Results of ASTEC-Na KASOLA pre-test analysis

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Simulation definition

- S1: Steady-state operation
  - Constant mass-flow
  - Constant heat-flux at heater
  - Constant mass-flow and inlet temperature at air heat-exchanger
- S2: Unprotected Loss-of Flow
  - Abrupt pump-trip (0 inertia)
- S3: Unprotected Loss of Heat-Sink
  - Abrupt loss of air feeding (100% to 0 % in 1 second)
- S4: Regulated temperature
  - Temperature is maintained constant at initial conditions (heat regulation)

S1: Steady state operation

- Initial and boundary conditions:
  - Heater power 400 kW
  - Pump-head 2.5 bar
  - Air inlet temperature 60 °C
  - Air flow-rate 6350 kg/h (1.764 kg/s)
  - Ambient temperature 60°C
  - Initial sodium temperature 300°C
  - Expansion tank pressure 2.5 bar
- Goal
  - Evaluate heat removal capacity
  - Evaluate heat losses from primary circuit
  - Reference computation for S2 and S3

S2: Loss Of Flow

- Initial and boundary conditions:
  - Same as S1 except:
  - Pump-head falls instantaneously to 0 at $t=t_{LOF}$
- Goal
  - Characterize the transition from forced to natural circulation
    - Which mass-flow is reached
    - Rapidity at which the mass-flow is being reached
    - Temperature spikes in the sodium

S3: Loss Of Heat Sink

- Initial and boundary conditions
  - Same as S1 except:
  - Air feeding at heat-exchanger stops in 1s
  - Sodium pump-head and heater power remains constant
- Goal
  - Characterize thermal inertia of the primary circuit
    - Rapidity of sodium heat-up
    - Evolution of heat losses through insulation

S4: Regulated temperature

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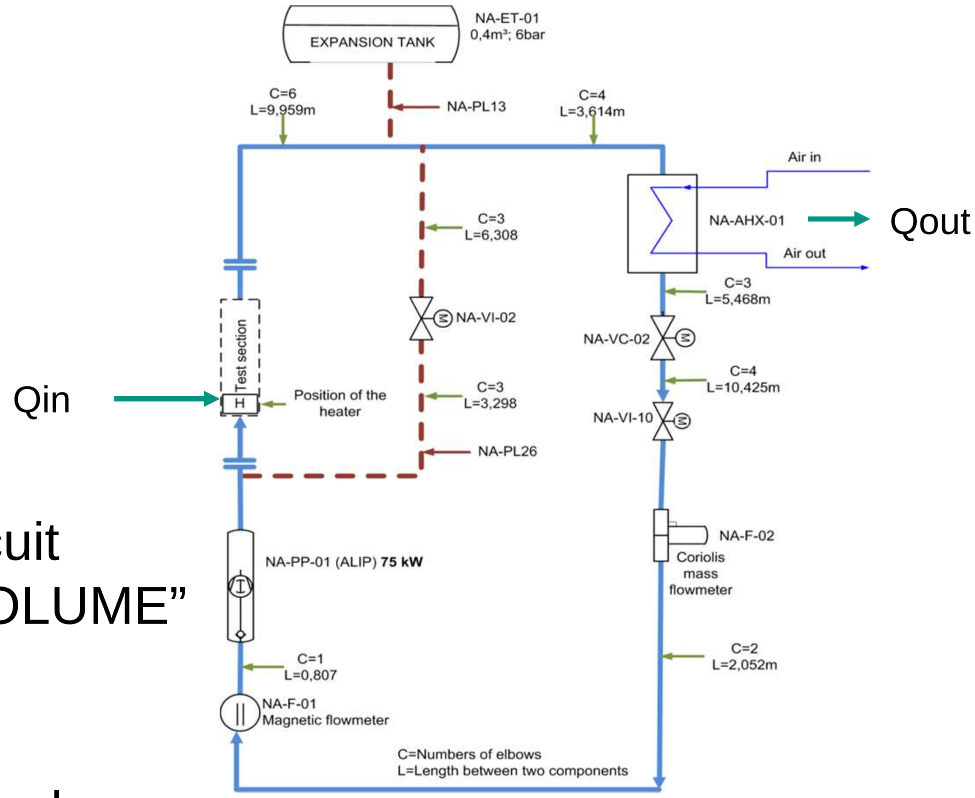
- Initial and boundary conditions
  - Same as S1 except:
  - Power of the heater is regulated in order to maintain a constant 300°C in the circuit
- Goal
  - Steady state heat losses at initial conditions
  - Heat removal capacity at initial conditions

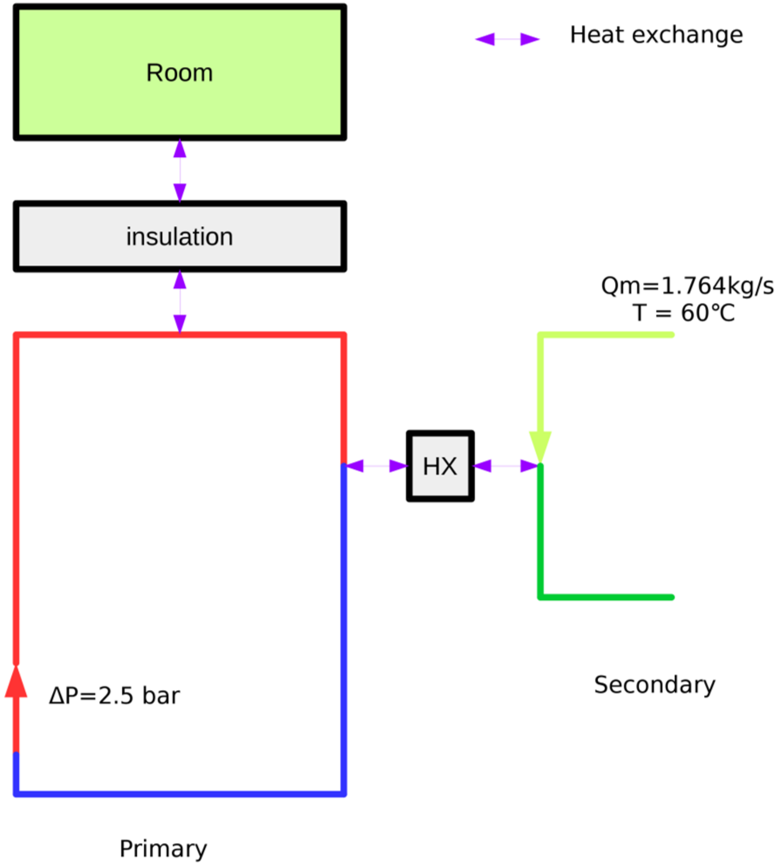
Modeling

- Schematic of the primary circuit
- The modeled circuit features
  - MHD Pump
  - Heater
  - Expansion Tank
  - Cooler
  - 3 Valves
- Both primary and secondary circuit are made with succession of “VOLUME” and “JUNCTIONS” structures
- Code to code comparison of the primary circuit has been performed against TRACE V5
- Simulation only address single phase thermal-hydraulic (CESAR module)



Modeling – Boundary conditions

- Following issue have been encountered during the modeling
  - Problem when trying to define an air mixture in the secondary circuit, hence N2 has been used as the cooling gas
  - Because it is not possible to create a heat exchange from one wall to another, the several insulation layer have been replaced by only one equivalent layer.



Modeling – Boundary conditions

- Insulation consist in five layers

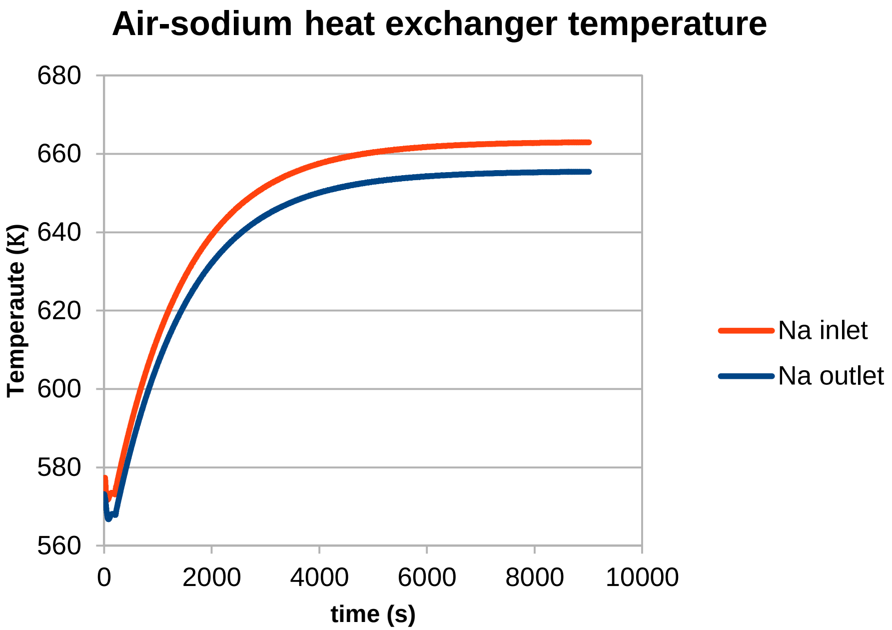
Layer	λ	Cp	ρ	Thick (mm)
1	16,3	500	8000	2,8
2	0,09	950	160	25
3	0,039	950	60	60
4	0,039	950	60	80
5	0,037	950	60	40

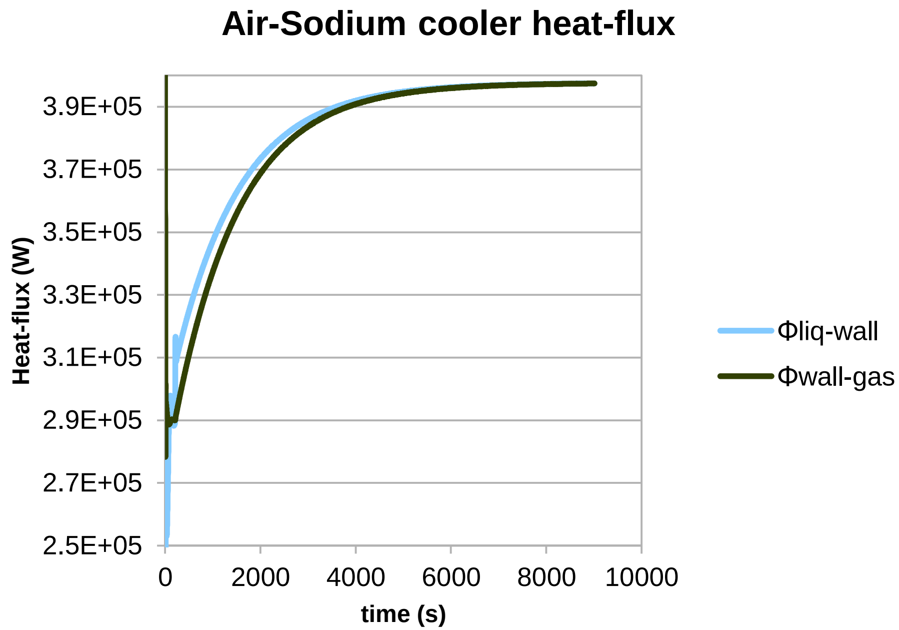
Properties of insulation layers

Layer	λ	Cp	ρ	Thick (mm)
1	0,042	675.25	165.62	207.8

Simulation results: S1

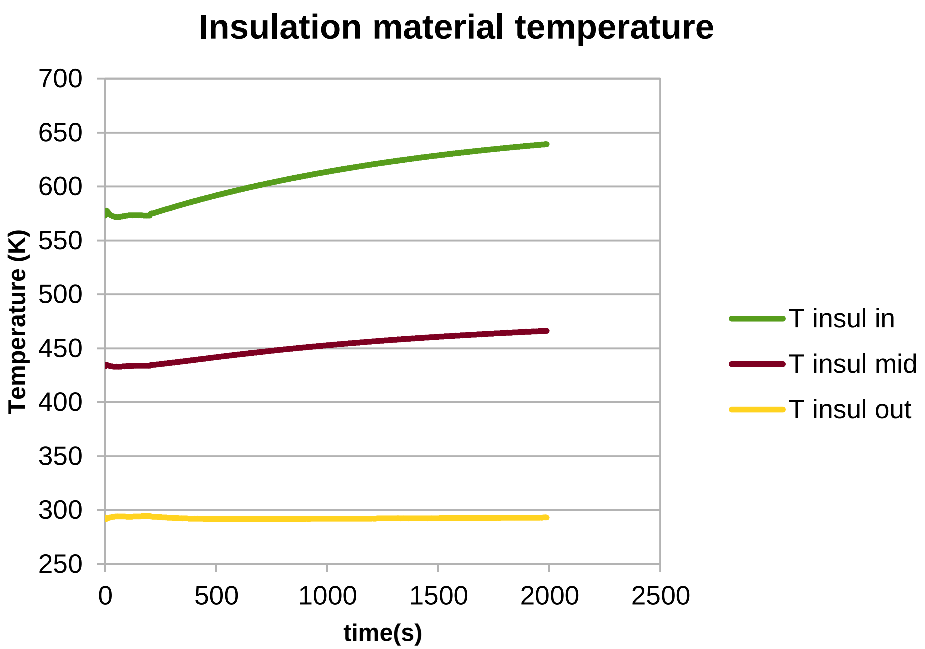
- The heat removal capacity of the secondary circuit is lower than the heater power. The sodium is hence heating-up during the transient
- The initial heat removal capacity of the heat exchanger, for the given initial conditions is about 306 kW

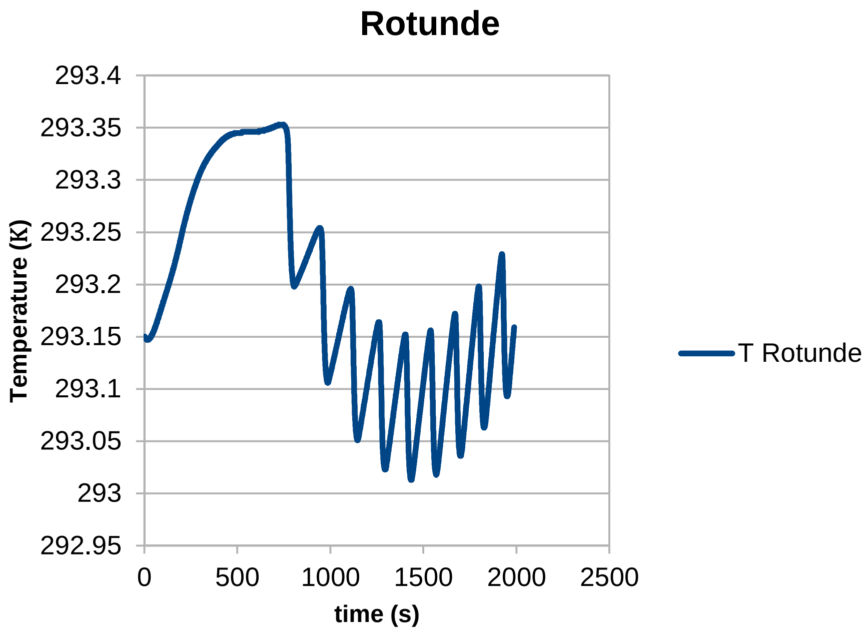




Simulation results: S1

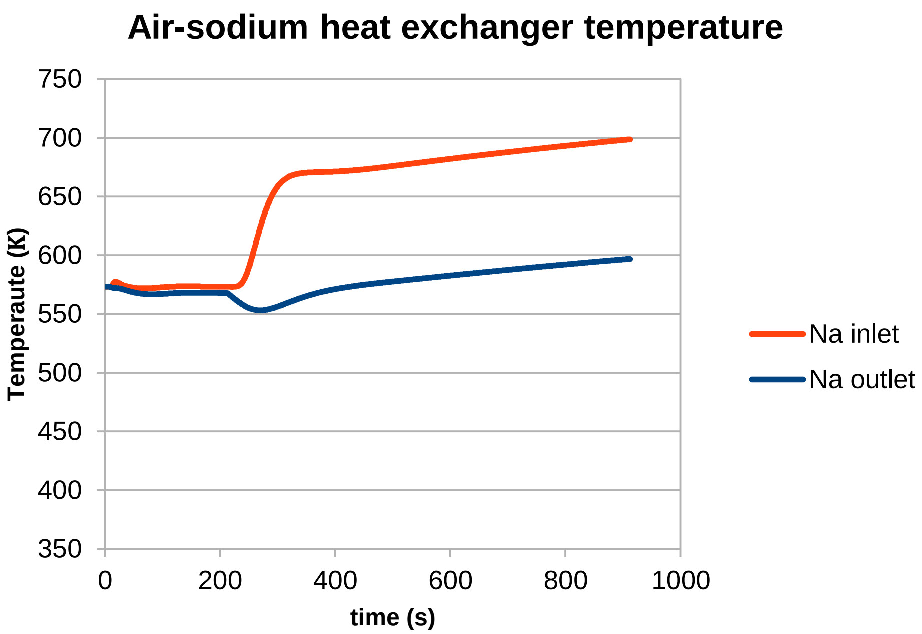
- Unexpected:
  - When the transient begins at 200 s, the outside temperature of the insulation material decreases. This causes the temperature and pressure in the rotunda to slightly decrease.
- Impact is negligible but the behavior is unexpected

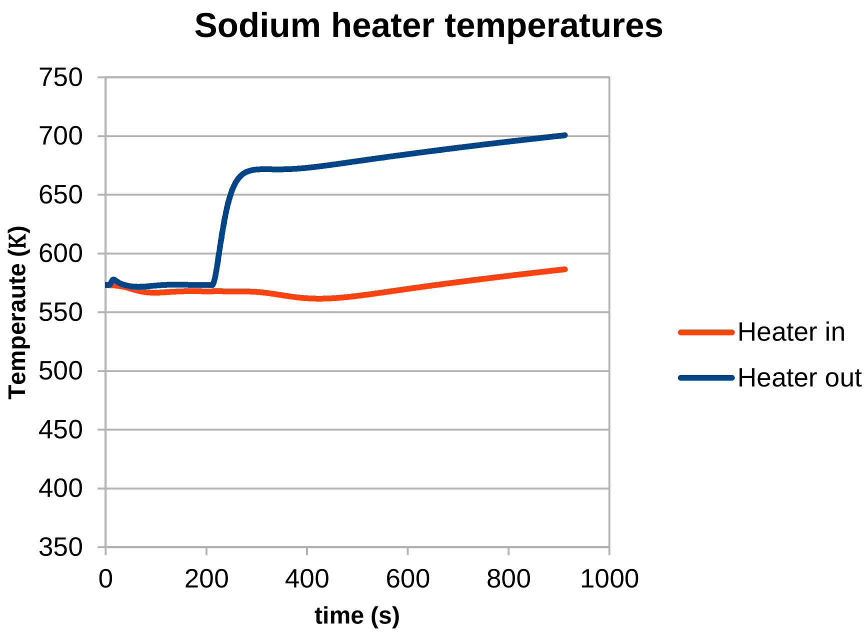




Simulation results: S2

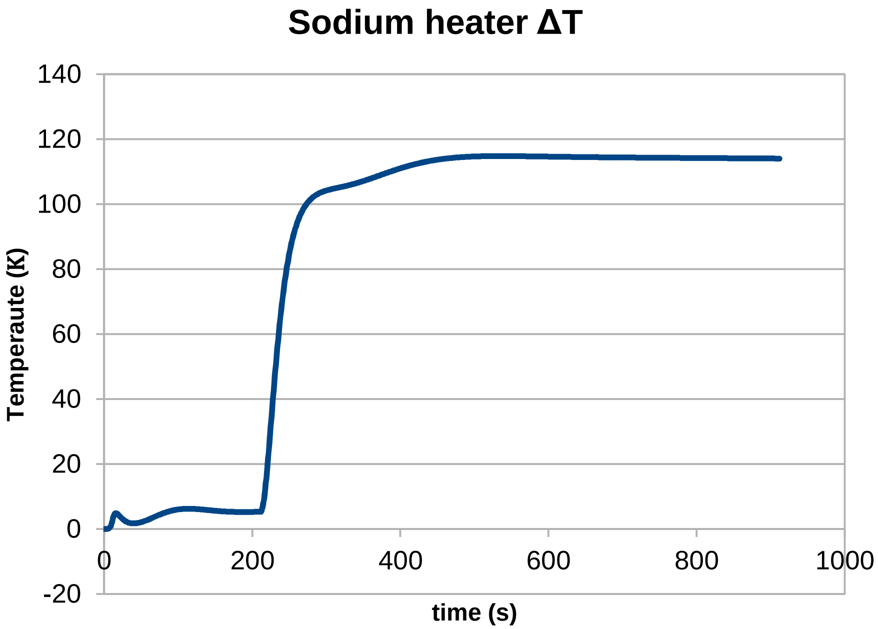
- Sharp temperature increase at ULOF

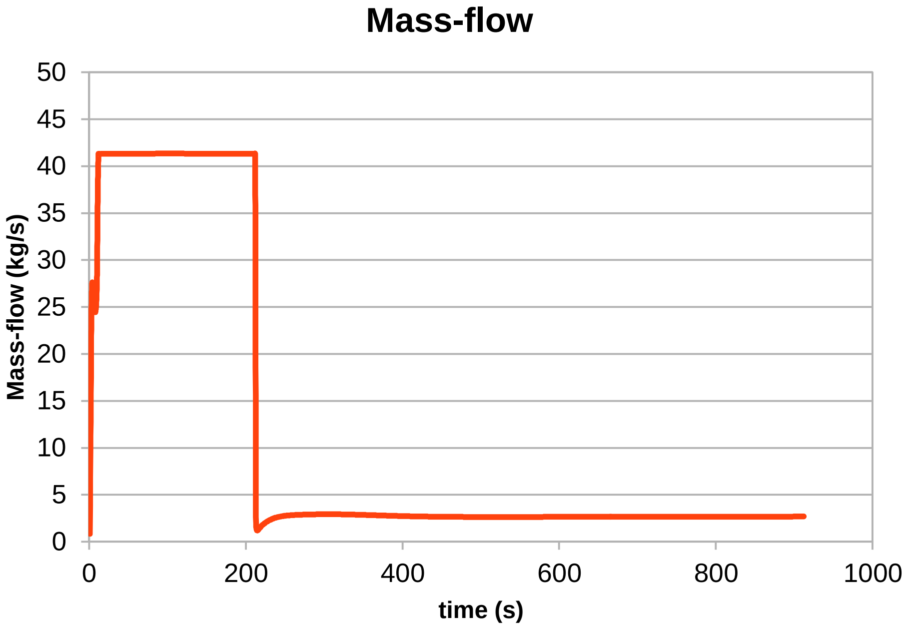




Simulation results: S2 (ULOF)

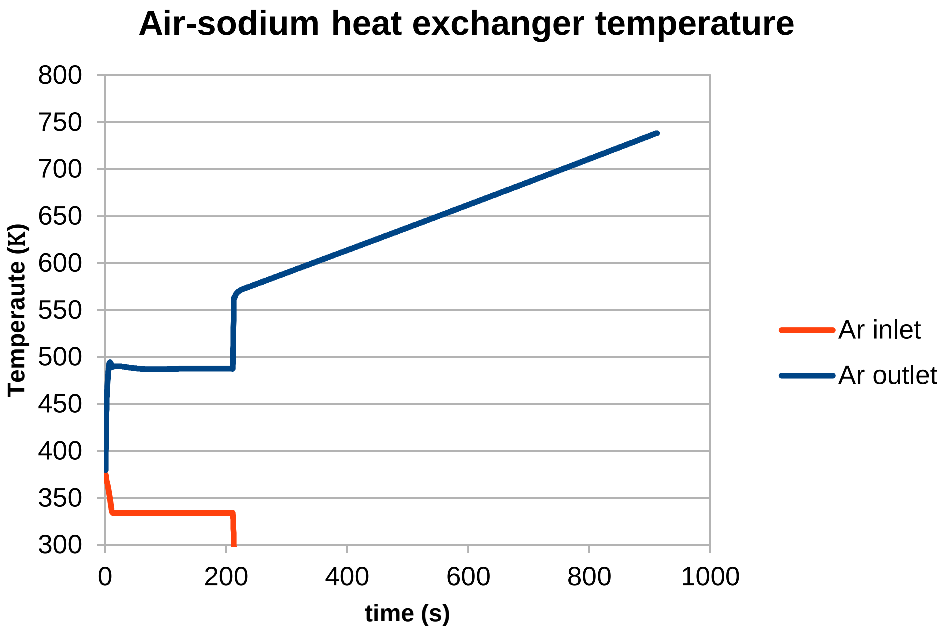
- Final mass flow in primary 2.69 kg/s

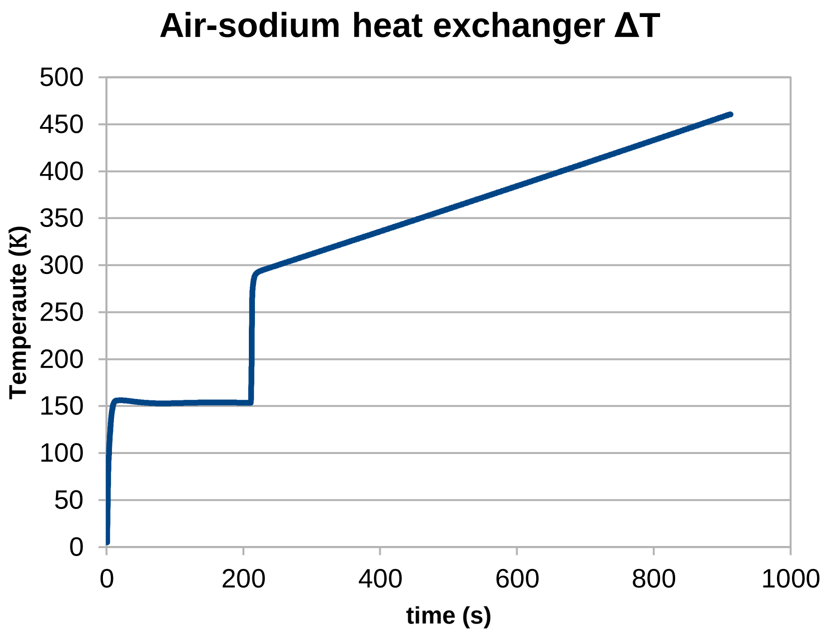




Simulation results: S3 (ULOHS)

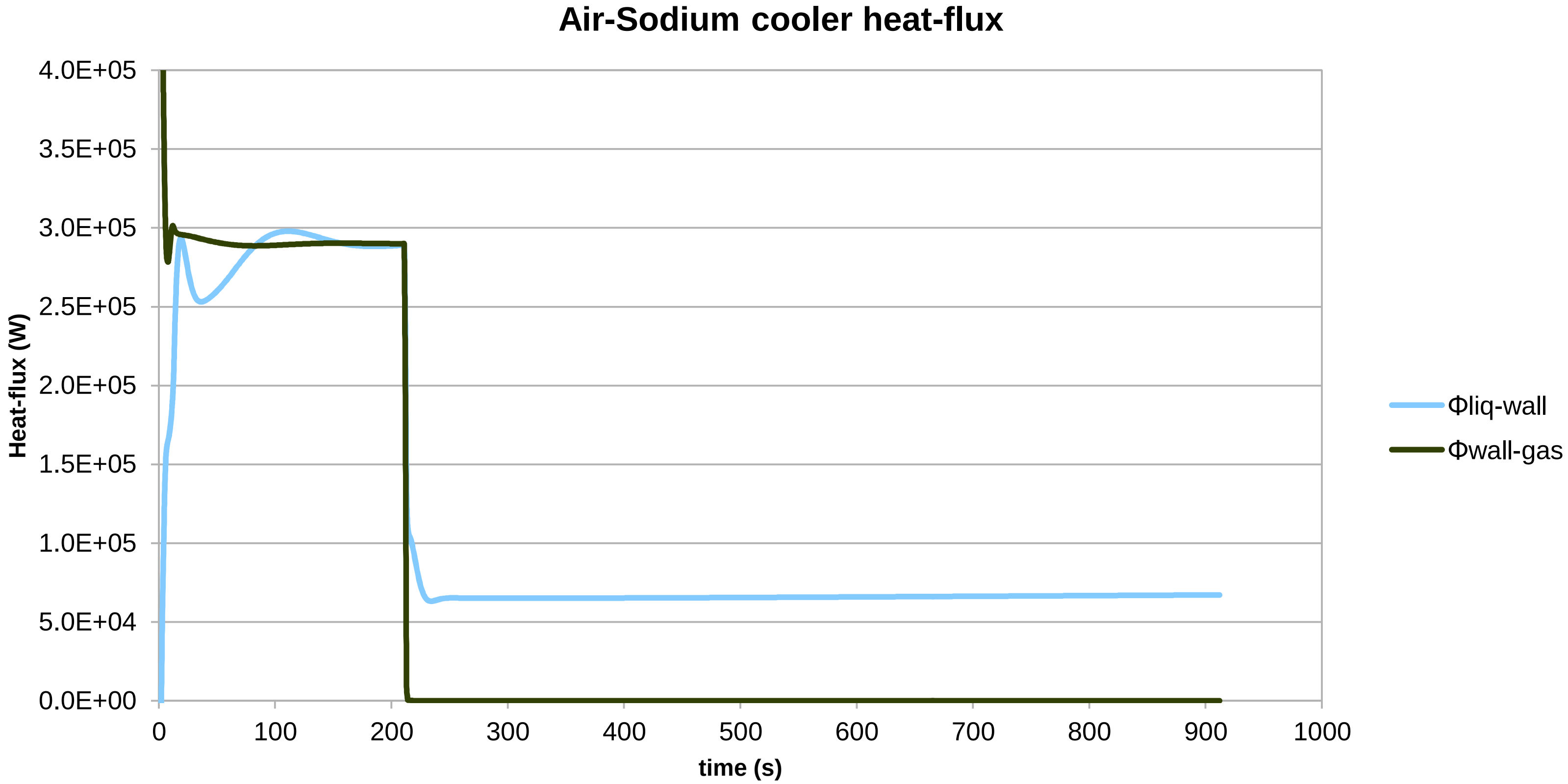
- The air temperature raises up by 85°C compared to initial conditions
- Afterward constant increase at 0.24°C.s-1





Simulation results: S3 (ULOHS)

- Heat fluxes in heat exchanger
- Flux decreases sharply to 0 on secondary side
- HX absorbs 67 kW due to its thermal inertia



Simulation results: S4 (Constant temperature)

- The heat removal capacity at initial conditions is only 290 kW
- Heater power stabilized at 292.1 kW