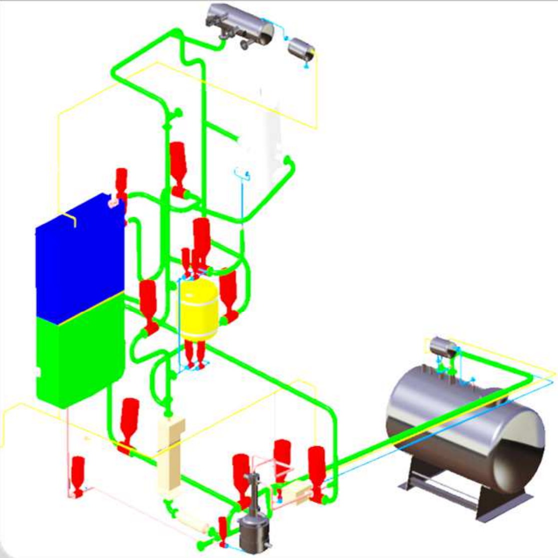
Karlsruher Institut für Technologie

jasmin
Joint Advanced Severe Accidents Modelling

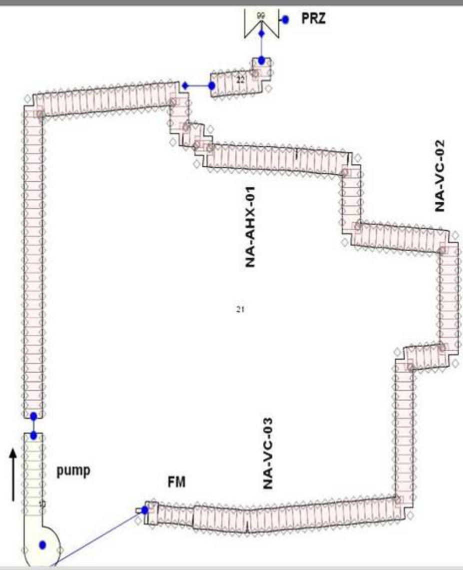
Code to Code validation:
Comparison of ASTEC and TRACE results on KASOLA loop

JASMIN WP 2.1
3rd Meeting, Petten, 25-26.03 2014

KIT-INR Institute for Neutron Physics and Reactor Technology

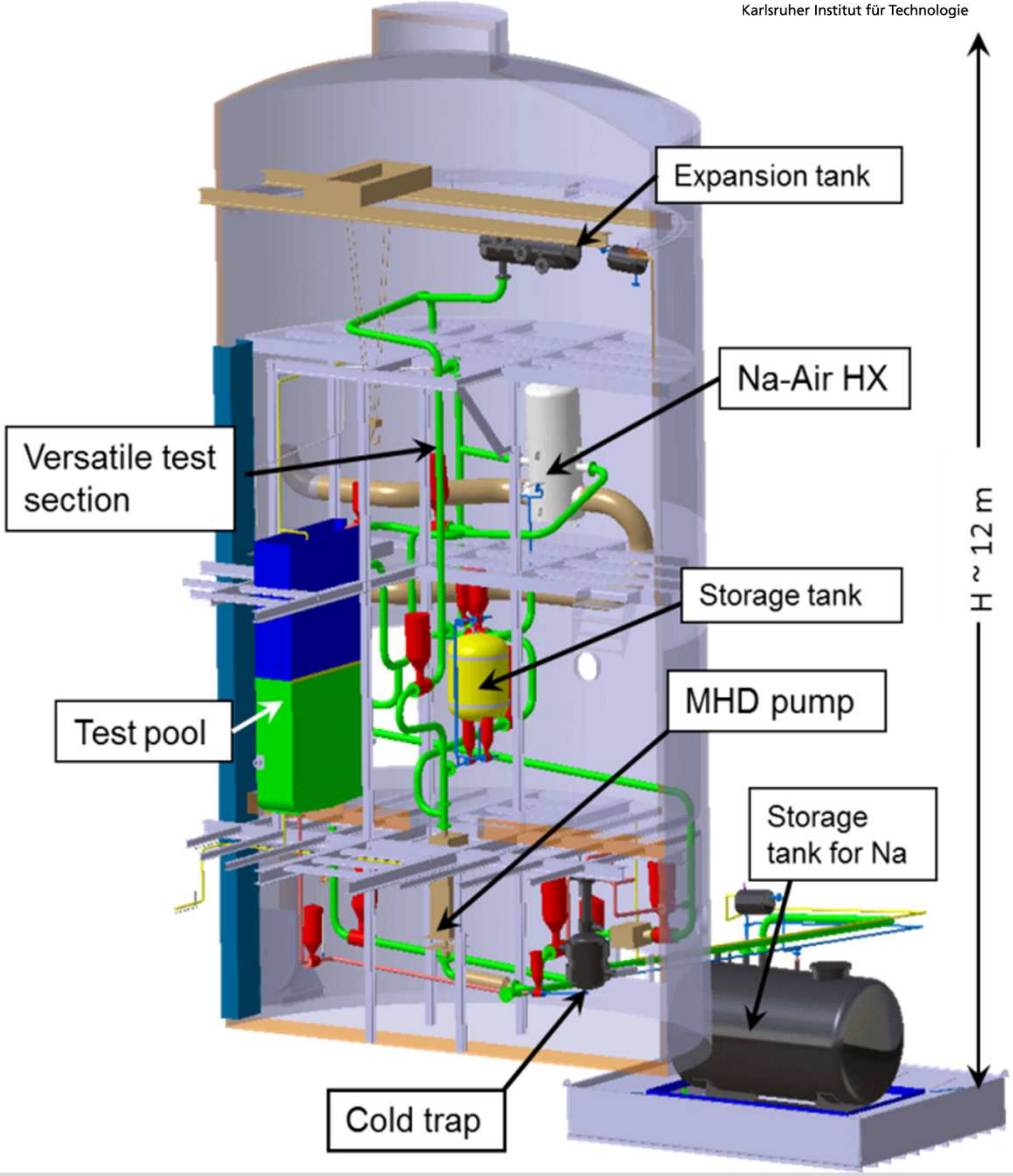


Presentation of KASOLA
Modelisation
Simulation
Outlook

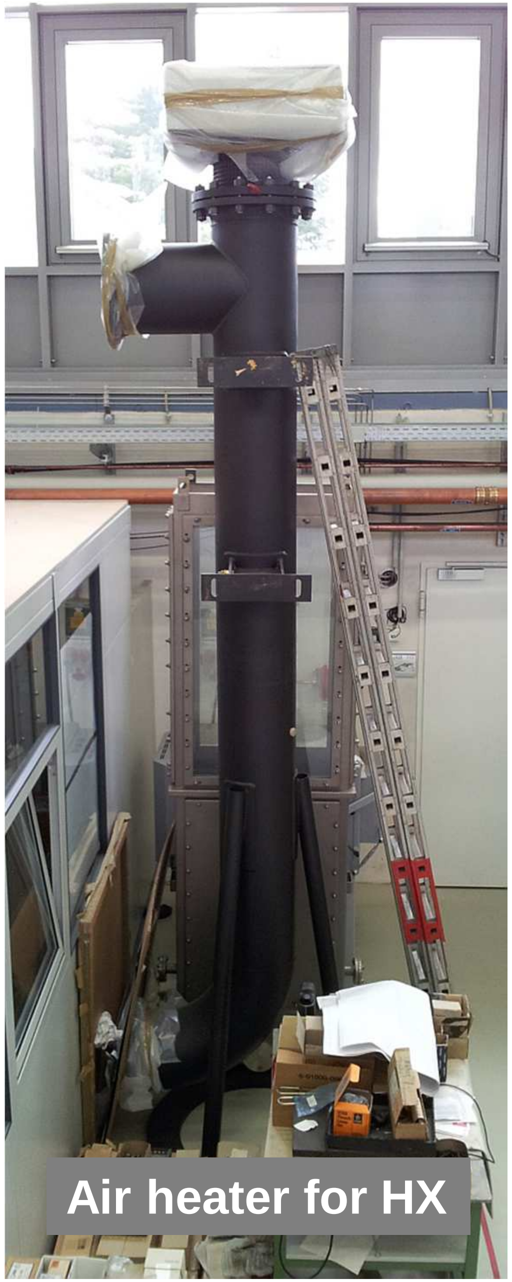


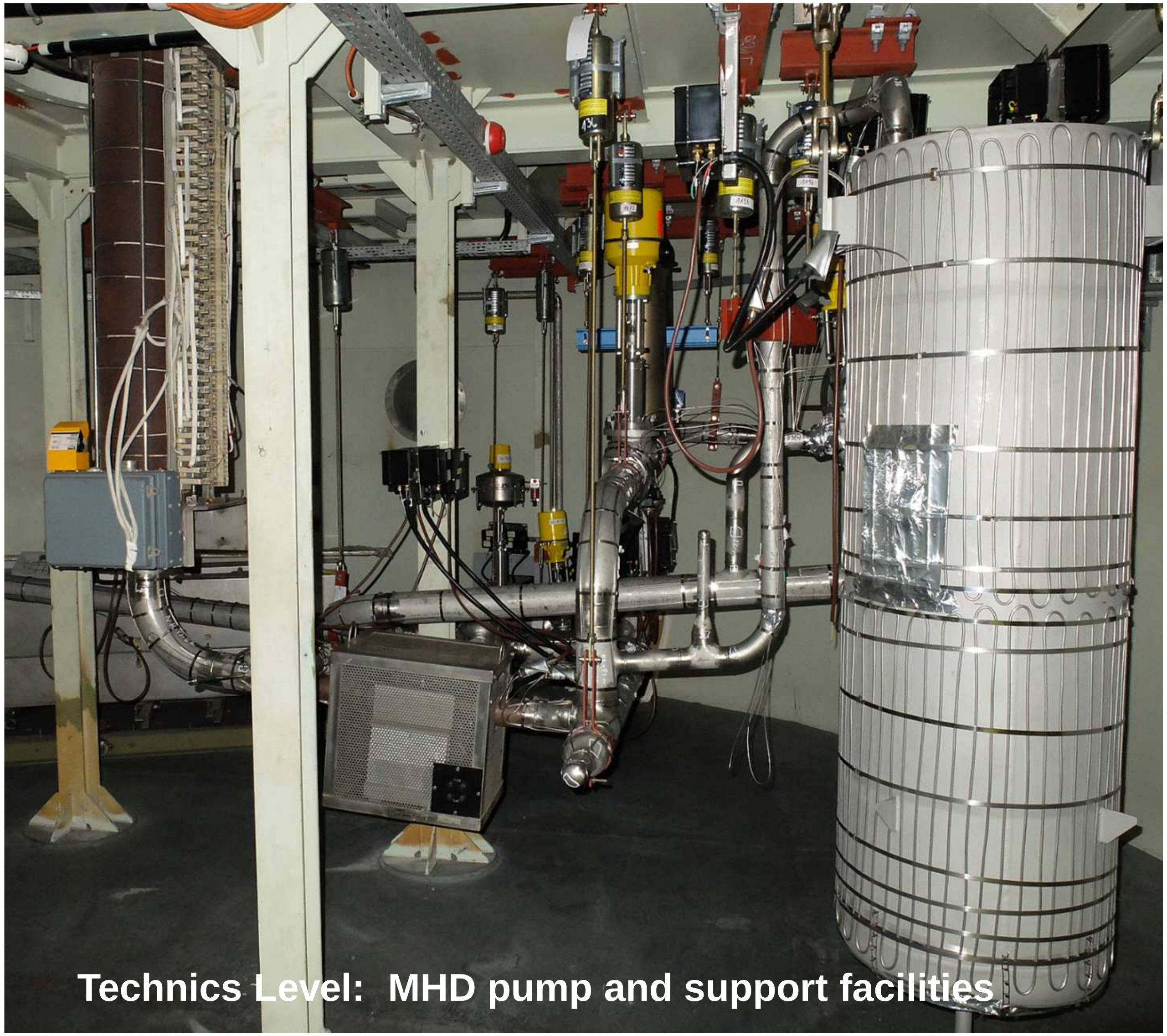
KASOLA

- Karlsruhe Sodium Laboratory
- Sodium experimental loop
- Temperature up to 550°C
- Mass flow rate up to 150 m³/h
- Pressure drop along the loop at full flow rate: 2.5 bar
- Heat-Sink capability 400 kW
- Loop length ~37.7m
- KASOLA report Issued end of January



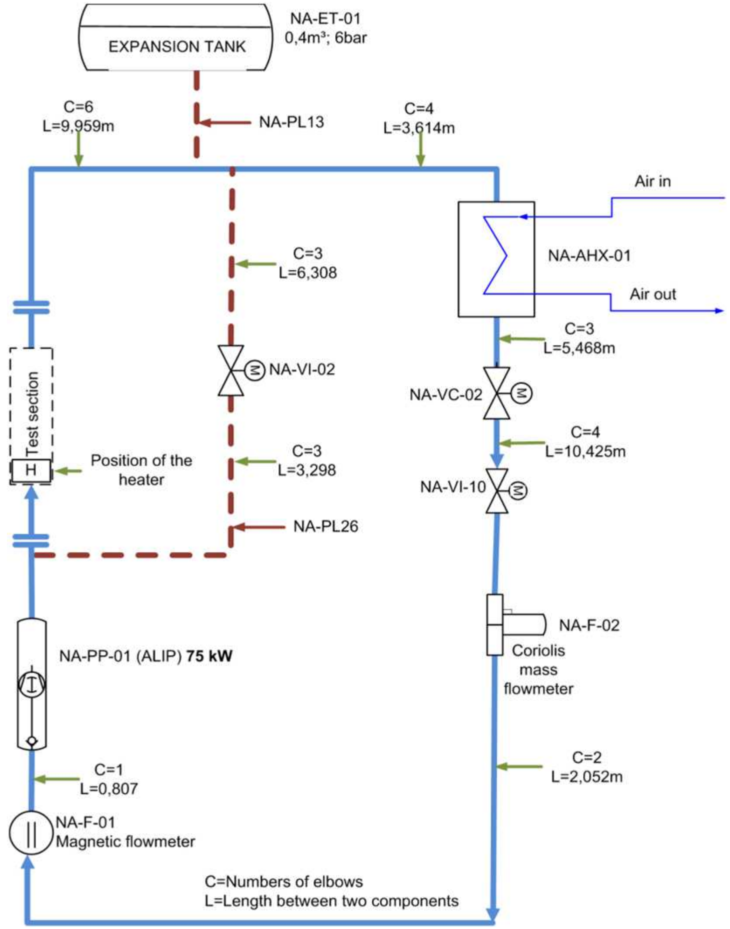
KASOLA Status





Circuit modelisation

- The circuit has been modeled with TRACE V5.0 and ASTEC-Na V1
- Basic test and transient have been carried out in order to compare the results of the two codes
- Simulation only address single phase thermal-hydraulic (CESAR module)
- The modeled circuit features
  - MHD Pump
  - Heater
  - Expansion Tank
  - Cooler
  - 3 Valves



Modeling and discretization

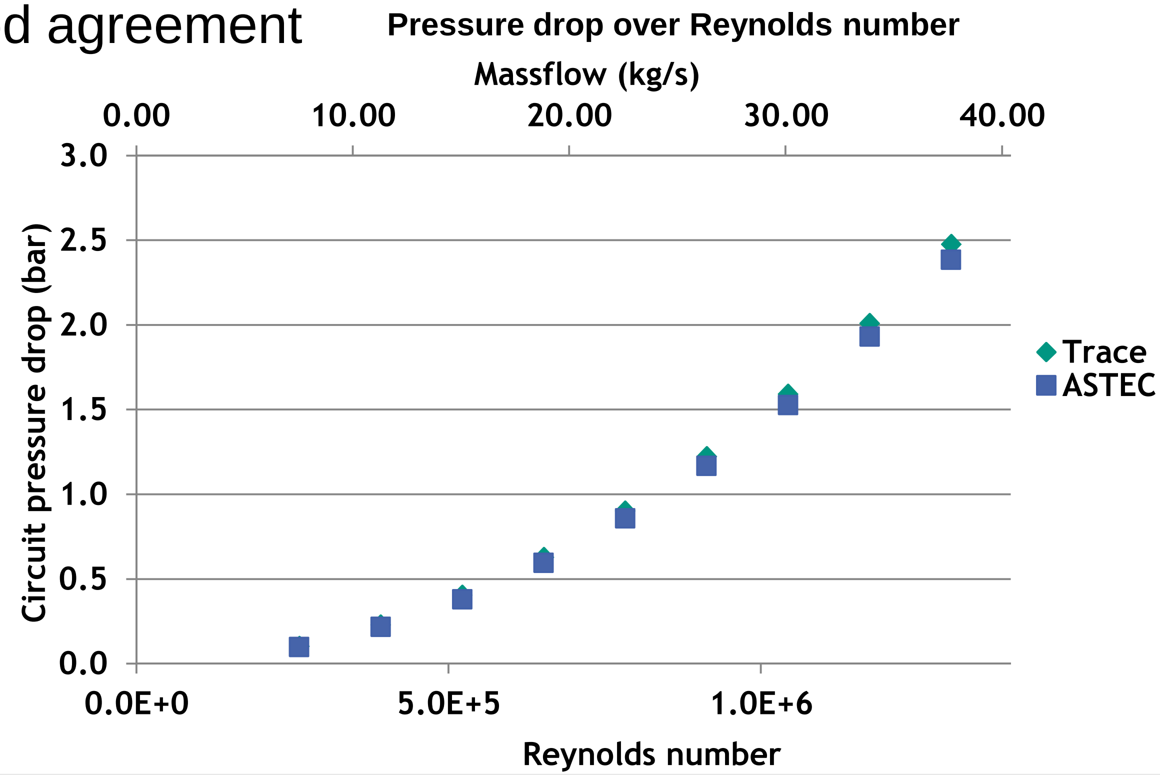
- Piping of real installation includes several elbows
- Each straight part of a pipe is modeled by one volume
  - Junctions link the volumes with appropriate pressure drop factors depending on the type of junction (elbows, T, valve etc.)
- The discretization is lowered in areas where measurements are made (cooler and heater)
  - Measurement areas discretized in section of 20 cm, in order to match the discretization of the TRACE model

Simulations

- Simulations undertaken
- 1) Constant temperature and mass flow
  - Goal:
    - Very basic simulation in order to compare overall pressure drop of the two codes and ensure good agreement
- 2) Natural circulation test
  - Goal:
    - More complex transient in order to compare thermal-hydraulic behavior
    - Gives input for real experiments on KASOLA loop
- 3) Pumptrip (transition from forced flow to natural circulation flow)
  - Goal:
    - Very dynamic transient
    - Allow to compare unsteady-state evolution

Constant temperature and mass flow

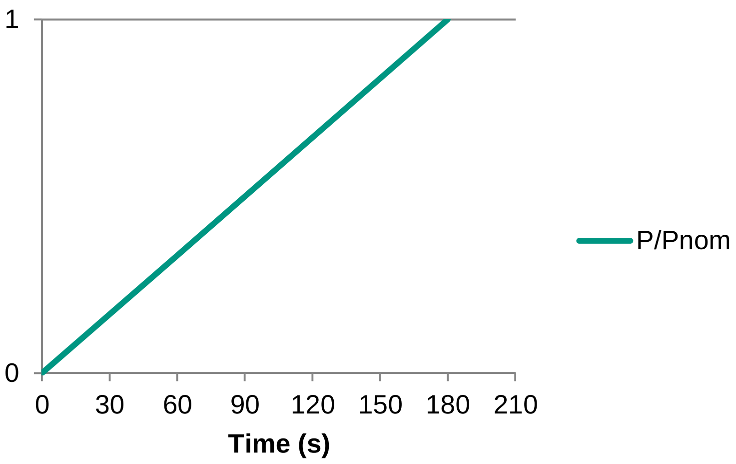
- Temperature is set at 473°C
- Simulations run for several mass-flow from 0 to nominal mass-flow (37.6kg/s)
- Pressure drop over the circuit is measured
- Results are in very good agreement
- Small differences in pressure drop are due to different physical models regarding regular friction pressure drop
- ASTEC uses Blasius
- TRACE uses Churchill

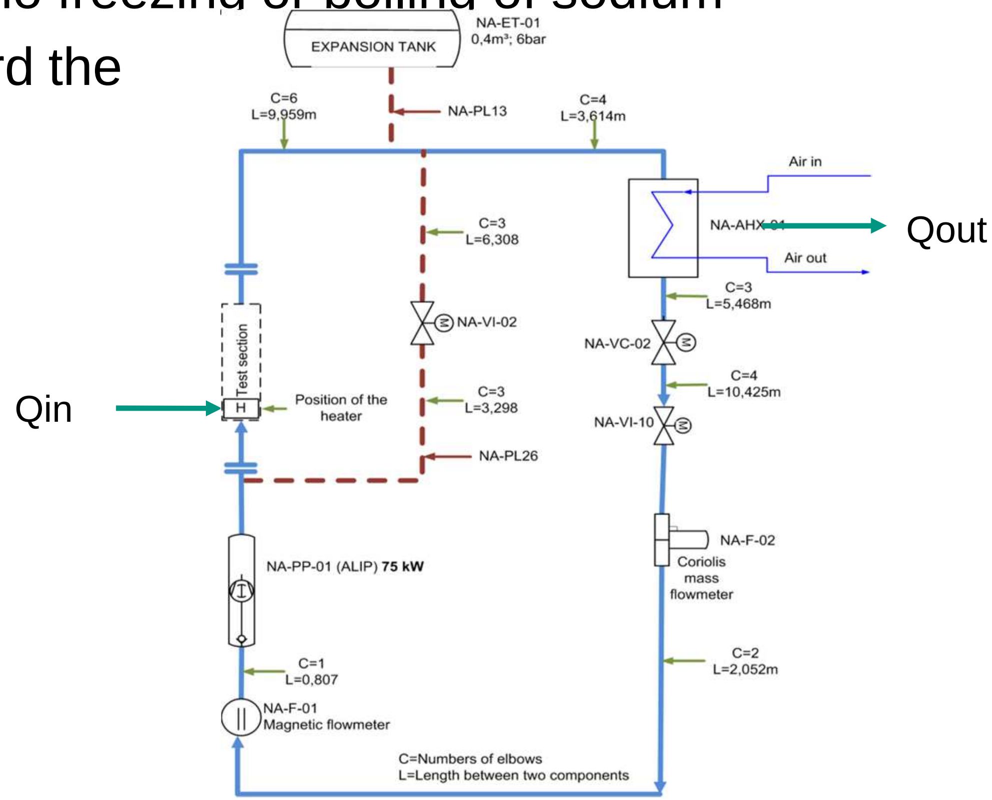


Natural circulation test

- The pump is shut-down
- Heater and cooler are activated with the same power
- Their power is ramped-up in order to have smooth establishment of steady-state conditions and no freezing or boiling of sodium
- For each simulation we record the final mass flow

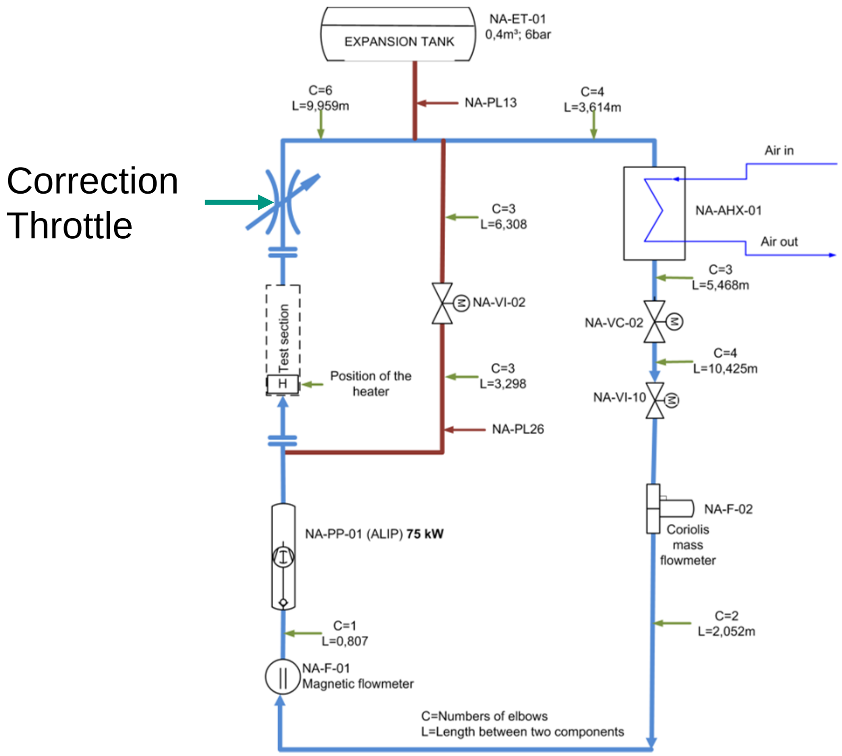
Power ramp-up





Natural circulation test

- Part of the difference between TRACE and ASTEC result is due to the difference of pressure drop at equal mass flow observed in the previous test
- In order to filter these differences, the pressure drop in ASTEC has been modified with an additional singular pressure drop in order to produce the same overall pressure drop as in TRACE
- This process is repeated iteratively until the ASTEC mass-flow converges



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Natural circulation test

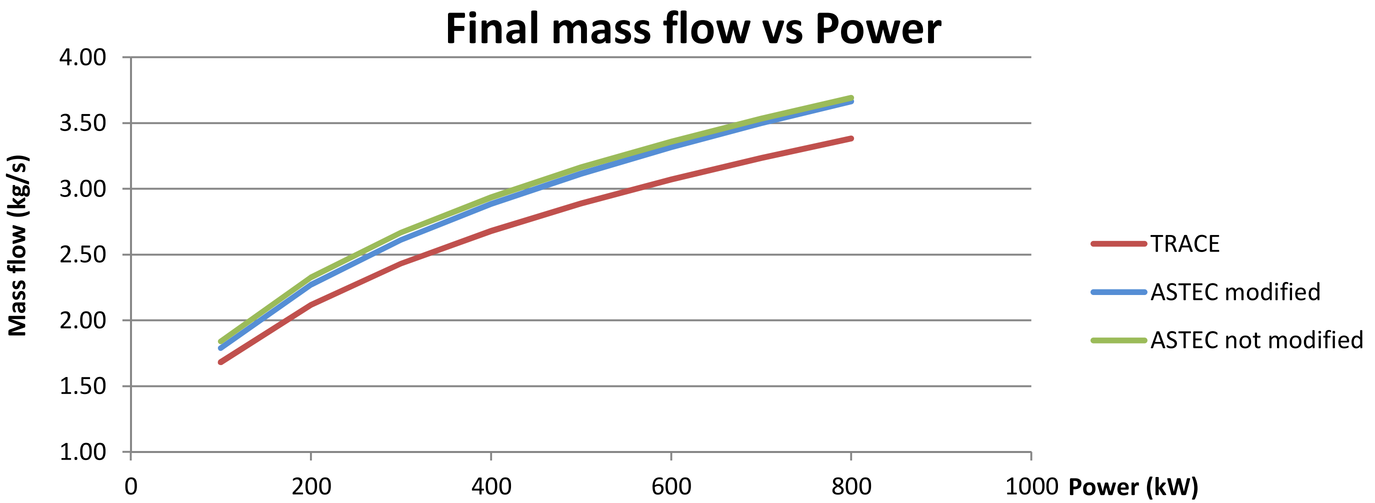
- Results show slightly better agreement once modified

	Codes mass-flow (kg/s)		
Power (kW)	ASTEC	TRACE	**Relative Error**
100	1.84	1.68	**9%**
200	2.33	2.12	**10%**
300	2.67	2.43	**10%**
400	2.94	2.68	**10%**
500	3.16	2.89	**9%**
600	3.36	3.07	**9%**
700	3.53	3.23	**9%**
800	3.69	3.38	**9%**

Original results

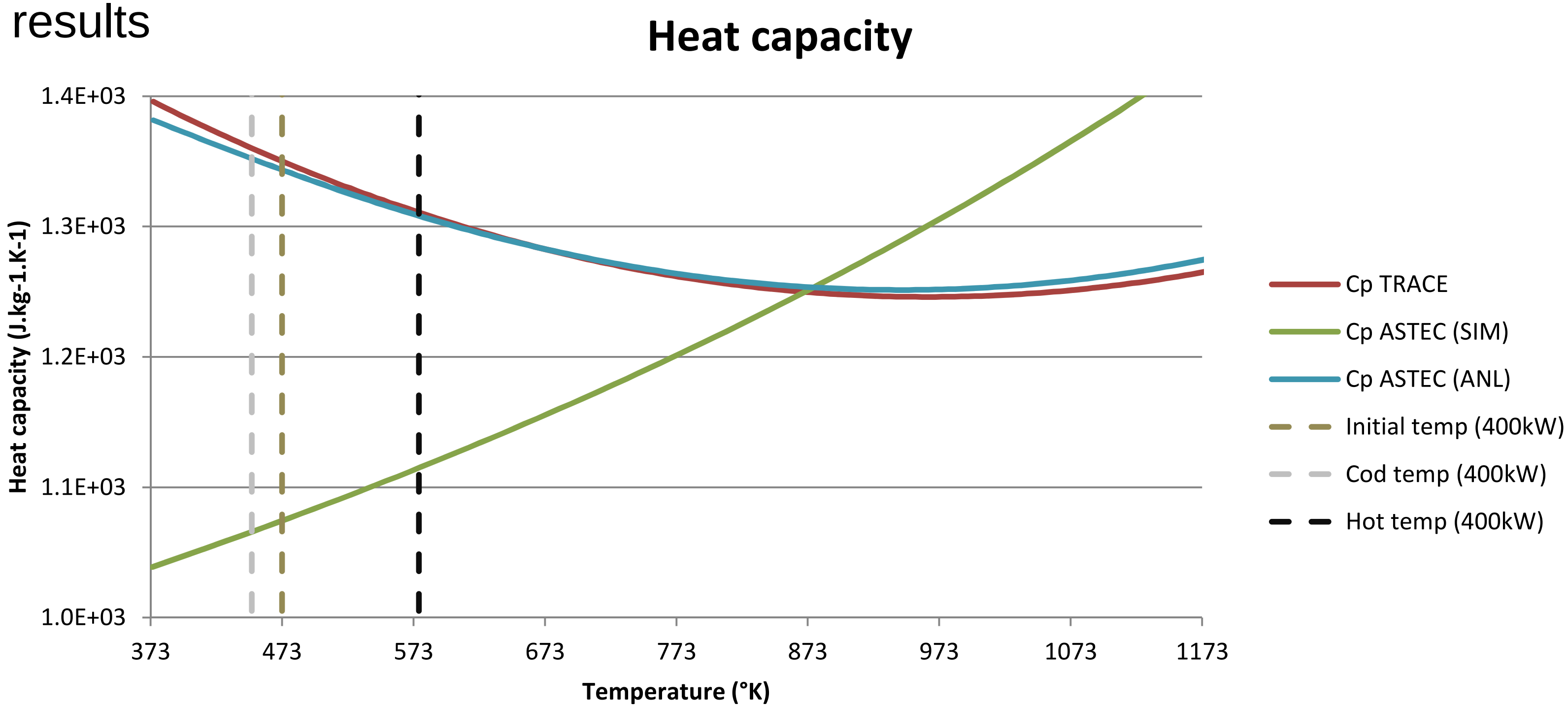
	Codes mass-flow (kg/s)		
Power (kW)	ASTEC	TRACE	**Relative Error**
100	1.79	1.68	**6%**
200	2.27	2.12	**7%**
300	2.61	2.43	**7%**
400	2.88	2.68	**8%**
500	3.11	2.89	**8%**
600	3.32	3.07	**8%**
700	3.52	3.23	**8%**
800	3.66	3.38	**8%**

Modified results (same pressure drop)



Natural circulation test

- Discrepancies seems to originate from differences of Sodium heat capacity data between the two software
- In ASTEC v1.1 it is possible to select other sources for Sodium properties (ANL)
  - Properties from this sources are closer to TRACE ones which give closer results



Natural circulation test

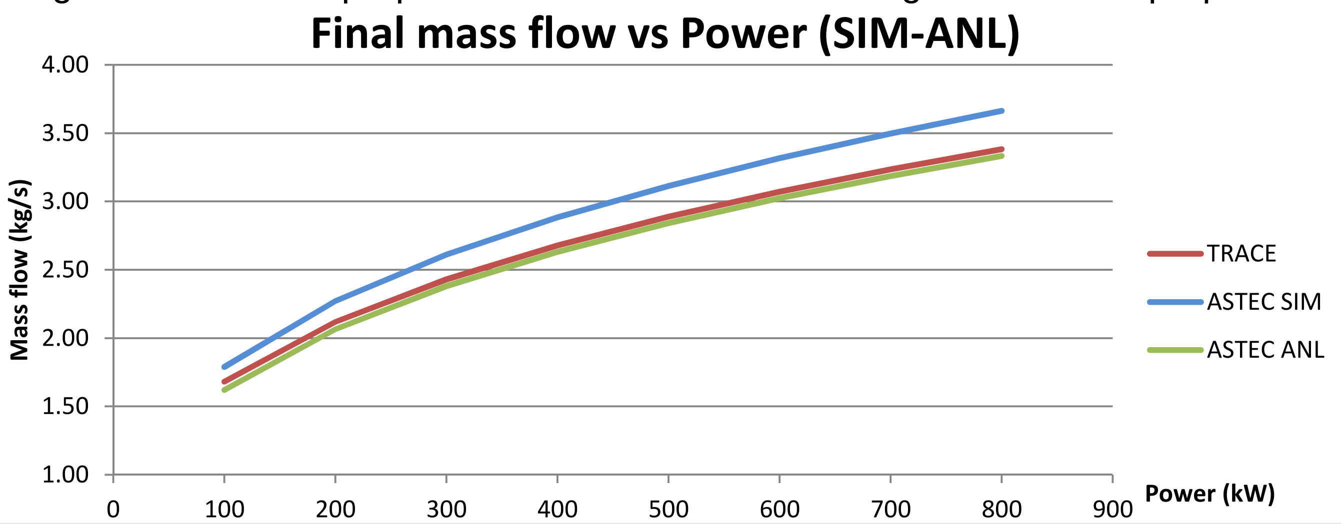
- Codes are in better agreement when selecting ANL sodium properties

	Codes mass flow (kg/s)		
Power (kW)	ASTEC	TRACE	Relative Error
100	1.79	1.68	6%
200	2.27	2.12	7%
300	2.61	2.43	7%
400	2.88	2.68	8%
500	3.11	2.89	8%
600	3.32	3.07	8%
700	3.52	3.23	8%
800	3.66	3.38	8%

Using default Sodium properties

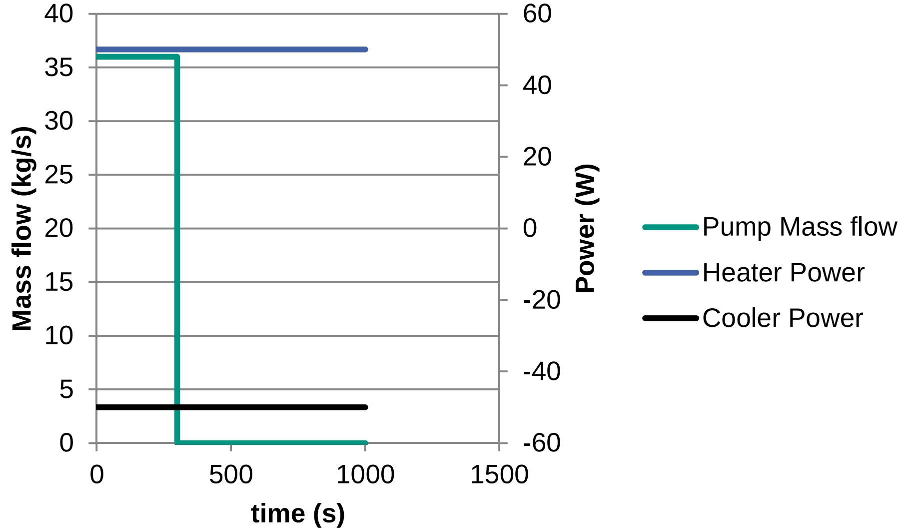
	Codes mass flow (kg/s)		
Power (kW)	ASTEC	TRACE	Relative Error
100	1.64	1.68	-3%
200	2.08	2.12	-2%
300	2.39	2.43	-2%
400	2.64	2.68	-2%
500	2.85	2.89	-1%
600	3.03	3.07	-1%
700	3.20	3.23	-1%
800	3.35	3.38	-1%

Using ANL Sodium properties



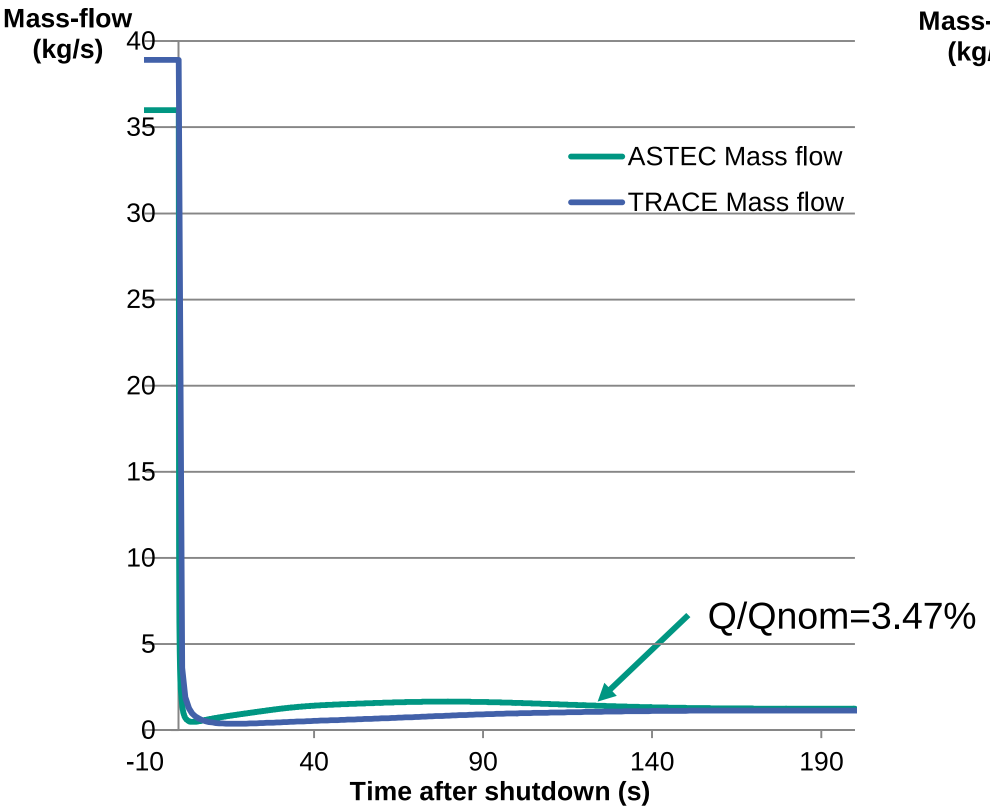
Pumptrip

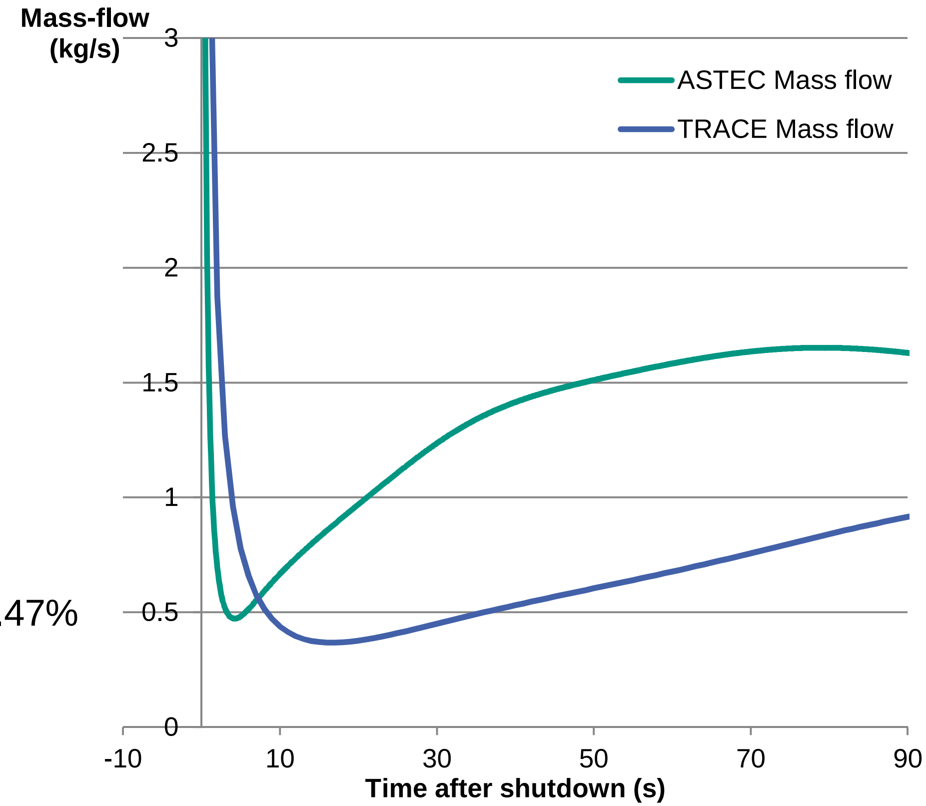
- The mass flow is regulated to a constant mass flow.
- The heater and cooler are activated with 50kW
- The pump is suddenly shut down
- The transition from forced flow to natural circulation is compared



Pumptrip-test

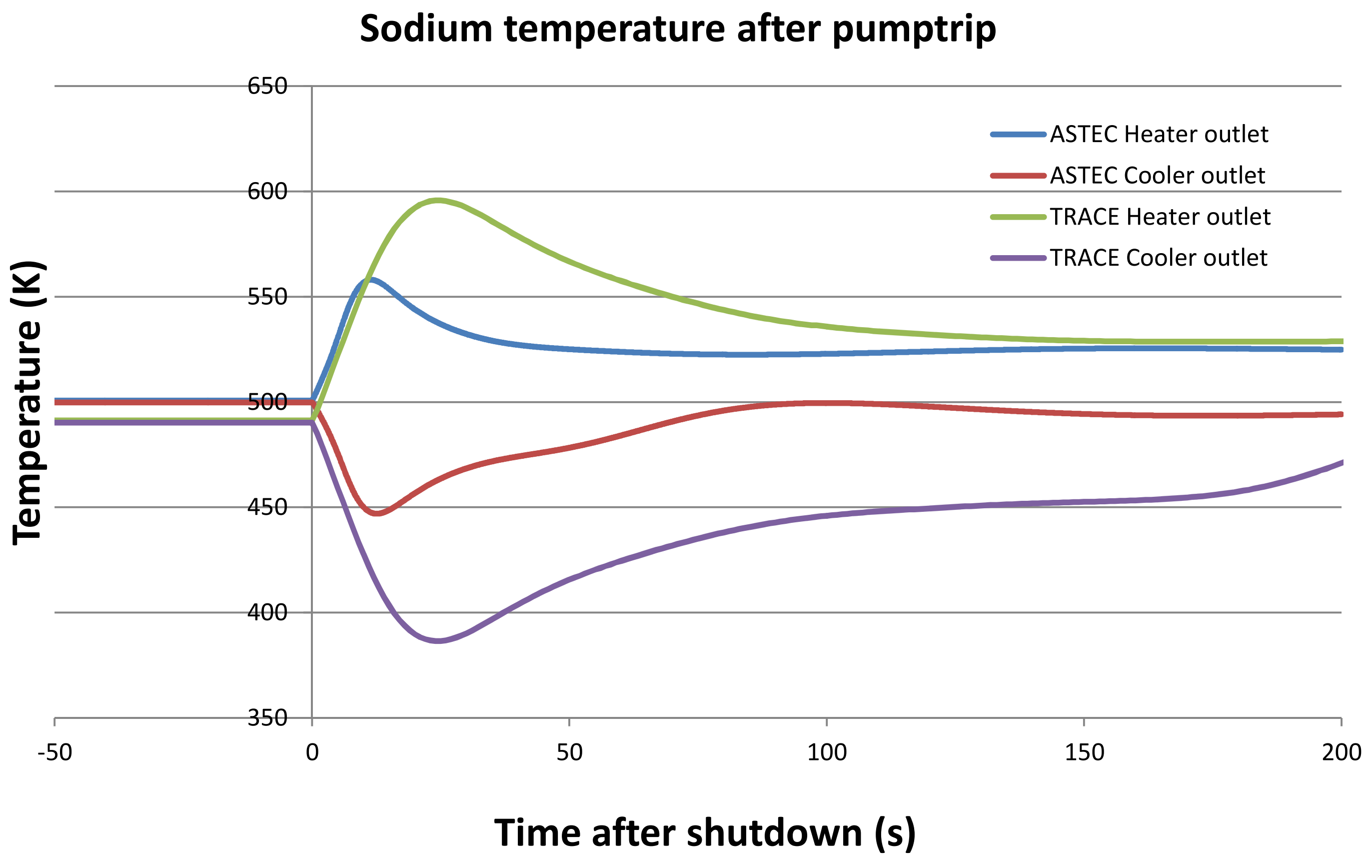
- Due to high friction in the loop, mass-flow falls sharply right after pump shuts down
- At 140s after trip both codes show good agreement





Temperature comparison after pumptrips

- Small differences in mass flow during transition between forced flow and natural circulation regime have significant impact on the temperature spikes



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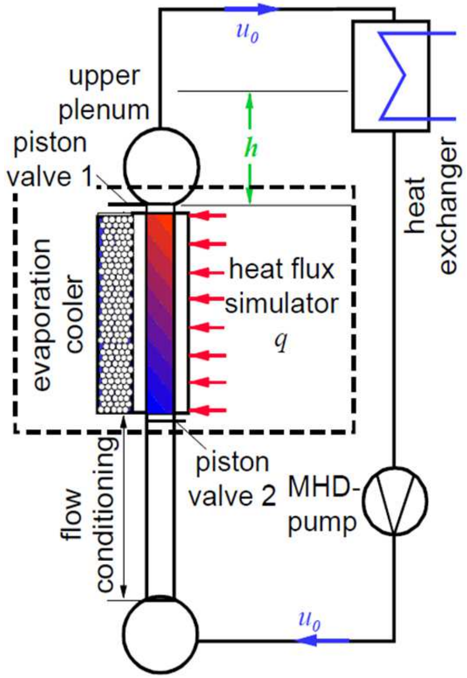
Summary and outlook

- The presented transients will be tested in the reality
  - Actual scenario might be tuned to comply to technical feasibility
    - 800 kW in Natural Circulation is probably too extreme
    - Possibility for higher cooling power than heating power is considered to enhance buoyancy forces
    - Adaptation to real pump coast down time
- Other transient and scenario to be simulated
  - Fast drain to the safety tank
- Experimental program
  - Base Loop
  - Experiments which will be conducted in other research programs will be useful benchmark as well (e.g. LIMTECH B1)



Limtech B1 experiment

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Thank you for your attention