

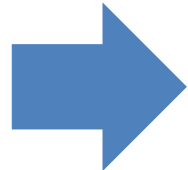
Generic wall model with integrated heat exchanger

Creativ SP2

D2.2.1

Surface temperature control

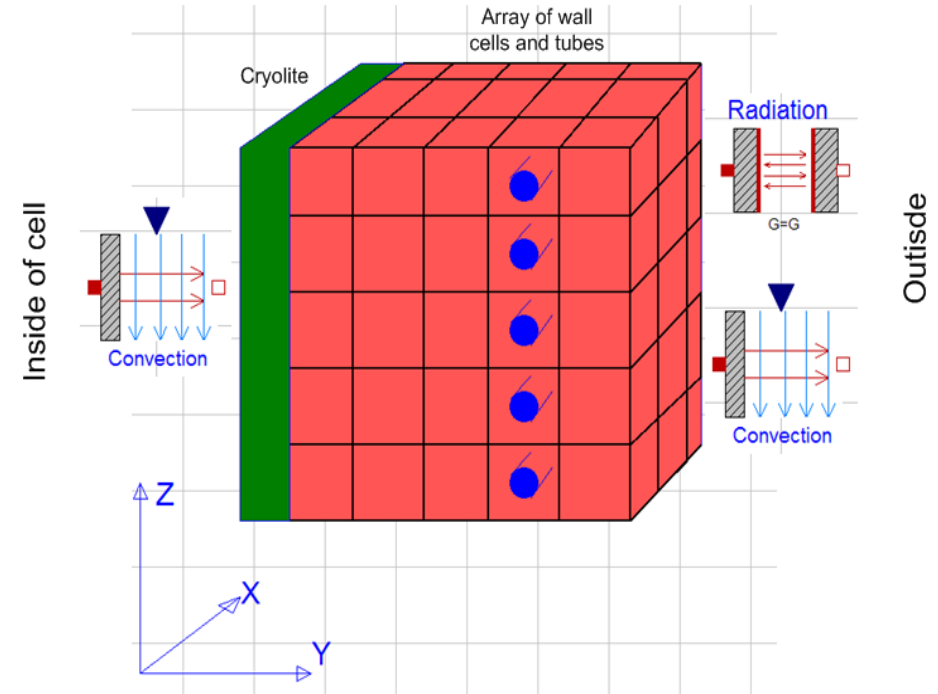
- Many systems use actively cooled tanks to control exothermic processes.
- Heat to be removed can be recovered at an temperature level suitable for energy recovery
- Such processes have often strict requirement on wall temperature



Need for detailed model

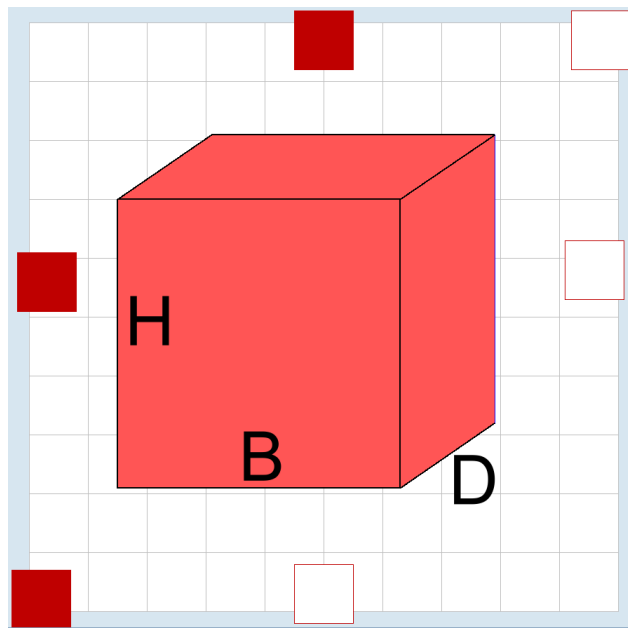
Modeling alternatives

- FEM (finite element modeling)
 - Accurate calculation of conduction
 - Calculation of convective heat transfer (working fluid side) challenging
 - Calculation power intensive, typical grid 1M nodes
- **“Physical” model** (*our choice*)
 - Convective heat transfer based on established correlation (20 years experience at SINTEF)
 - Much less calculation power intensive (typically 1000 nodes) > parametric studies are easier
 - Conduction part must be carefully tested

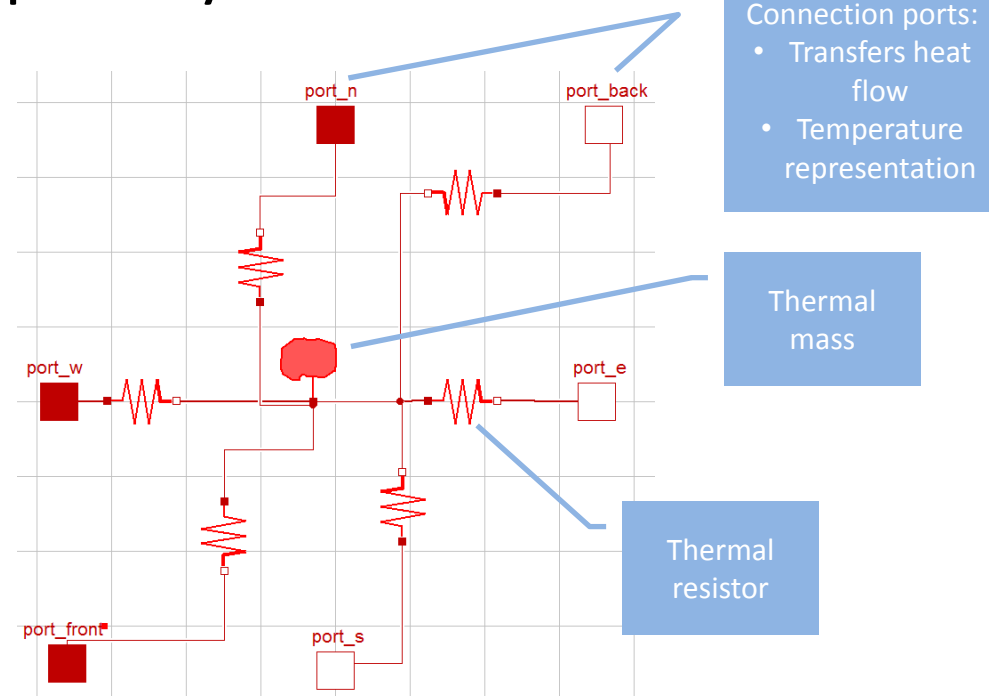


Wall model elements

- Each part of the wall consist of 3D-blocks
- Behaviour for heat conduction and heat capacity
- Transient behaviour capability



Wall node - external connections



Wall node - internal models

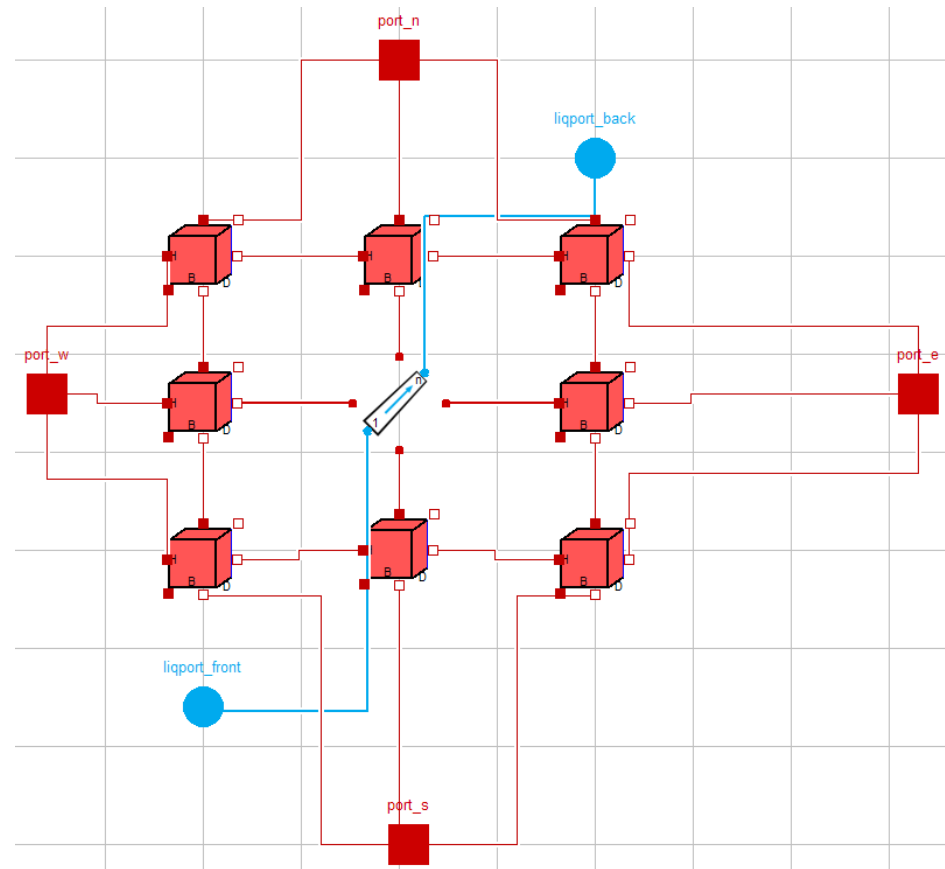
Connection ports:
• Transfers heat flow
• Temperature representation

Thermal mass

Thermal resistor

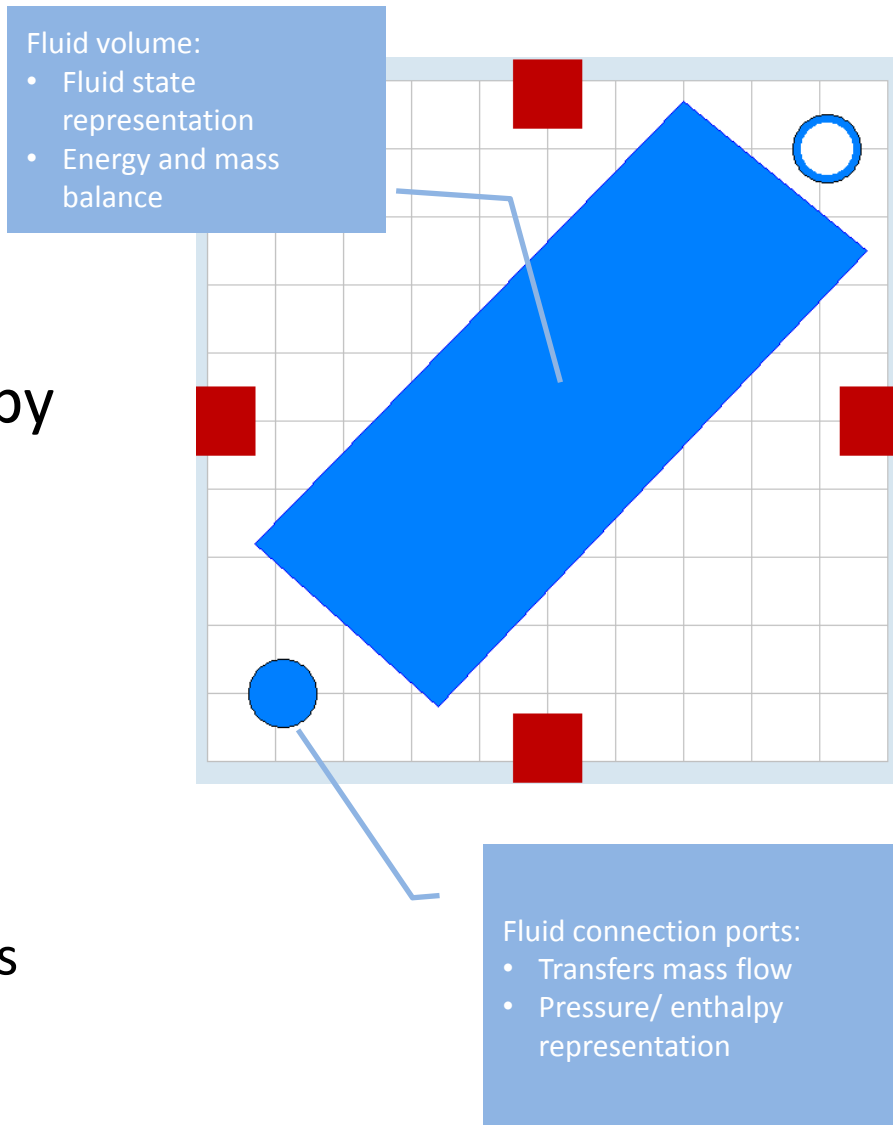
Integrated heat exchanger

- Heat exchanger modeled as embedded pipes connected to array of wall blocks
- Current version use Modelica's built-in thermodynamical property data for a range of fluids



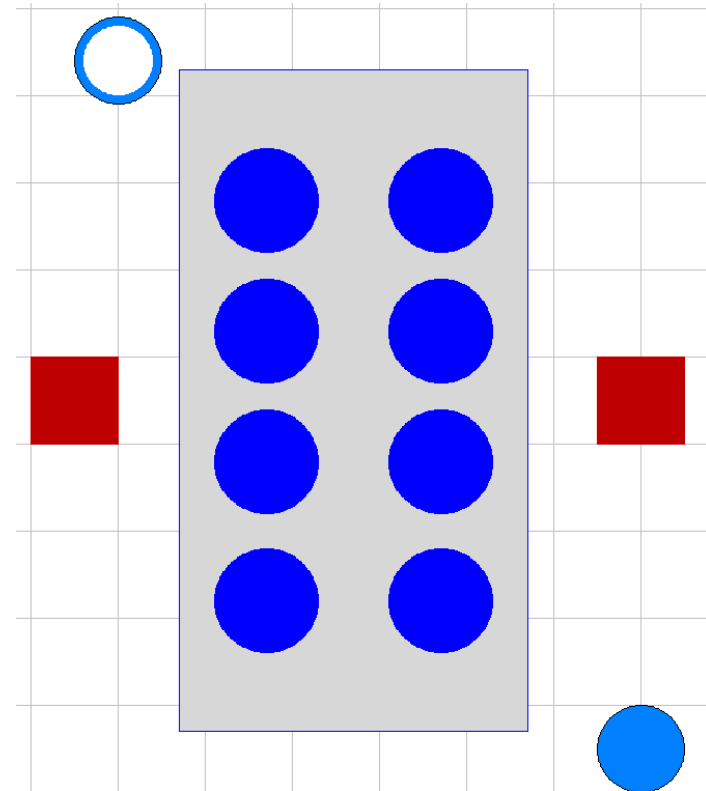
Embedded pipe model

- Heat conduction in 2 dimensions, fluid flow in the third
- Fluid flow characterized by
 - Friction on pipe wall
 - Heat transfer across pipe wall – 4 directions (based on correlations)
 - Enthalpy change of fluid volume
 - Transient energy and mass balance of fluid volume



HX-model

- Wall segment with integrated fluid pipes
=> Heat exchanger
- Assembled of *wall nodes* and *embedded pipes*
- Configuration options include:
 - Number of tube rows
 - Number of tubes per row
 - Number of flow passes per row
 - Tube/pass connection config:
 - Simple: Crossflow/Counterflow/co-current flow
 - Advanced: Any configuration or combination

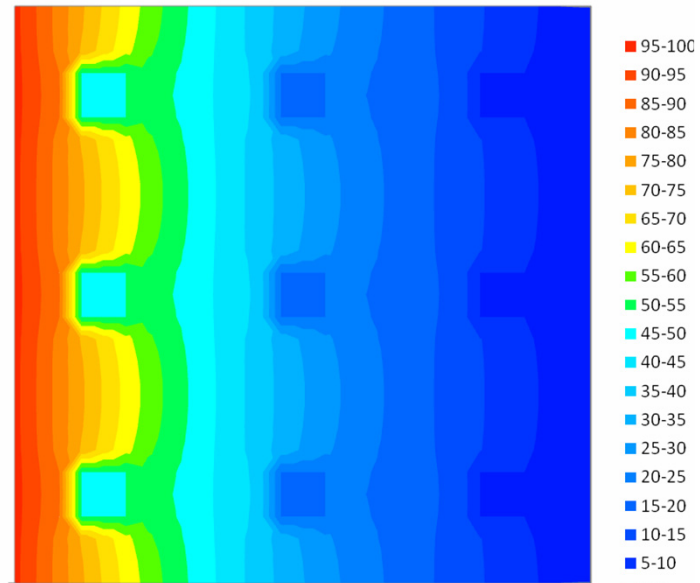


Verification vs. Quickfield

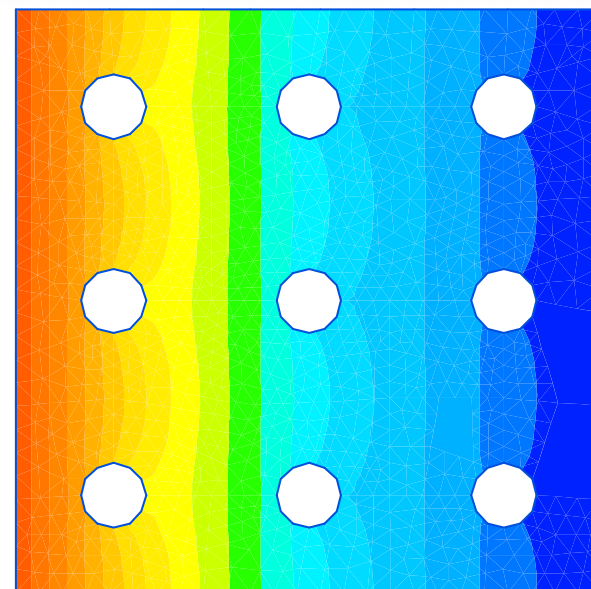
- Quickfield is a commercial finite element software
- Good agreement in heat flow
- Modelica model seem to return a more realistic temperature profile around pipes

Note: Slightly different color scale in the pictures

	n Nodes	Qwest	Qeast	Qpipes
Quickfield [W]	1206	1825	-431	1394
Modelica [W]	1296	1772	-391	1381
Abs. Deviation [W]		53	-40	13
Rel. deviation		2.9%	9.2%	0.9%



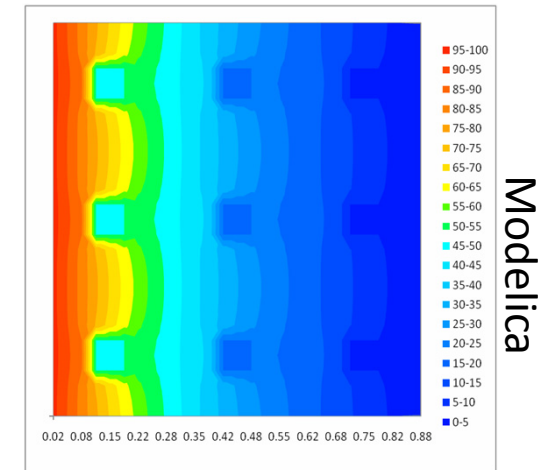
0.02 0.08 0.15 0.22 0.28 0.35 0.42 0.48 0.55 0.62 0.68 0.75 0.82 0.88



Verification vs. Quickfield

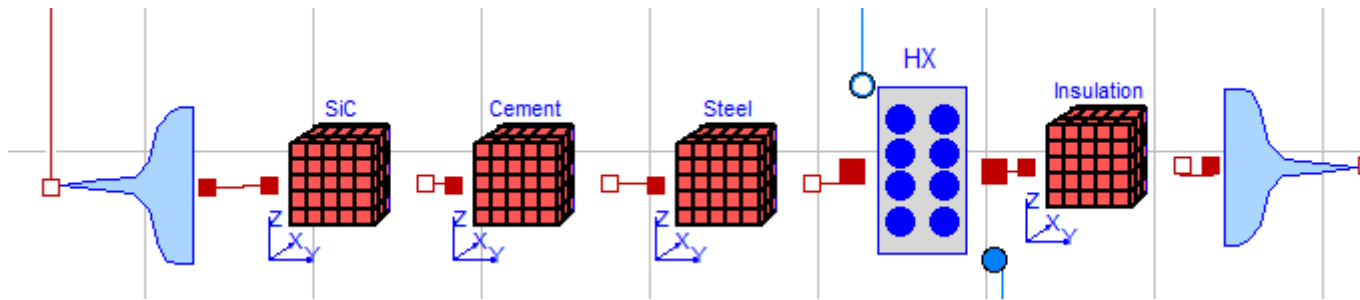
- Analysis of accuracy vs. node count
- 2D analysis

	n Nodes	Qwest	Qeast	Qpipes	Dev. Qwest	Dev. Qpipes
Quickfield [W]	8715	1822	-426	1396	-	-
Modelica [W]	81	1695	-382	1313	7 %	6 %
	324	1750	-386	1364	4 %	2 %
	729	1765	-389	1376	3 %	1 %
	1296	1772	-391	1381	3 %	1 %
	2916	1778	-393	1385	2 %	1 %
	6561	1782	-394	1388	2 %	1 %



Good match from relatively low node count

Assembled wall+HX model



- Several wall sections with different material properties
- Integrated heat exchanger with selected fluid and tube configuration
- Investigation of control capability of a wall embedded heat exchanger
- Investigation of the potential for heat recovery

Models developed during this work:

(including pre-requisites for main models)

	Short description of model
Wallmodel2011_export	
base_elements	
ThermalResistor	Thermal conductance element
HeatCapacitor	Thermal mass element
wall_boundary	Definition of boundary temperatures
BodyRadiation_alucell	Heat radiation model
cryolite_with_convection	Heat flow dependent resistor with phase change and thermal mass
fluidport_manifold	Header/manifold for fluid ports, needed for pipe model and assembling heat exchangers from individual pipes
ShortPipe_heatports_htccorr	Embedded pipe model with 2D heat flow
Fluid_pump	Fluid pump with controllable mass flow
smoothTrans	Asymptotic smoothing function, important for stability in heat transfer coefficient correlations
WallTempinit	Initialization of wall section temperatures
wall_dim_composite	Dimensions and node allocation of wall sections
cubic_comp	
wall_cube	Single wall cell, represents 1 solid wall node with conduction and thermal mass
wall_solid_composite	Wall section assembled of wall cells for uniform material
d3_heatnode_manifold	Header/manifold for heat ports, connecting single heat node to several others
wall_brute_htccorr_winit	Wall section with single row of integrated pipes, basis for heat exchanger configurations
hxConf	
conf_2r_1ppr_ew	Pre-assembled wall-heat exchanger section of a defined configuration