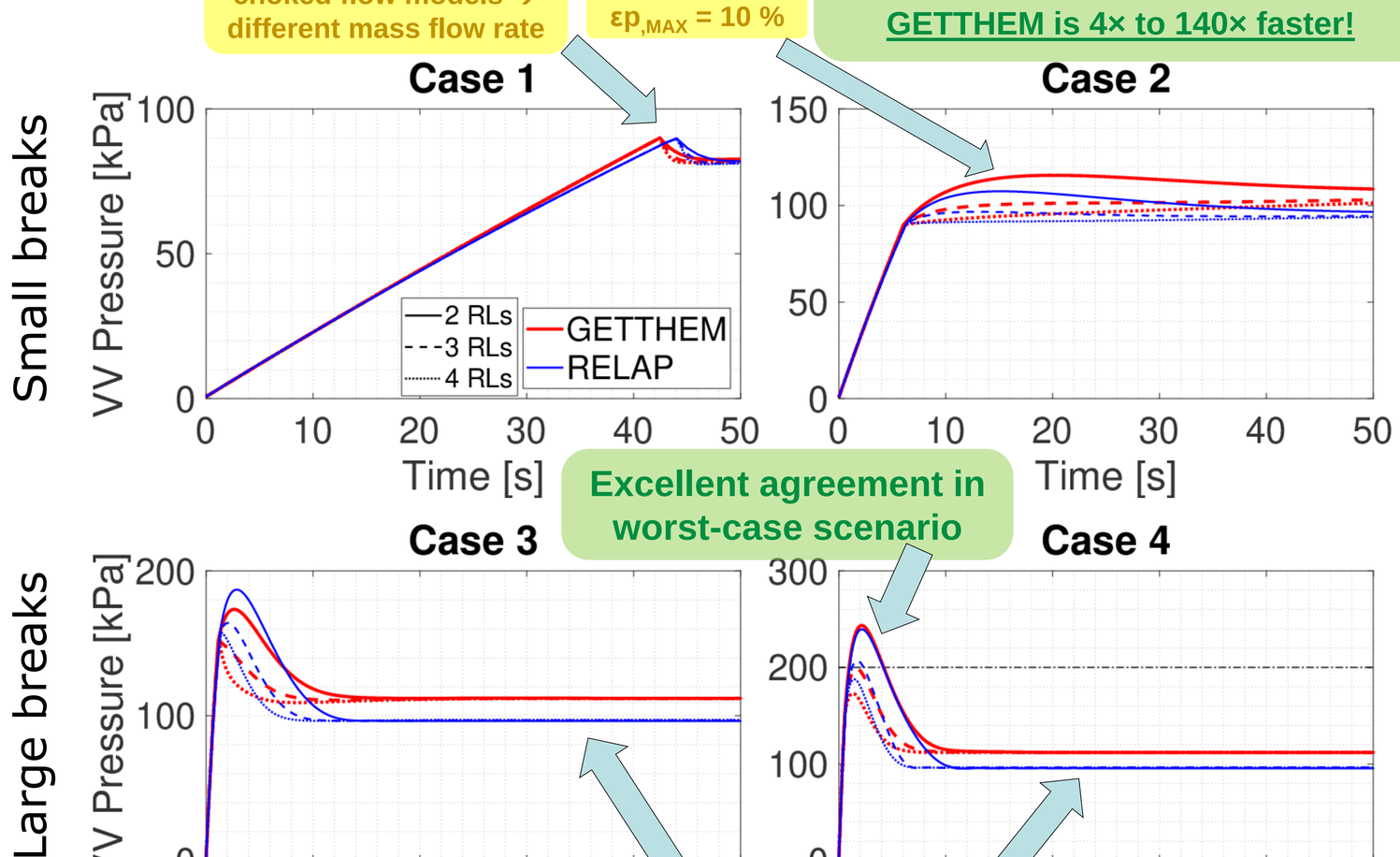
Effect of different choked flow models → different mass flow rate

$\varepsilon p_{,MAX}$ = 10 %

Computational times [s] (single-core)

	GETTHEM	RELAP
Minimum	0.09	13
Average	3	18

GETTHEM is 4× to 140× faster!



Excellent agreement in worst-case scenario

Discrepancy at steady-state induced by different expansion models → different temperatures

CONCLUSIONS and PERSPECTIVE

✓ First verification of the GETTHEM code against the certified RELAP code carried out for an in-VV LOCA from a He-cooled BB in the EU DEMO

✓ Currently the two codes presents differences:
- Choked flow model → differences in mass flow rate → timing
- Gas transformation model → differences in temperature → steady-state pressure

✓ However, differences in peak pressure and timing always below ~10 %

→ Improvements in GETTHEM VVPSS modelling:
- Use of 1D components for VV, PHTS and EV
- Introduction of natural convection in EV

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[2] A. Froio et al., Dynamic thermal-hydraulic modelling of the EU DEMO WCLL breeding blanket cooling loops, *Fus Eng Des* 2017
[3] A. Froio et al., Benchmark of the GETTHEM vacuum vessel pressure suppression system (VVPSS) model for a helium-cooled EU DEMO blanket, *Safety and Reliability* 2017
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[5] A. Froio et al., Thermal-hydraulic analysis of the EU DEMO helium-cooled pebble bed breeding blanket using the GETTHEM code, *IEEE TPS* 2018

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