# ClaRa$^+$ Use Case – Failure and Start-Up of Parallel Pumps

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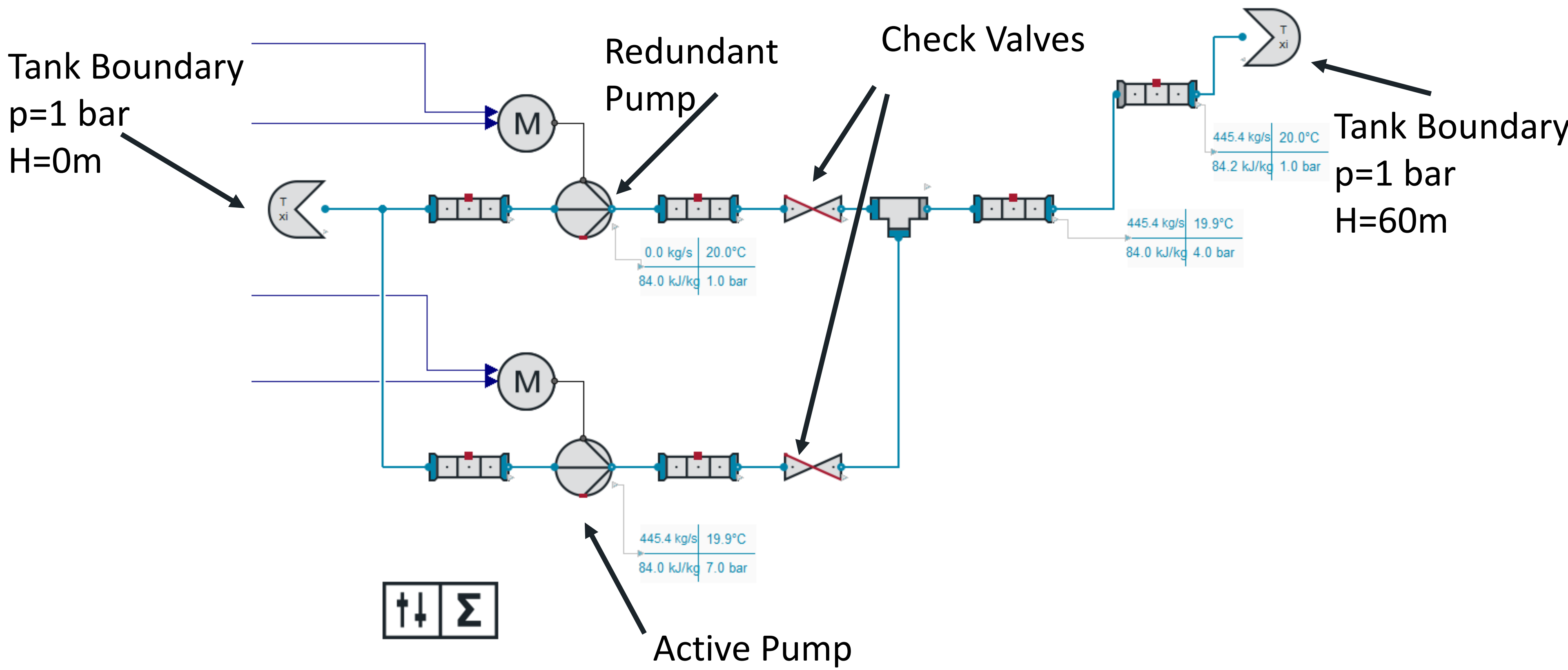
# Scenario

- Two pumps in parallel, first one in operation, second one as back up
- Failure of first pump (disconnection from power supply)
- Second pump starts up (DOL start up)

- Risks:
  - Water hammer
  - Head loss due to slow switching over of the pumps

# Scenario




» Risks:

- Water Hammer
- Evaporation during switch over due to head loss

# What physics need to be considered?

- Behaviour of check valves → New Valve Model in next release
- Pressure loss correlations ✓ $ClaRa^+$
- Pressure wave propagation ✓ $ClaRa^+$
- Start-up und backflow of pumps → New Pump Model in next release

# The 4-Quadrant Pump

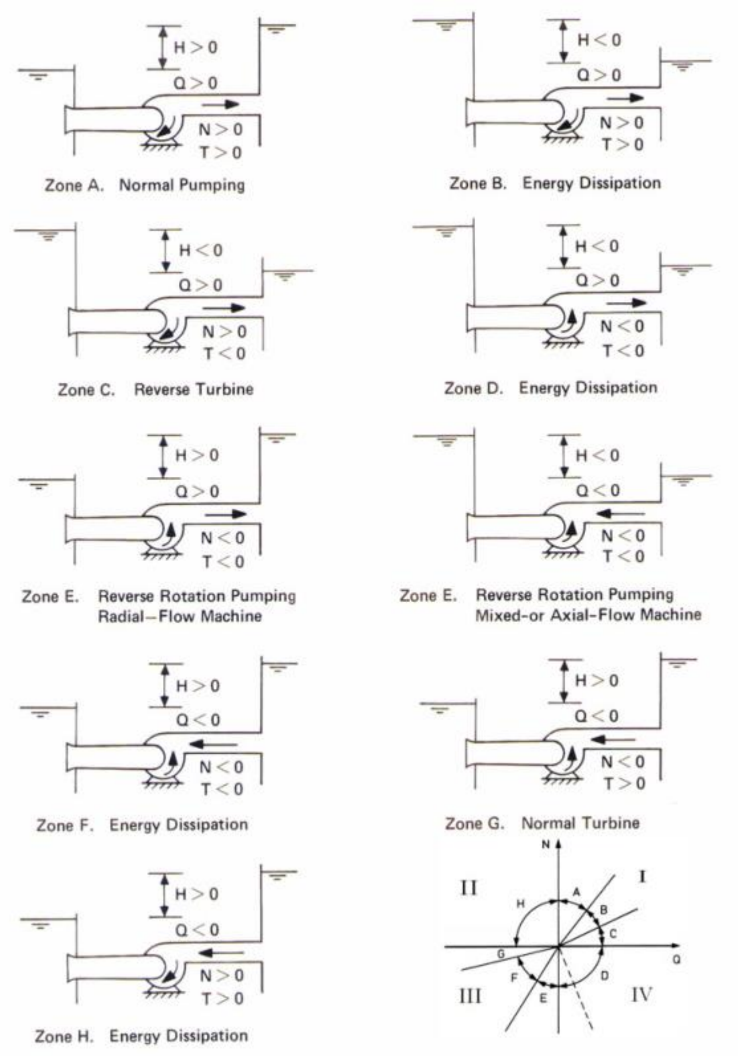



**Fig. 4-1.** **Different zones and quadrants of pump operation.** (After C. S. Martin [1983].)

- Pump behaviour depends on head (H), flow (Q), speed (N) and torque (T)
- Results in 8 zones of operation
- 4-Quadrant pump refers to speed and flow
- Torque and head curves for all 4 Quadrants needed
- Usually no manufacturer information on other zones/quadrants than normal pumping

# The 4-Quadrant Pump

» **Homologous curve approach**

→ Behaviour of pump (torque and head) in all quadrants, for all(!) speeds can be expressed in one head and one torque curve

» Normalising according to rated conditions

$$h = \frac{H}{H_r},\ v = \frac{Q}{Q_r},\ \alpha = \frac{N}{N_r},\ \beta = \frac{T}{T_r}$$

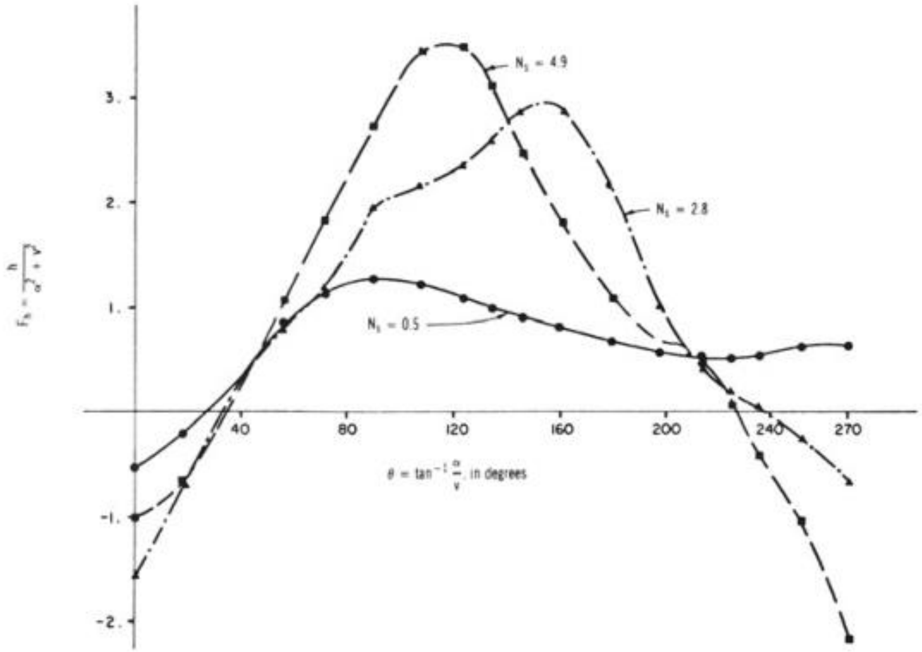
» Recalculation in coordinate system

$$y(\Theta) = \frac{h}{\alpha^2 + v^2},\ \Theta = tan^{-1}\left(\frac{\alpha}{v}\right)$$

» Usage of atan2 function allows combination of all four quadrants in one graph without poles

» $\Theta$ can be varied between 0° and 360° covering all four quadrants

# The 4-Quadrant Pump




Taken from Chaudry „Applied Hydraulic Transients“,

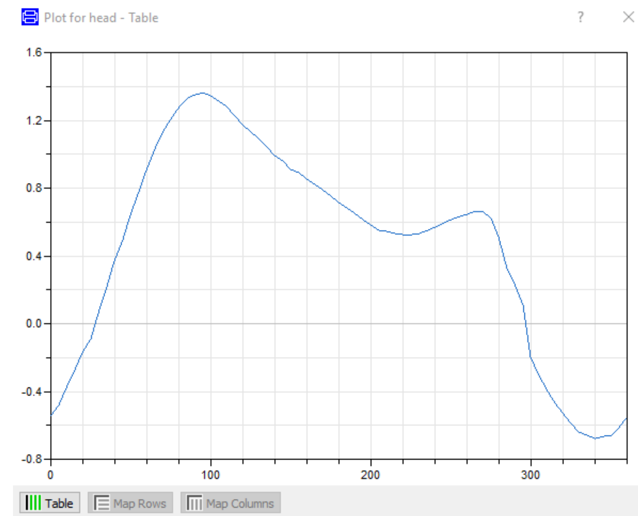
- Pumps with the same specific speed have approx. the same behaviour
- Only few curves are available from literature

# The 4-Quadrant Pump

- ClaRa⁺ supplies several homologous curves from literature for different pump types and specific speeds
- User can chose the one most appropriate for his application
- Curve stored in table

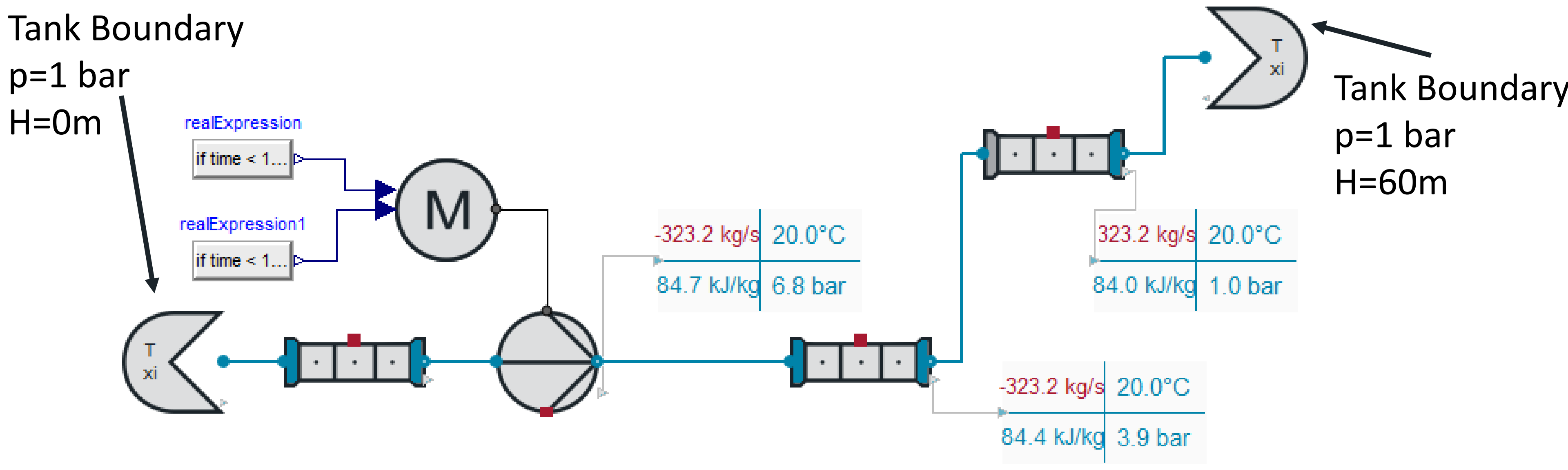
→ known area can be fitted by user

- Rated conditions are given by the user



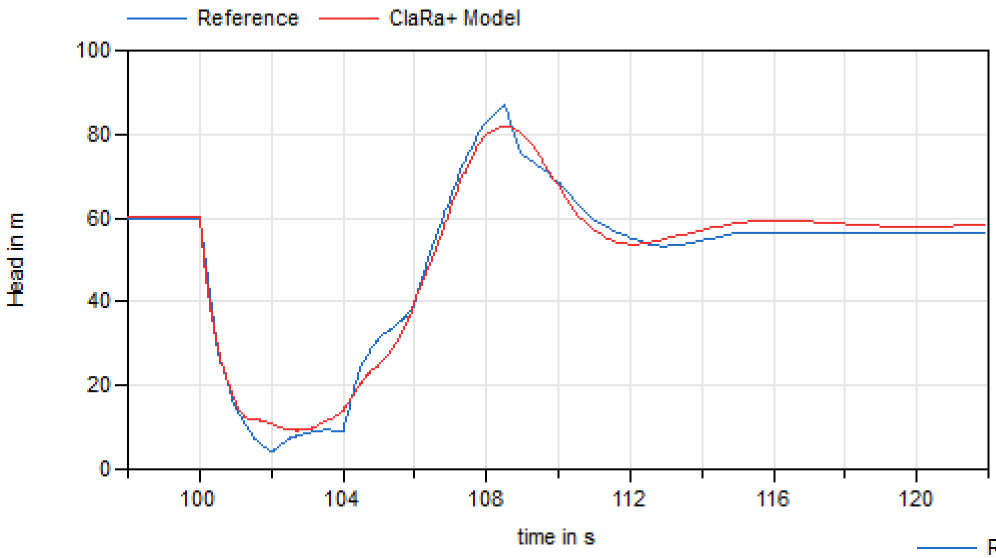

| | | | |
|---|---|---|---|
| Hydraulics | ClaRaPlus.Components.TurboMachines.Fundamentals.PumpHydraulics.HeadHc | | Hydraulic characteristic |
| Energetics | ClaRaPlus.Components.TurboMachines.Fundamentals.PumpEnergetics.Torque | | Model for losses |
| head_nom | 60 | m | Nominal head |
| V_flow_nom | 0.5 | m³/s | Nominal volume flow |
| tau_nom | 1520 | N·m | Nominal torque |

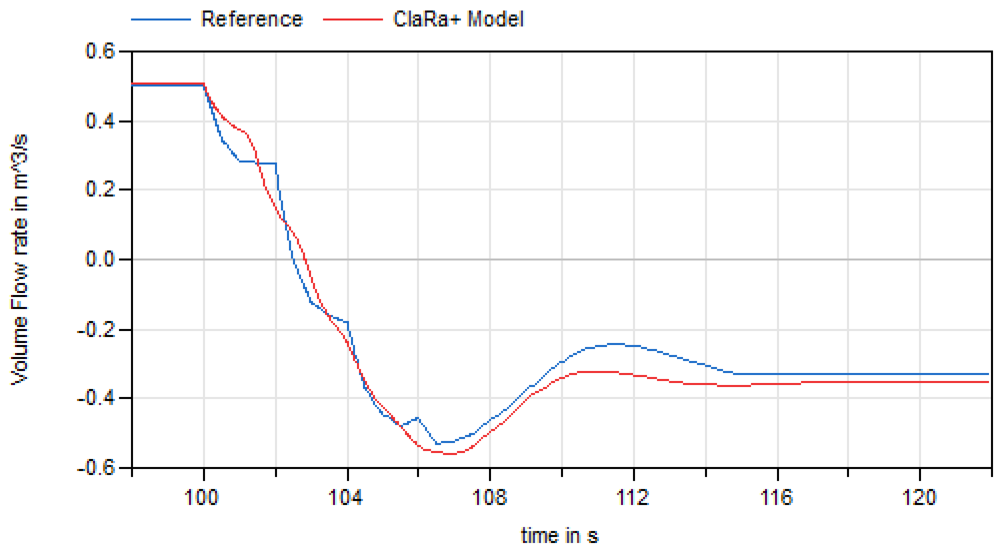
# Validation Case




- Failure of pump (disconnection from electrical grid)
- Fluid flows downhill, pump changes direction of rotation
- Taken from Chaudry „Applied Hydraulic Transients“, Example 4.4

# Validation Case Results

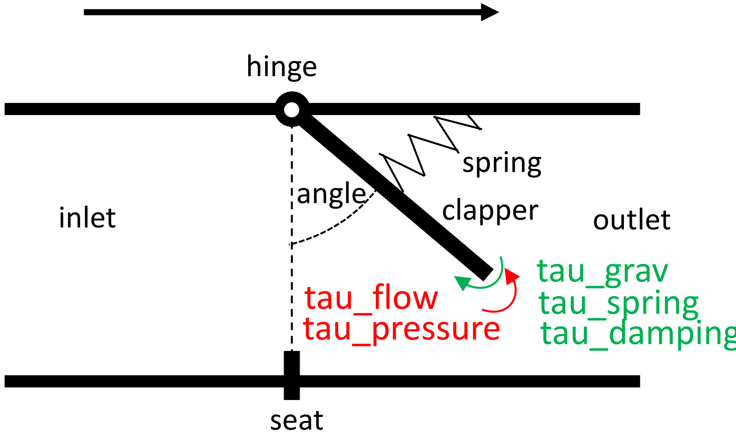


# Check Valve

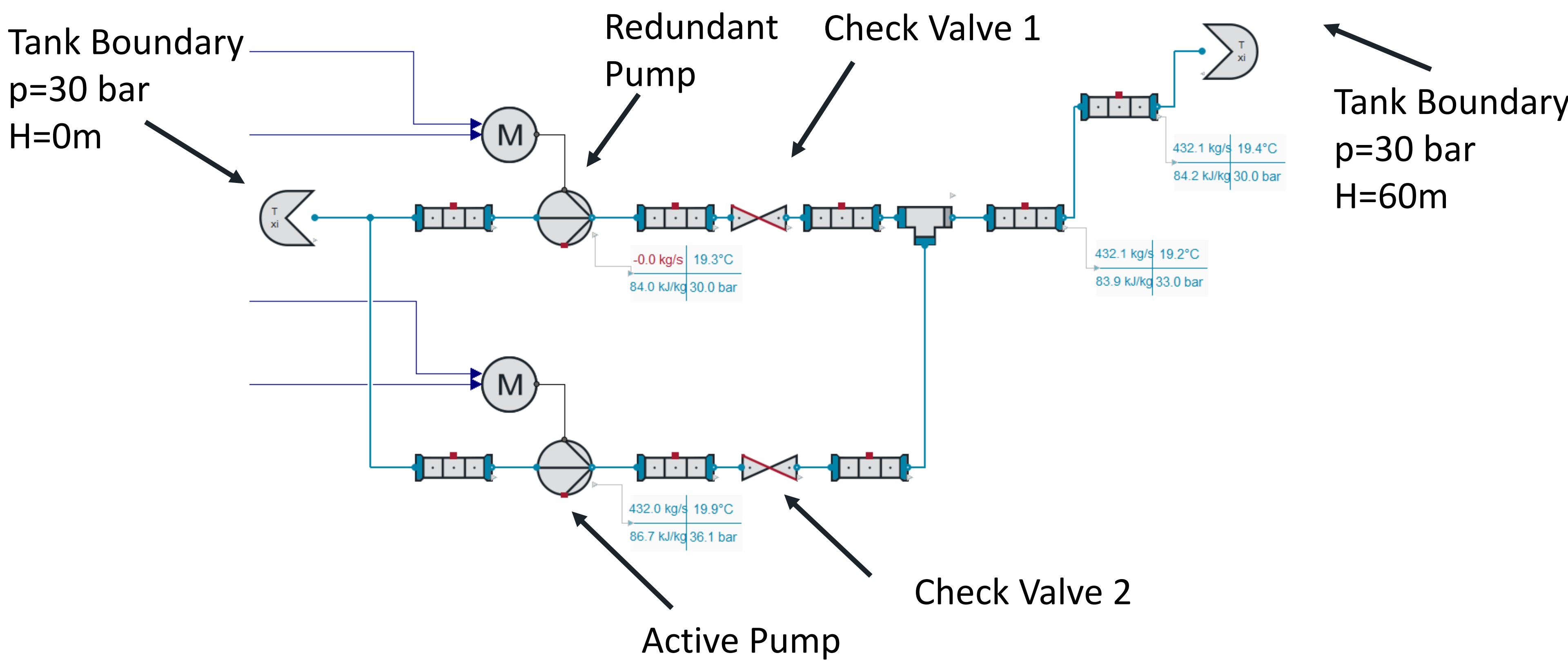
- Clapper check valve
- Are we sure that it is allowing flow in just one direction?

- Clapper opens on direct flow and closes on backflow
- Mechanics of the clapper is taken into account
- Balance equation of torque:
- tau_total = -tau_gravity - tau_spring + tau_pressure - tau_damping + tau_flow;




- Conclusion: we have a finite closing time, backflow is possible!

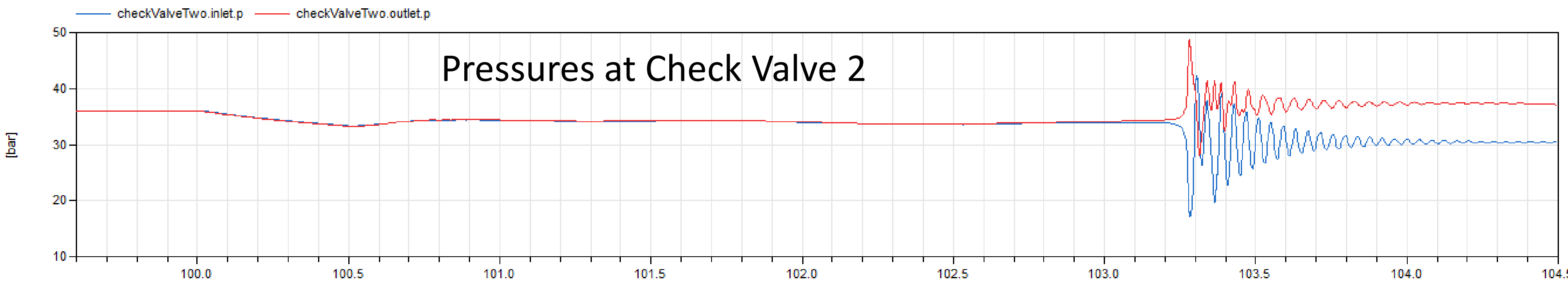
# Going back to initially presented Scenario

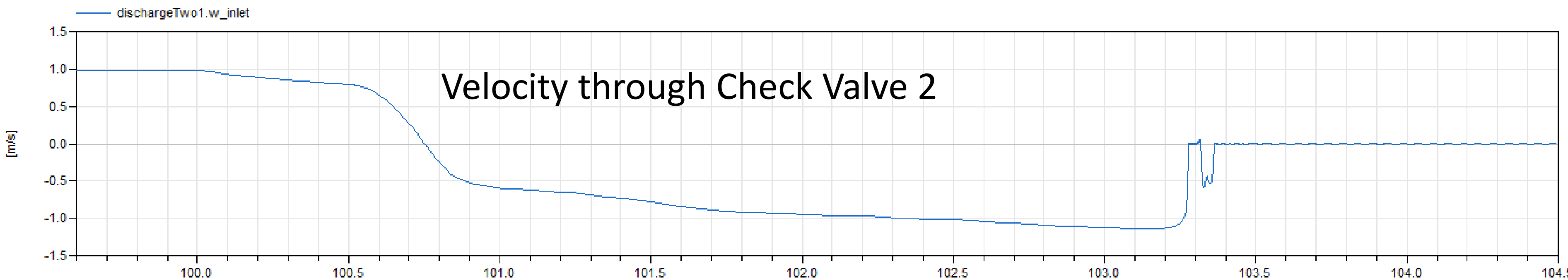


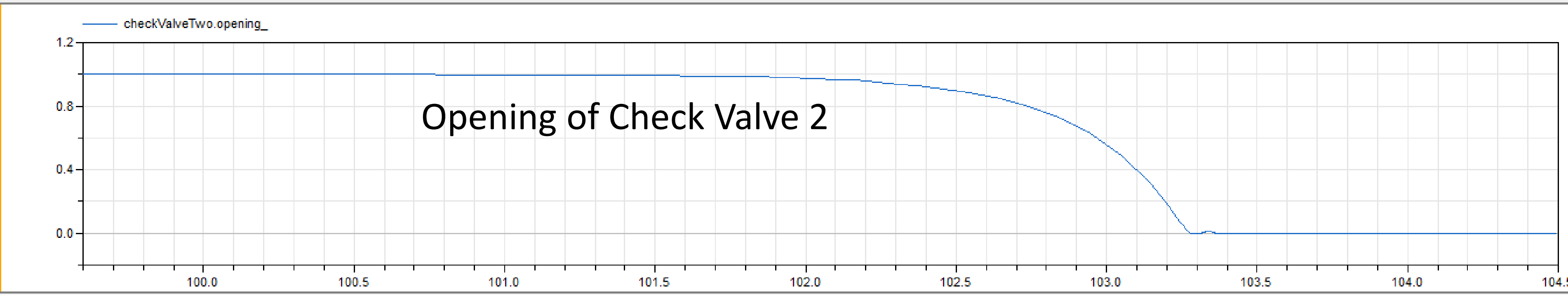

» Risks:

- Water Hammer
- Evaporation during switch over due to head loss

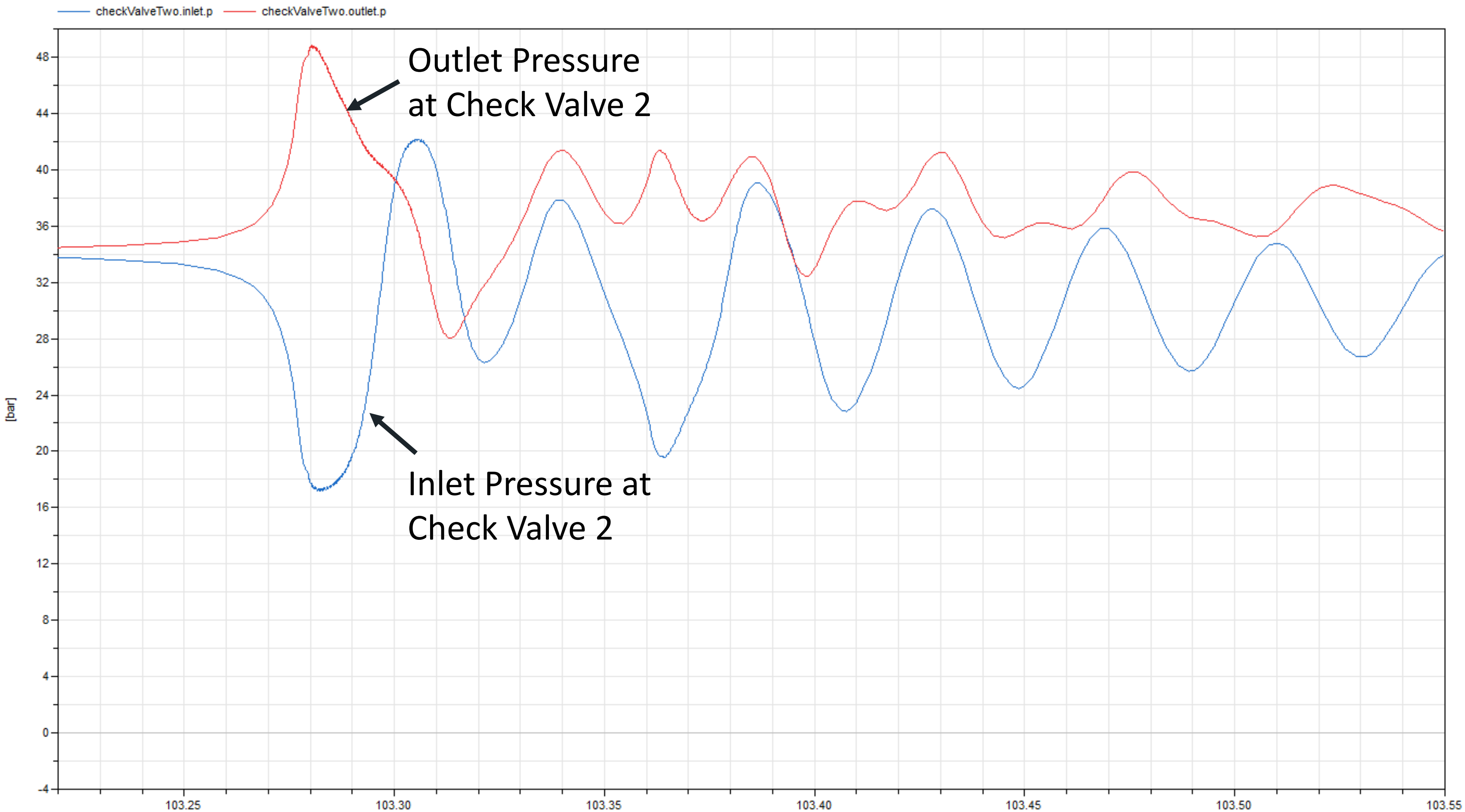
# Scenario Results



# Scenario Results



# Conclusion

- ClaRa$^+$ is able to calculate start-up and failure behaviour of pumping systems
- Pressure wave propagation is considered
- Maximum and minimum pressures can be calculated
- Behaviour of check valves can cause severe water hammers