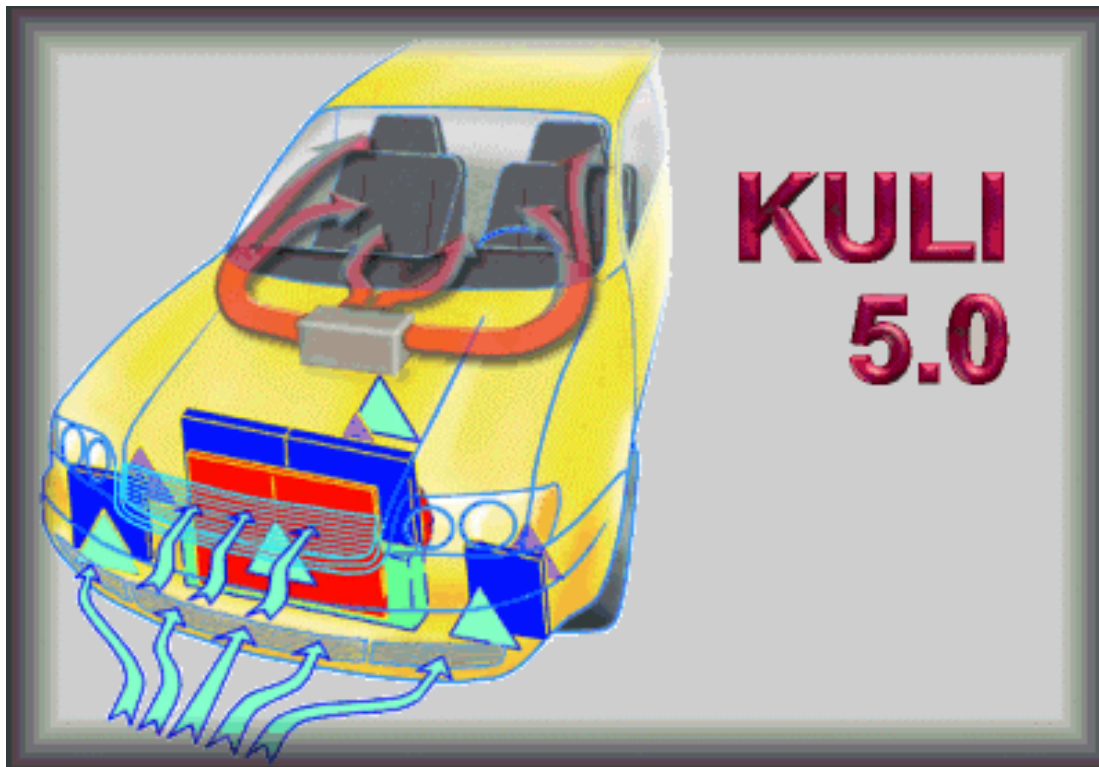


KULI Fluid



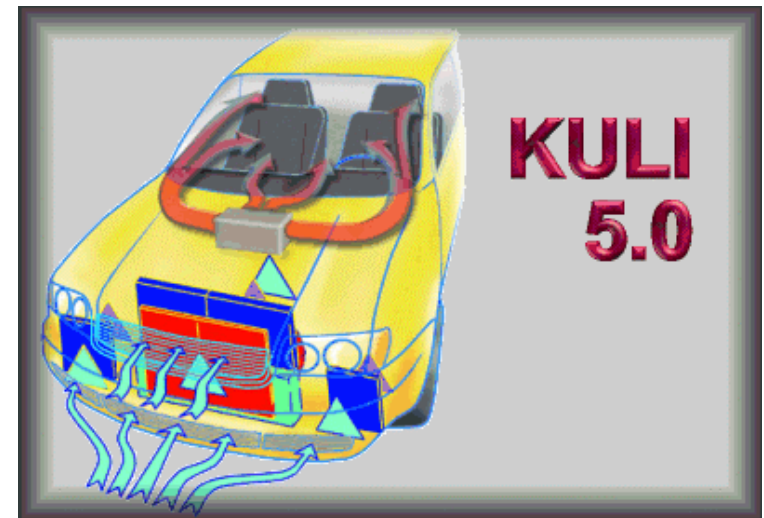
Analysis of Branched Fluid Networks

- ◆ Thermostatic Valve Control
- ◆ Pumps
- ◆ Tubes, Bends, Manifolds
- ◆ KULI Heat Exchangers

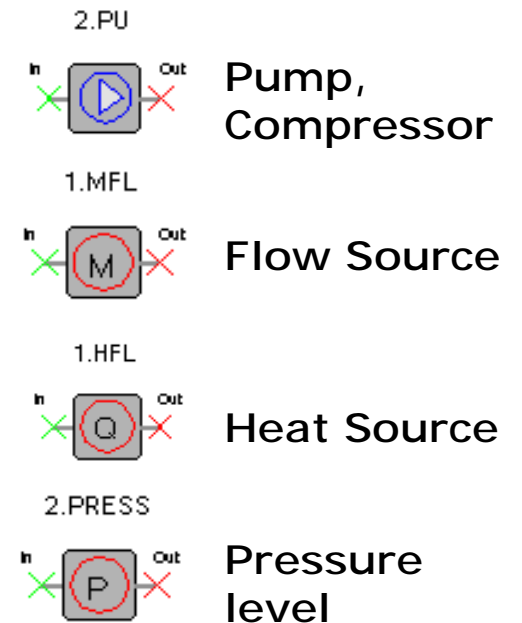
Thomas Anzenberger, ECS Steyr

Overview

- Demands for a KULI Fluid Circuit
- KULI Fluid Components
- Technical Specification
- Graphical User Interface
- Practical Application
- Further Development



Heat and Flow Sources, Pumps



Demands

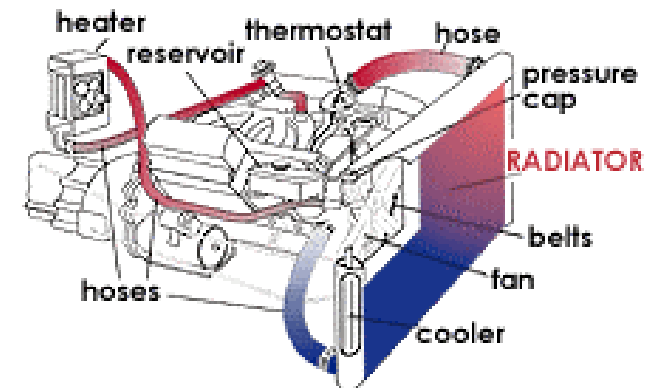
No restrictions for
Component Connections
and Heat Exchangers

Open Circuit
(Definition of inlet
properties)



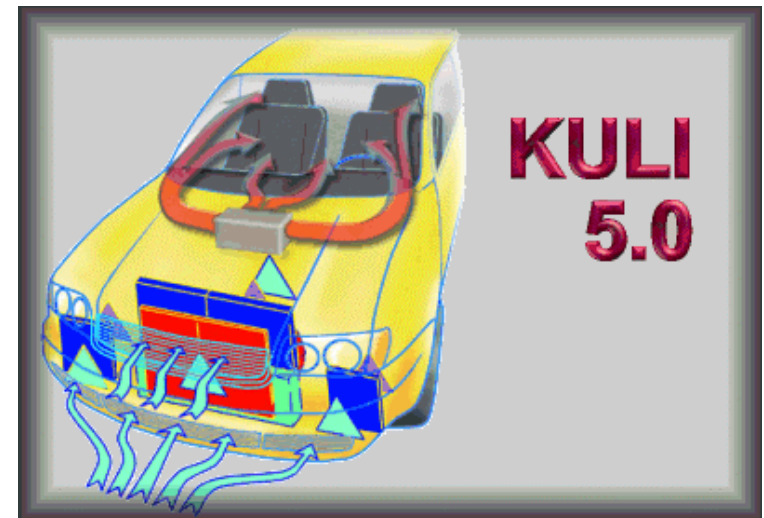
Closed Circuit
(Circuit
equalization)

Single Phase Fluid,
Incompressible,
Heat Transfer,
1D flow

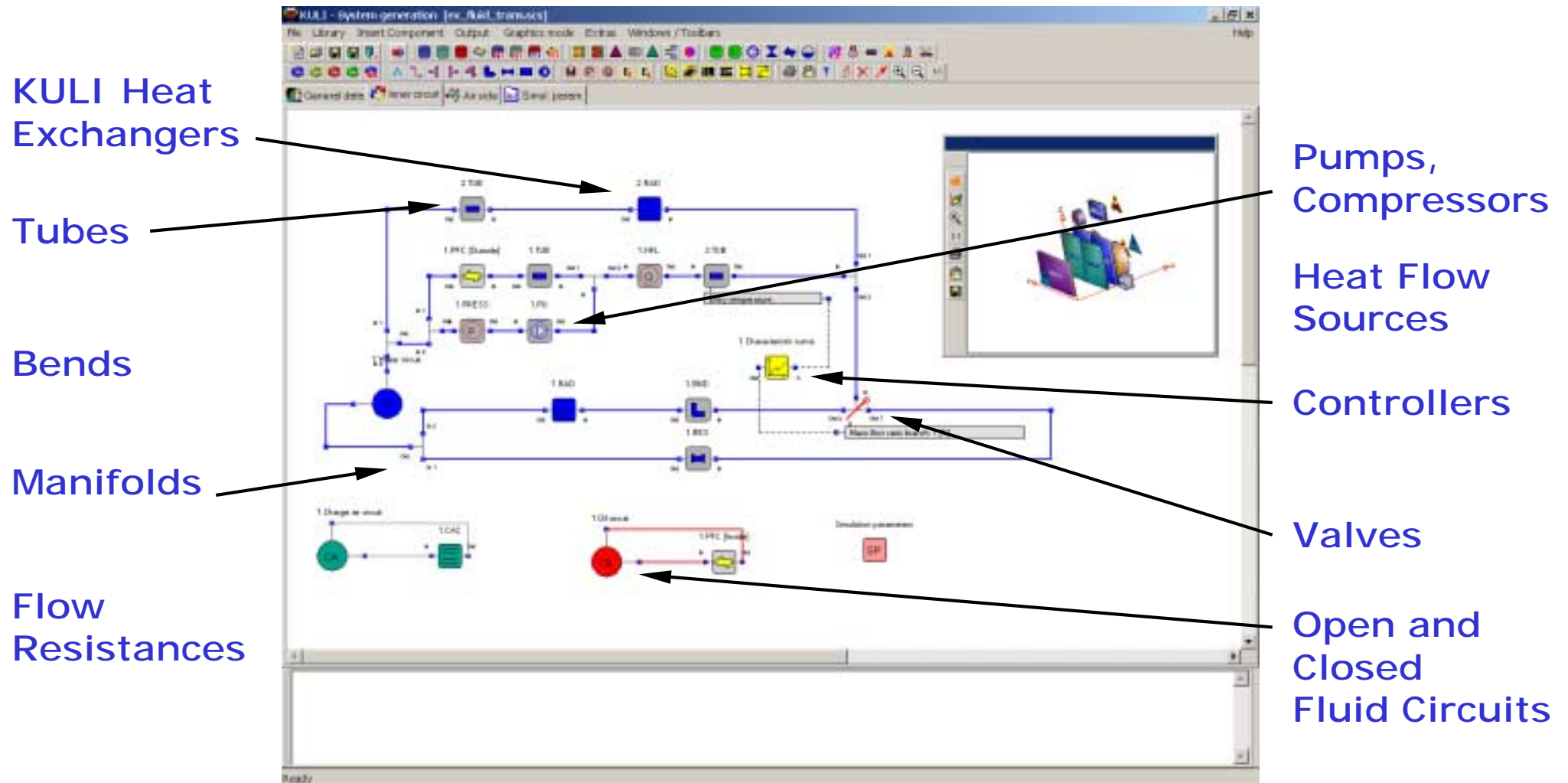


Overview

- Demands for a KULI Fluid Circuit
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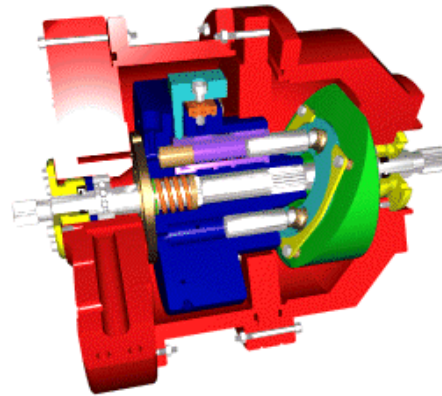


KULI Fluid

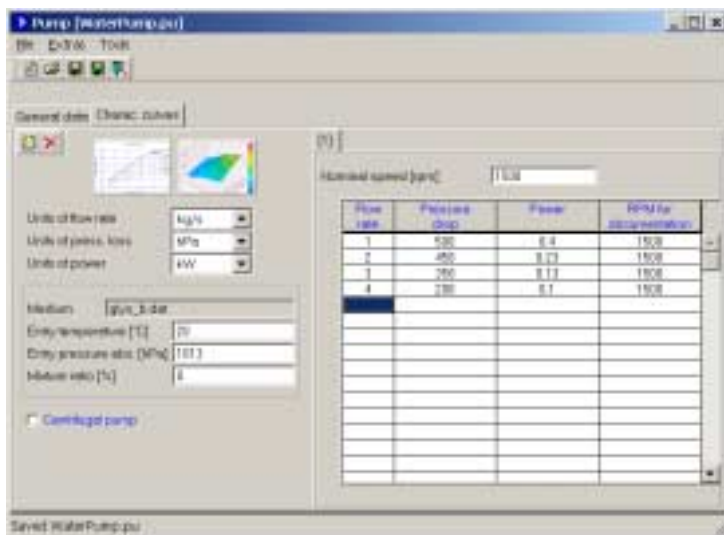


KULI Fluid

Pumps, Compressors



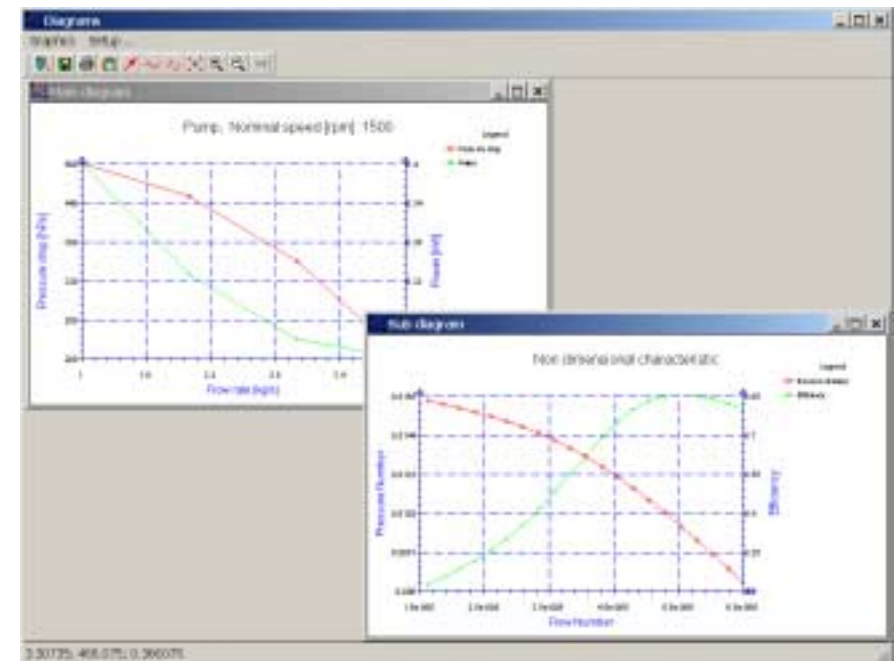
Input Data (measured performance curve)



Transformation



Non Dimensional
Characteristic



KULI Fluid

Tubes, Bends, Manifolds



Tube [Tube_1.2m_D10mm.tub]

File Extras

User: ECS-Steyr
Date (if current): Montag, 31. Mai 1999 09:51:48
Title: Example

Type: Tube
Manufacturer: ECS-Steyr
Series: Example
No.: Example
Measured data file: Example

☒ Tubular
☐ Non tubular

Inner-diameter [mm]: 10

Wetted area [mm²]:
Wetted perimeter [mm]:

☒ Heat transfer

Thickness [mm]: 1.5
Thermal conductivity [W/m K]: 270
Ambient temperature [°C]: 50
☒ Air velocity in perc. of driving speed [%]: 15
☐ Air velocity [km/h]:

Tube-length [mm]: 2000
Pipe roughness [mm]: 0.06

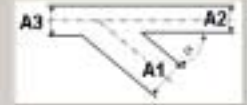
Ready

Bend [Bend_90deg_D10mm.bnd]

File Extras

User: ECS
Date (if current): Freitag, 12. Oktober 2001 13:32:48
Title:

Gross section A1 [mm²]: 180
Gross section A2 [mm²]: 180
Gross section A3 [mm²]: 1.5
Angles [°]: 45



Modified

Input Data (based only on
geometric information)

Bend [Bend_90deg_D10mm.bnd]

File Extras

User: ECS-Steyr
Date (if current): Dienstag, 18. Jun 1999 09:10:18
Title: Example FULUAC

Type: Manifold
Manufacturer: ECS-Steyr
Series: Example
No.: Example
Measured data file: Example

☒ Tubular
☐ Non tubular

Inner-diameter [mm]: 10

Wetted area [mm²]:
Wetted perimeter [mm]:

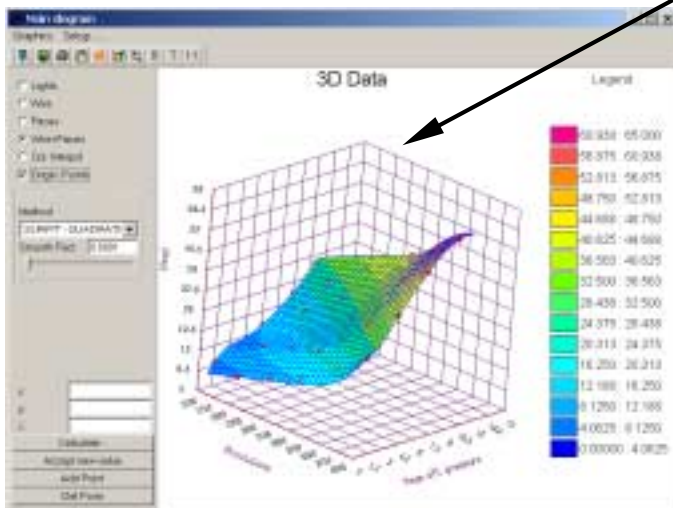
Convolute radius [mm]: 60
Angle of deflection [degree]: 90

Ready

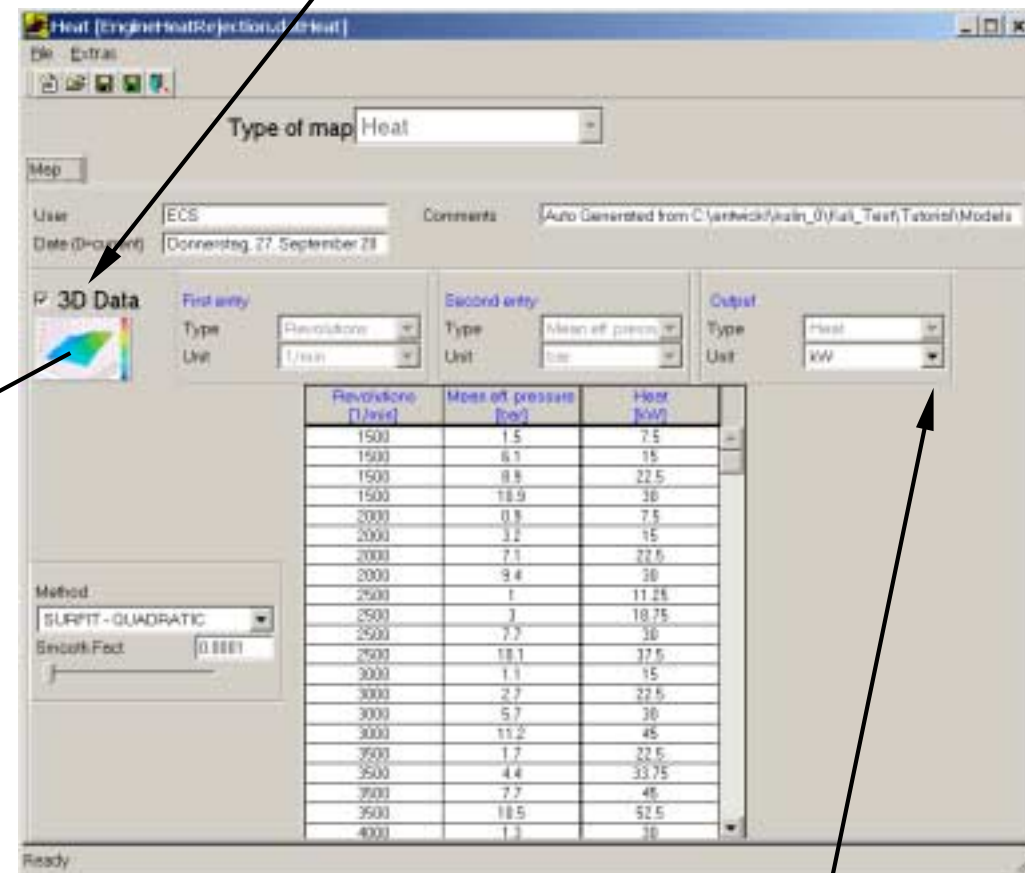
KULI Fluid

Heat, Pressure
and Flow Sources

Visualization of
Input Data



2D or 3D Input Data



Heat [engineheatRejectionHeat]

Type of map: Heat

User: ECS Comments: Auto Generated from C:\erheck\kulin_0\kuli_Test\Tutorial\Modell

Date (Project): Donnerstag, 27. September 28

3D Data visualization icon

First entry: Type: Revolutions Unit: 1/min

Second entry: Type: Mean of pressure Unit: bar

Output: Type: Heat Unit: kW

Revolutions [1/min]	Mean of pressure [bar]	Heat [kW]
1500	1.5	7.5
1500	6.1	15
1500	8.8	22.5
1500	18.9	30
2000	0.8	7.5
2000	3.2	15
2000	7.1	22.5
2000	9.4	30
2500	1	11.25
2500	3	18.75
2500	7.7	30
2500	18.1	37.5
3000	1.1	15
3000	2.7	22.5
3000	5.7	30
3000	11.2	45
3500	1.7	22.5
3500	4.4	33.75
3500	7.7	45
3500	18.5	52.5
4000	1.3	30

Method: SURFIT - QUADRATIC

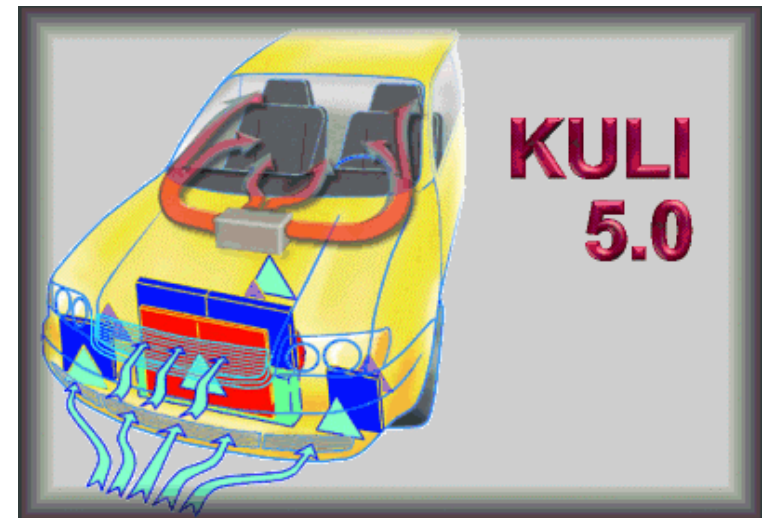
Smooth Fac: 0.0001

Ready

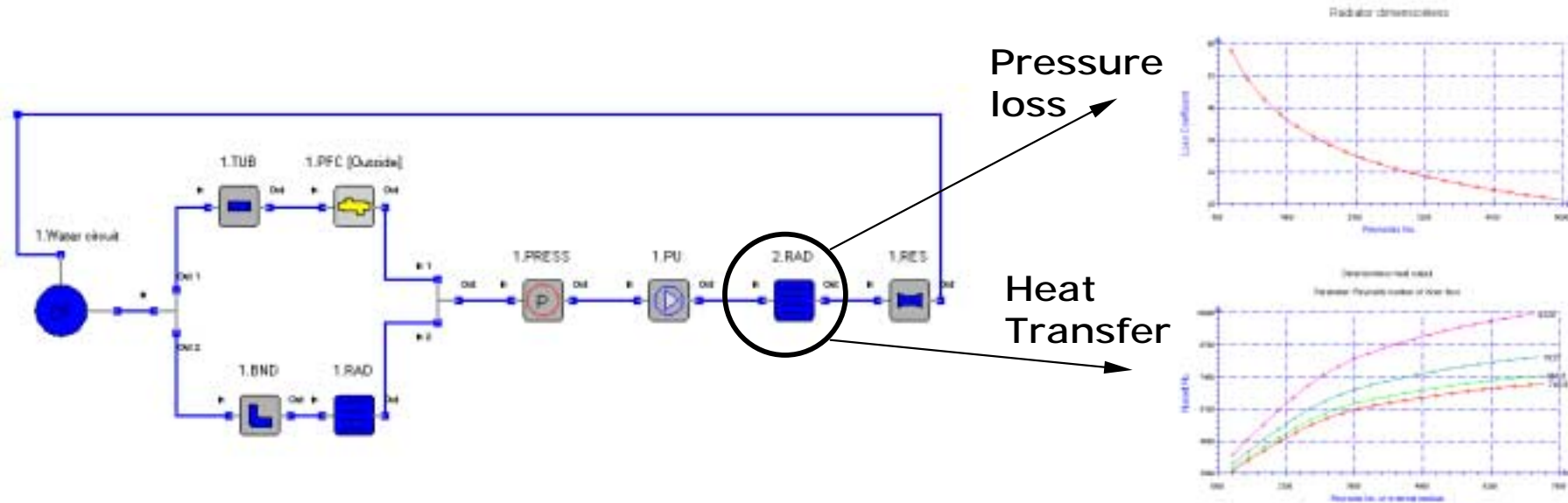
Input and Output unit definition

Overview

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Specification



Stream Line Flow Theory

$$\frac{p_1}{\rho} + \frac{1}{2}u_1^2 + \left(\frac{\Delta p}{\rho}\right)_{1 \rightarrow 2} = \frac{p_2}{\rho} + \frac{1}{2}u_2^2 + \Delta q_{1 \rightarrow 2}$$

Specific Energy
Terms

Pressure Loss
Equation



Heat Transfer
Equation

$$\vec{m} = \begin{Bmatrix} \dot{m}_1 \\ \dot{m}_2 \\ \vdots \\ \dot{m}_j \end{Bmatrix} \quad \vec{p} = \begin{Bmatrix} p_1^{in} \\ p_1^{in} \\ \vdots \\ p_j^{in} \end{Bmatrix}$$

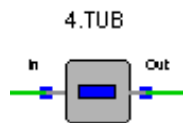
Mass Flow,
Pressure
Distribution

$$\vec{h} = \begin{Bmatrix} h_1^{in} \\ h_1^{in} \\ \vdots \\ h_j^{in} \end{Bmatrix}$$

Enthalpy
(Temperature)
Distribution

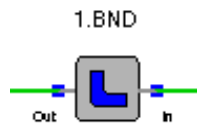
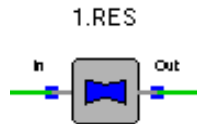
Specification

Tubes, Resistances, Bends, Manifolds

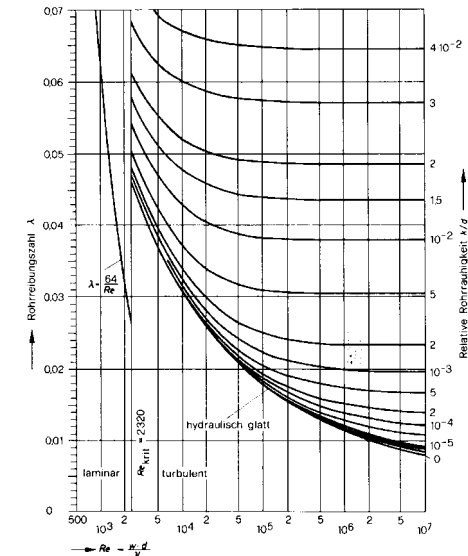


Pressure Loss
Calculation

$$\Delta p_{1 \rightarrow 2} = \xi \frac{\rho v^2}{2}$$



Heat Transfer
Calculation



Colebrook Diagram

Leading Air
Stream

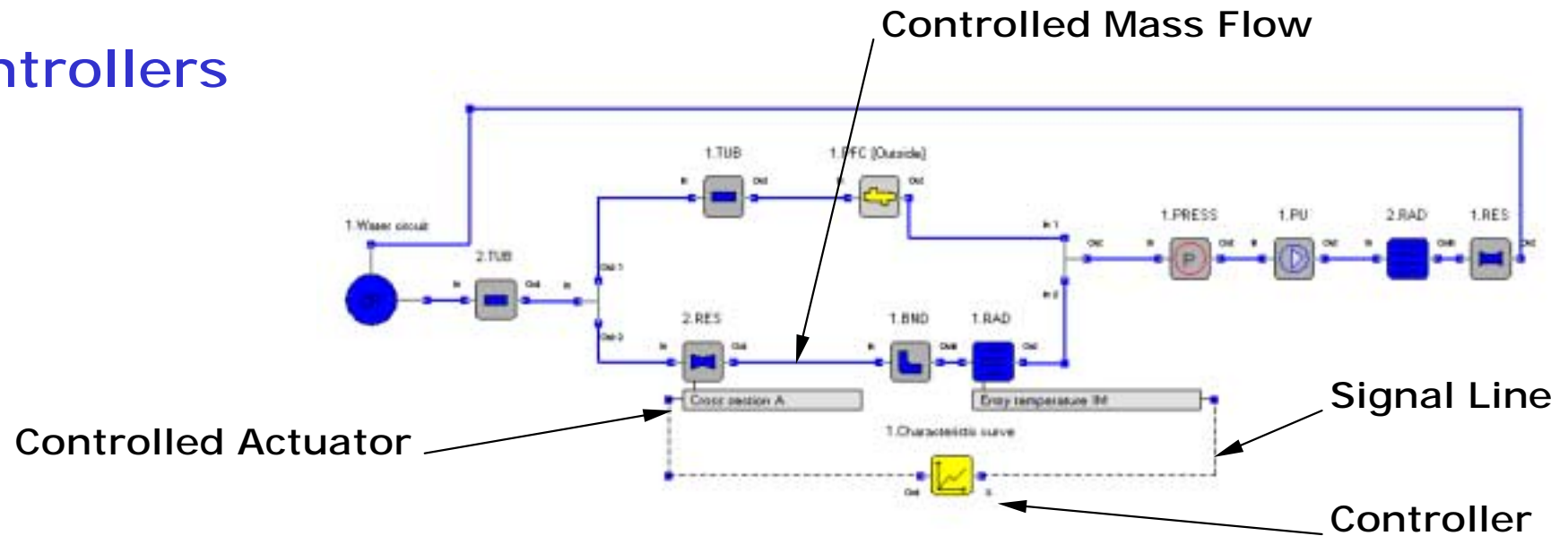
Theorie:
Cross
leading air
flow

$$\alpha_a = \frac{Nu \lambda_{Air}}{L}$$

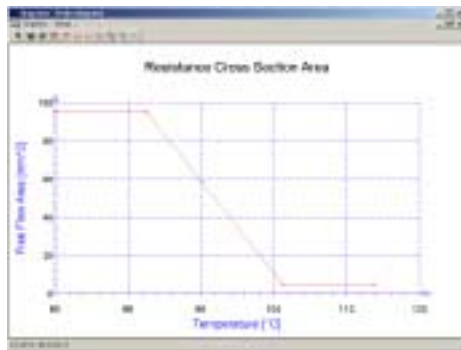
Heat flow

Specification

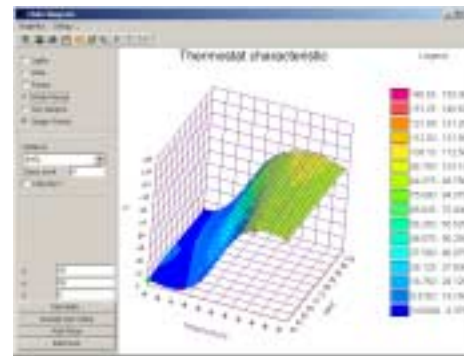
Controllers



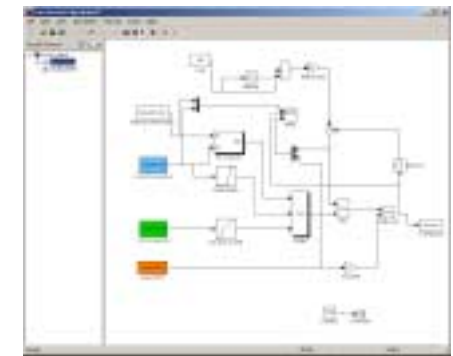
Controller Characteristic



2D Characteristic Line



3D Map

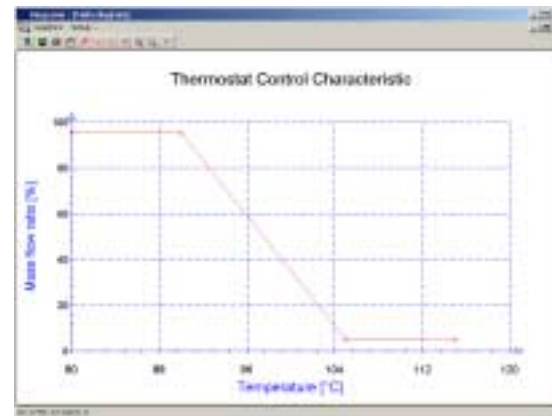


MATLAB/SIMULINK

Valves, Controlled Valves

Controller Characteristic

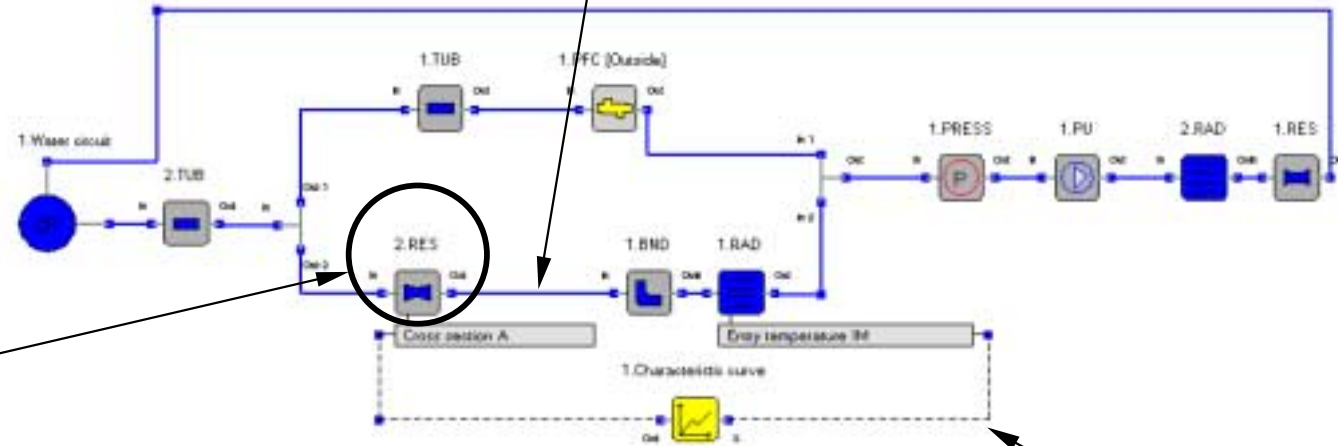
Signal Line



Specification

Controlled Resistances

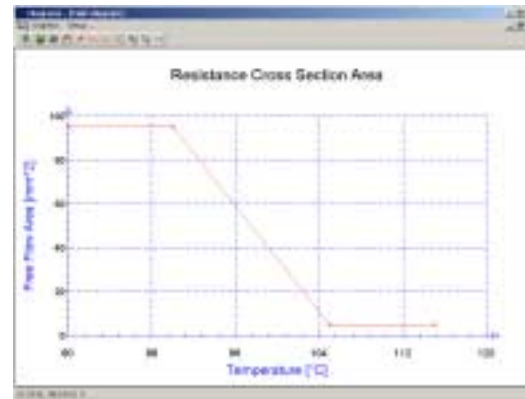
Controlled Mass Flow



Controlled Cross Sectional Area

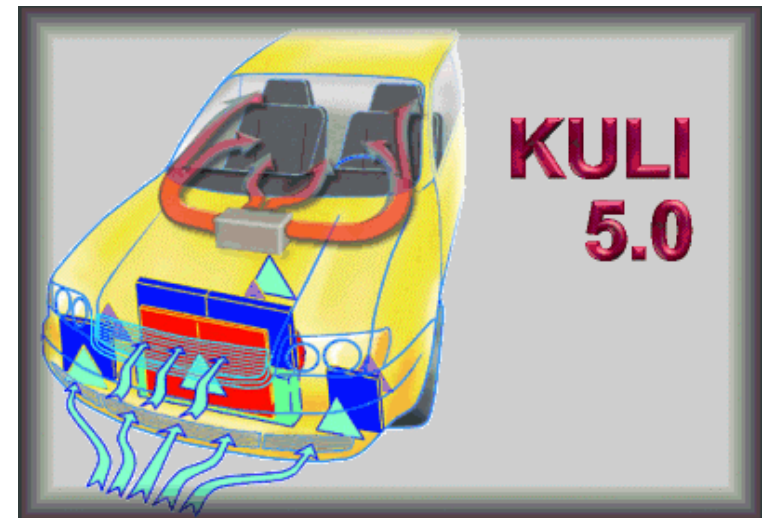
Controller Characteristic

Signal Line



Overview

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GUI

Component Toolbars
(dockable)

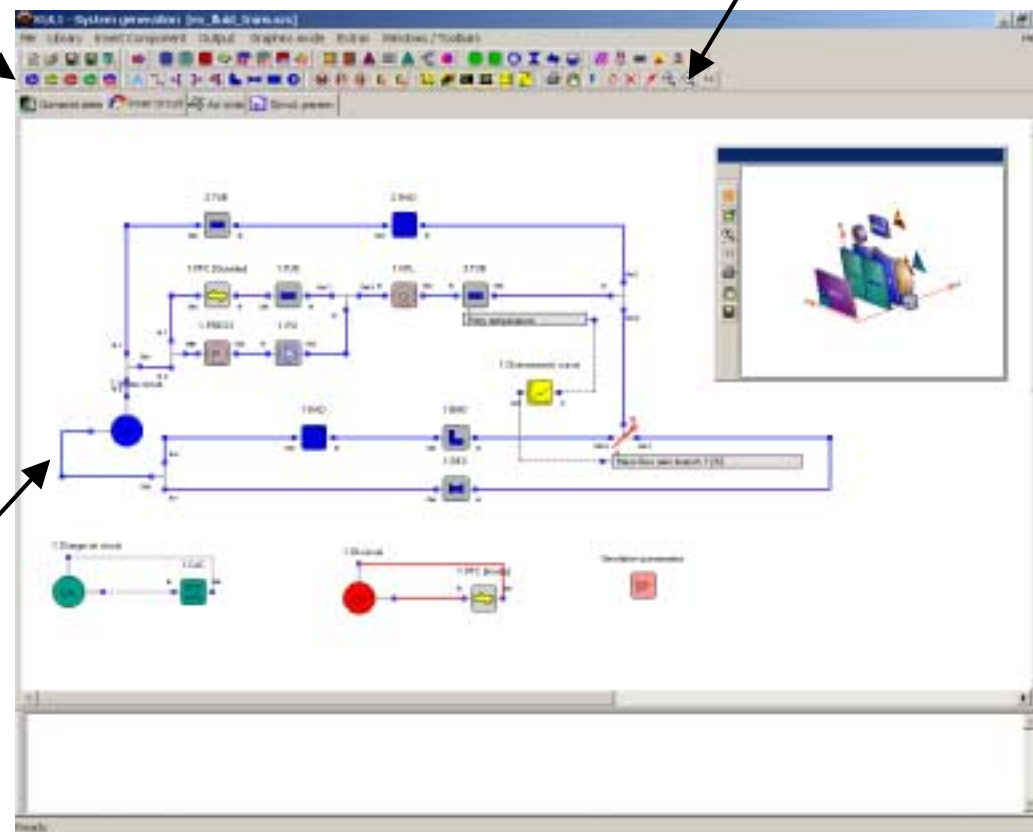
Zooming, Editing Tools

2D Fluid Network
View

3D Air Network
View

Complex
Connector Lines

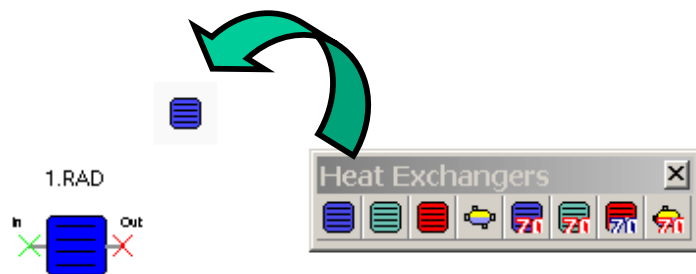
Unrestricted
Component
Arrangement



GUI

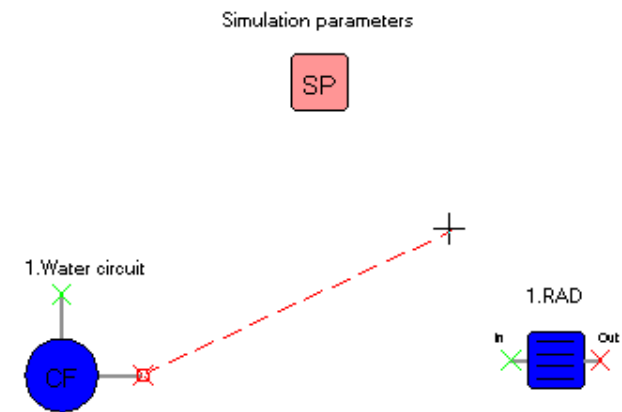
Handling

Insert Components from
the Component Toolbars



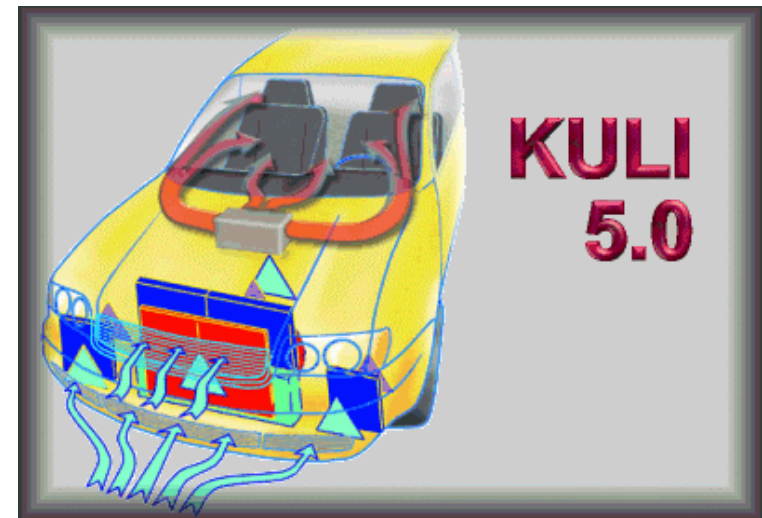
Connect Components
only by Clicking

Sensitive Menu



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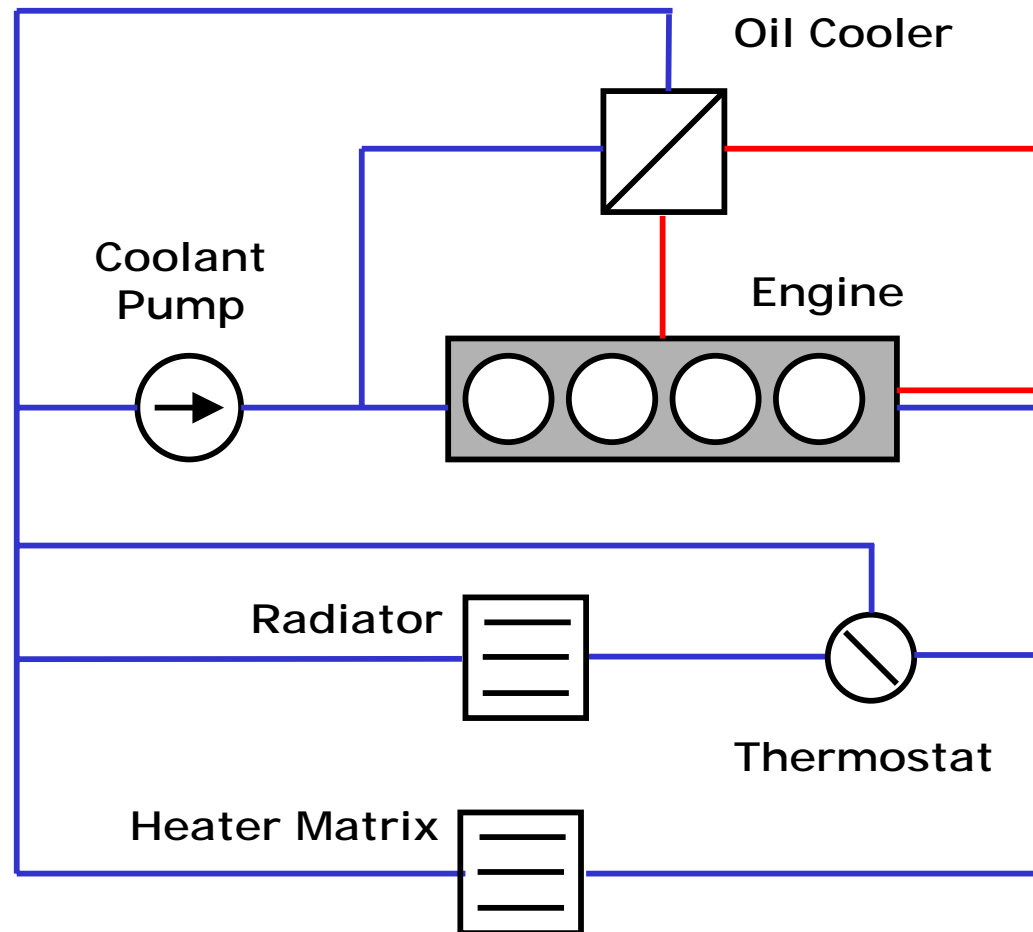


Application

System Layout

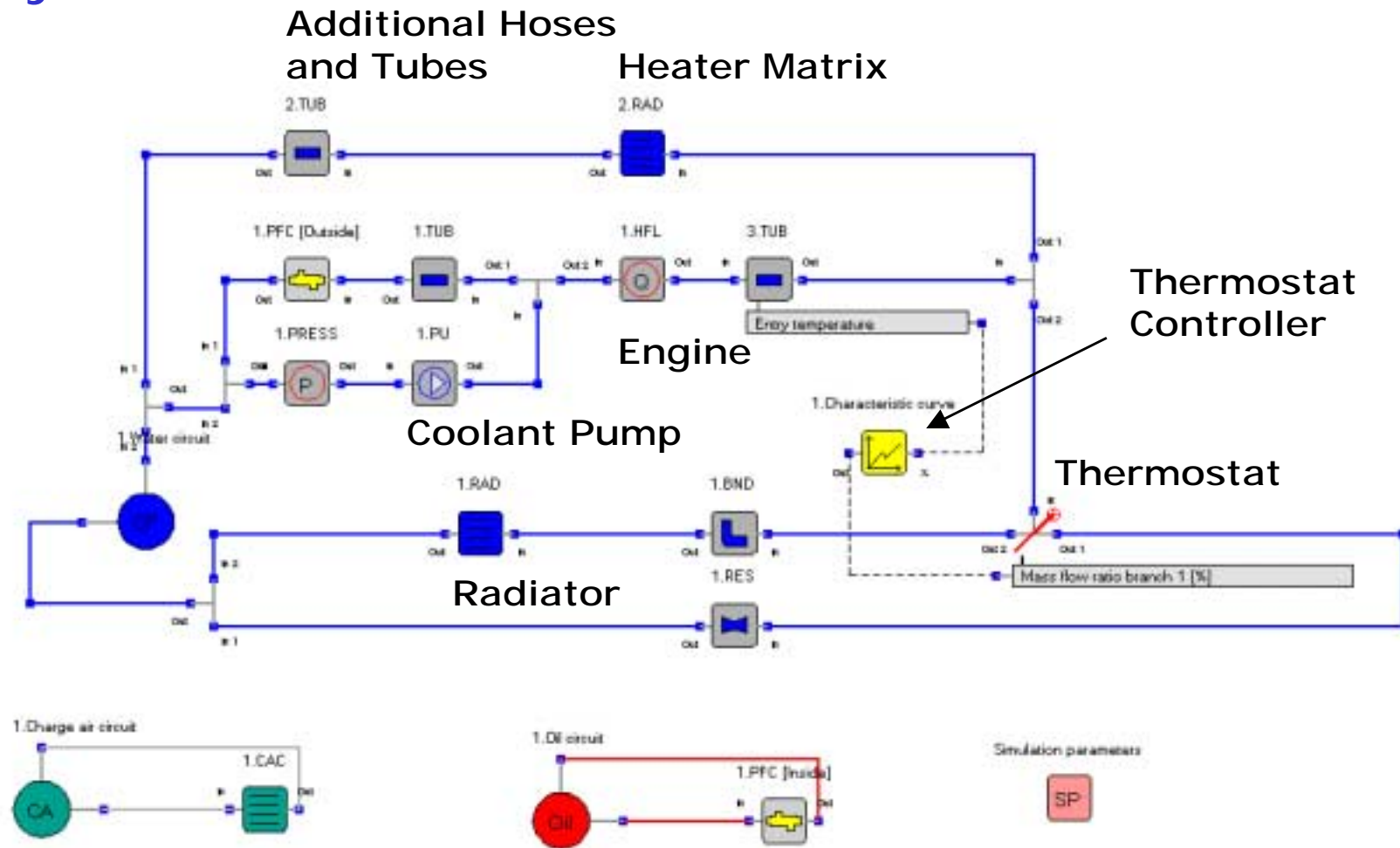


- Oil Circuit
- Coolant Circuit



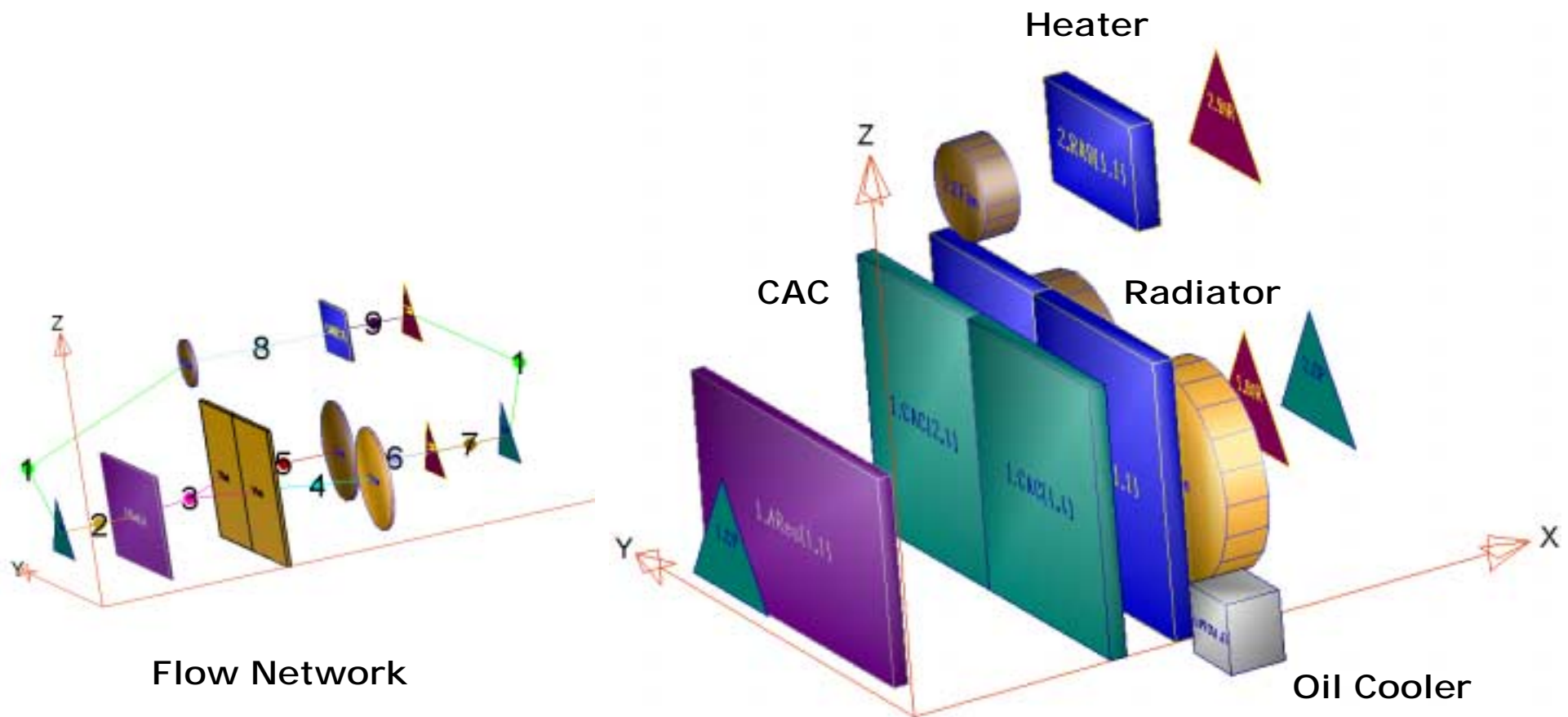
Application

KULI Layout



Application

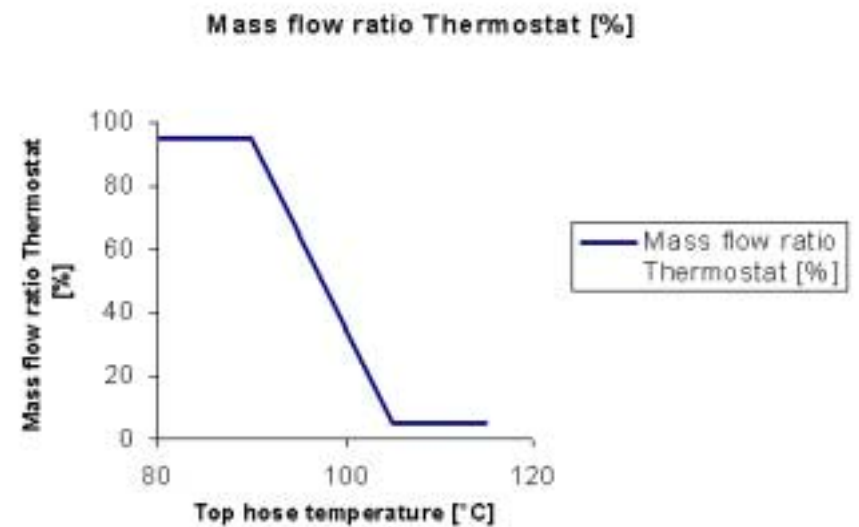
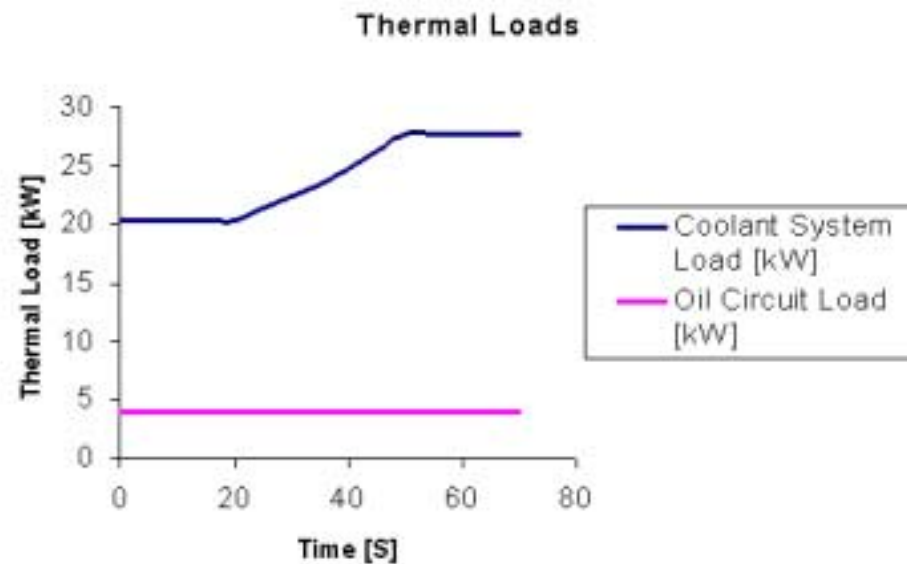
Air Flow Layout



Application

Simulation Parameters

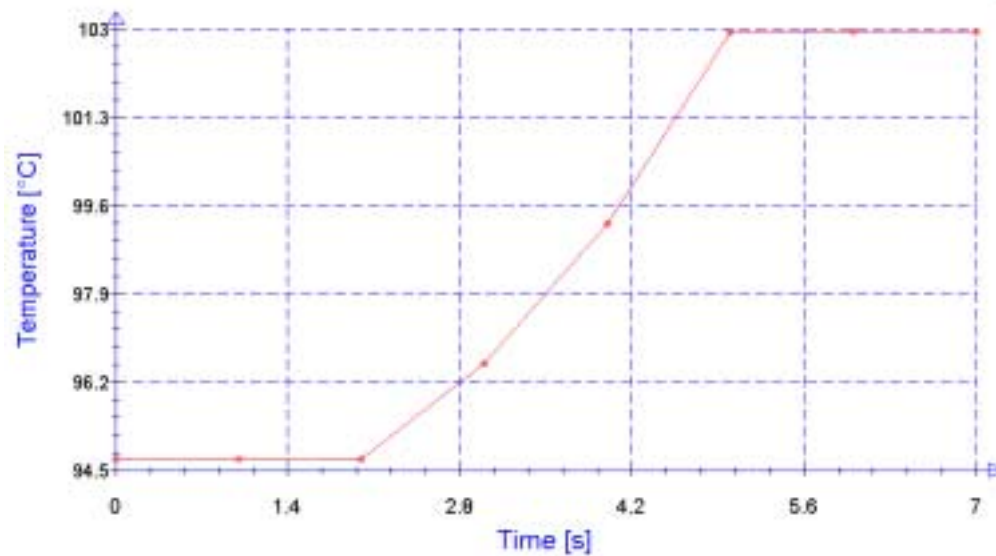
Constant Driving Speed: 40 km/h
Constant Engine Speed: 2500 1/min
Ambient Temperature: 20°C



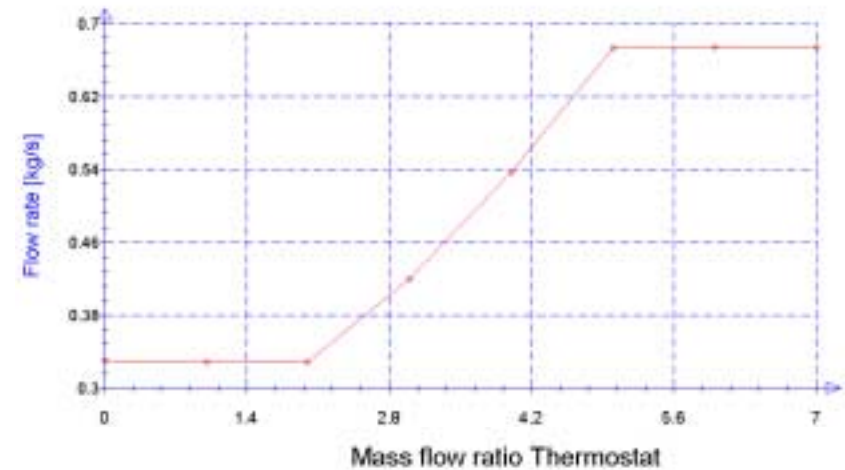
Application

Results

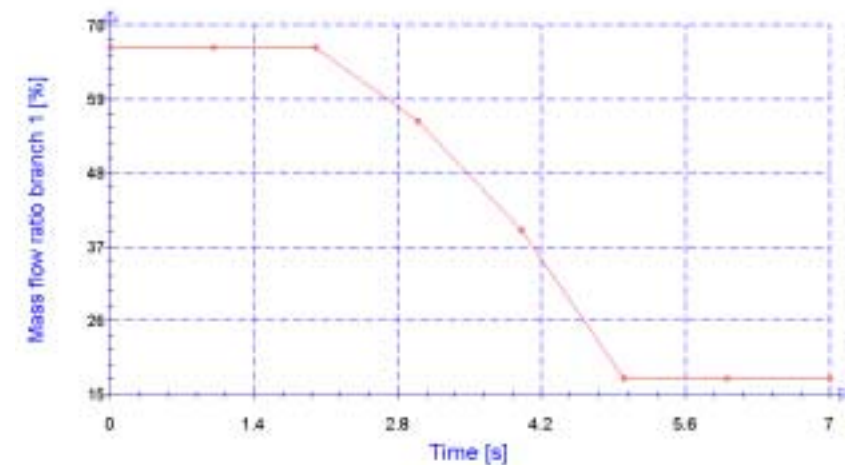
Radiator top hose temperature



Radiator Mass Flow Rate

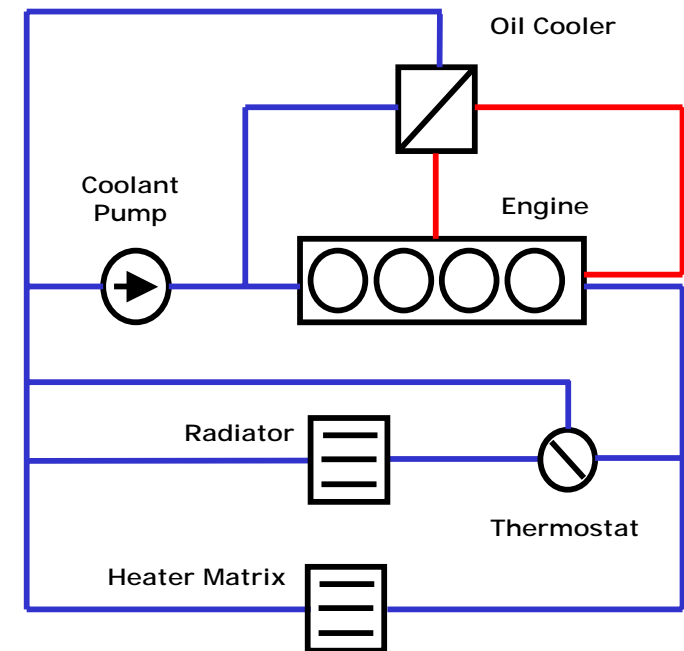
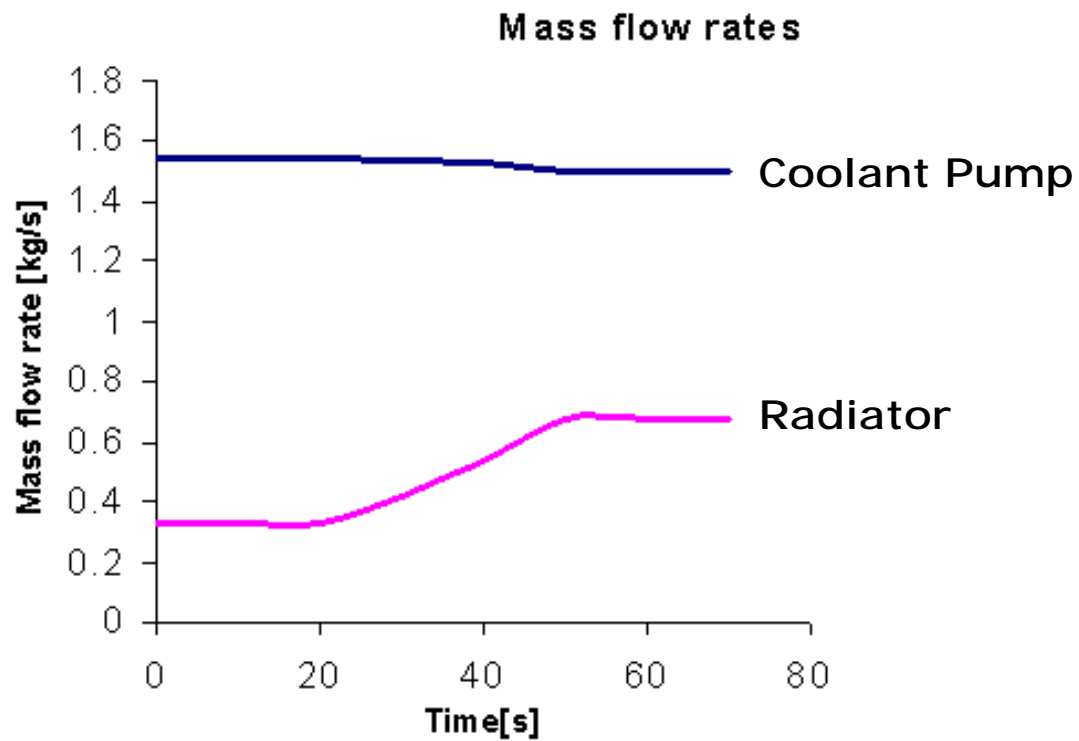


Mass flow ratio Thermostat



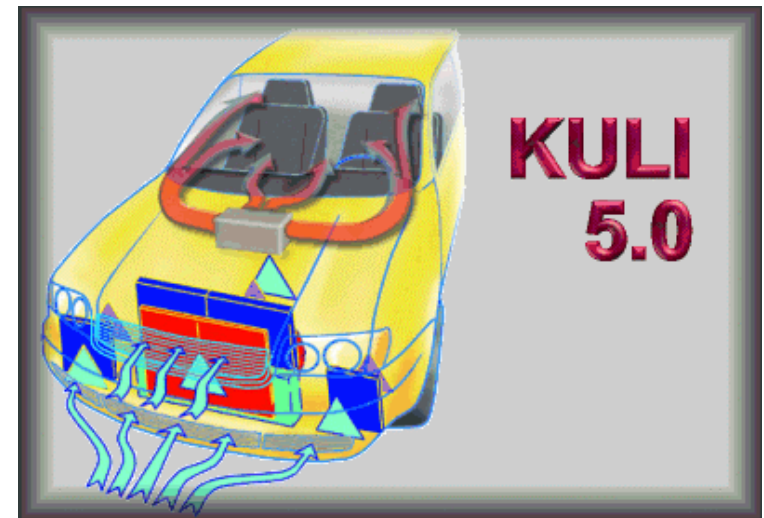
Application

Results



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Further Development

- Component Models Considering Thermal Conduction
- Complex Specification for Fluid Pumps
- Characteristic-line Based Model for Tubes/Resistances
- Graphical User Interface Improvements

Summary

- Modeling of branched Fluid Networks
- No restrictions for all KULI Heat Exchangers
- Complete Integration to KULI Air Flow Network
- Analysis Models for Pumps, Tubes, Manifolds, ...
- Integrated 2D of 3D Controllers
- MATLAB/SIMULINK Interface using COM
- Graphical User Interface

The End

**Thank You For
Your Attention**

**Thomas Anzenberger,
and the ECS-Steyr KULI Team**