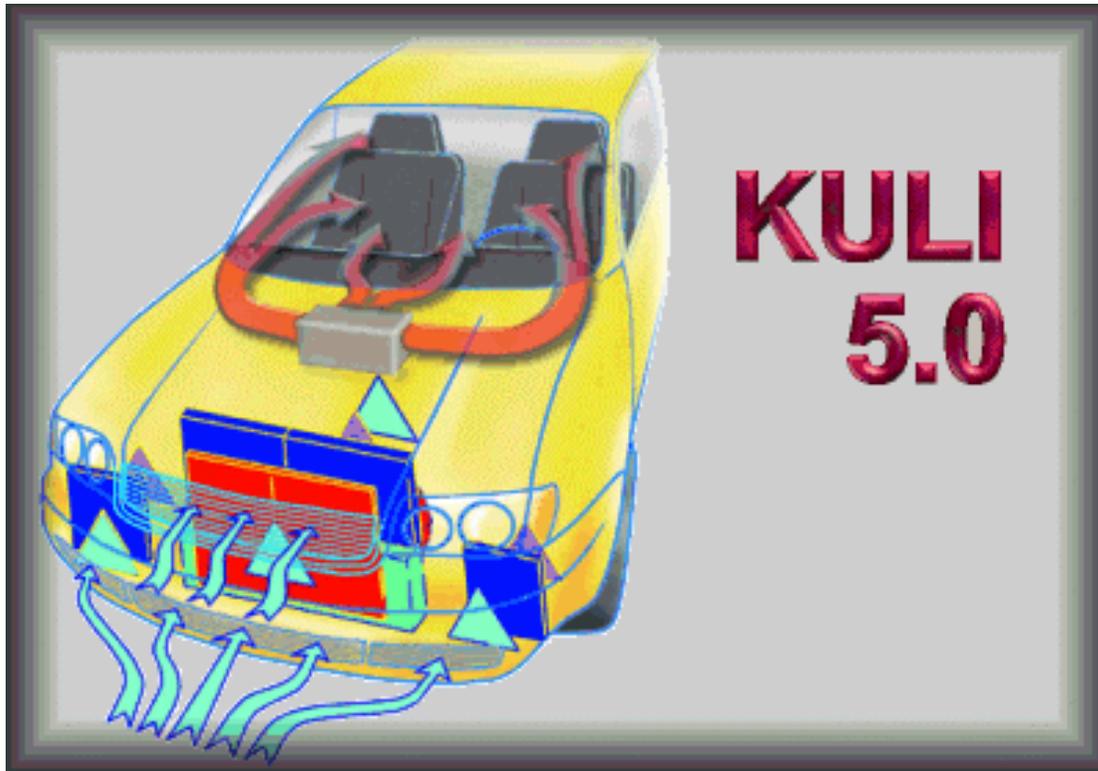


KULI Fluid



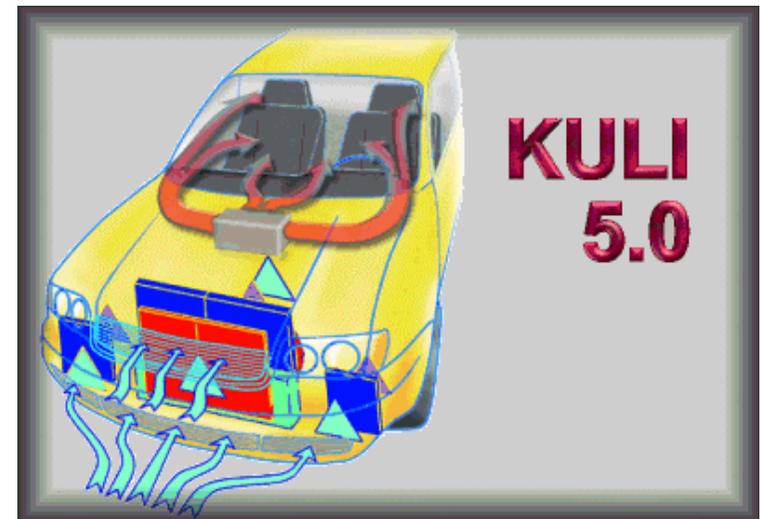
Analysis of Branched Fluid Networks

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

Thomas Anzenberger, ECS Steyr

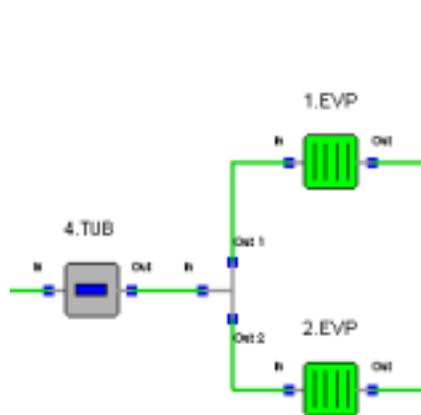
Overview

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

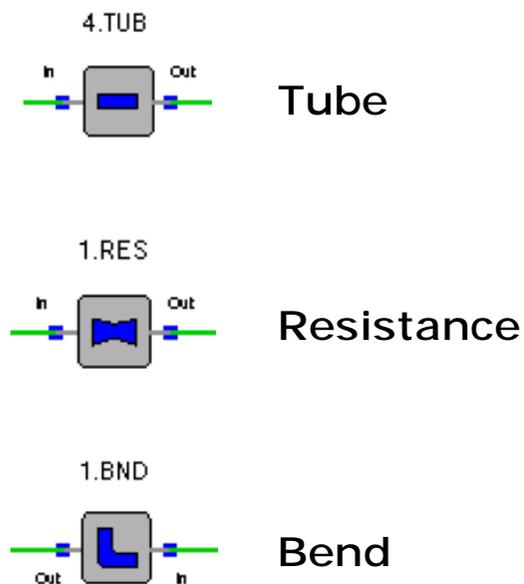


Demands

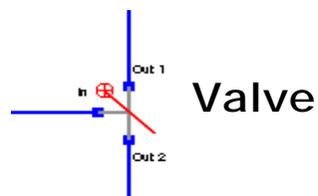
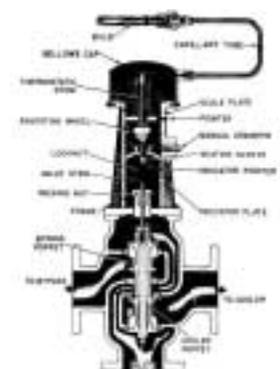
Branched Networks



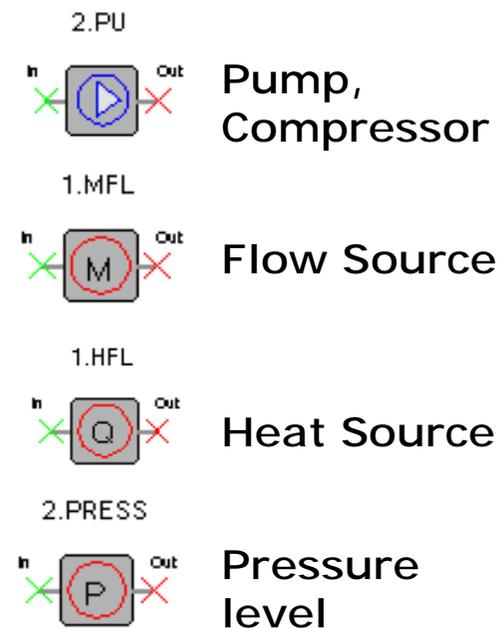
Tubings, Resistances



Thermostatic Valves



Heat and Flow Sources, Pumps



Demands

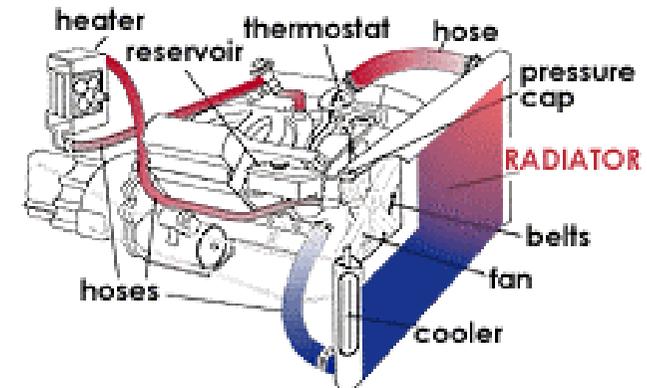
No restrictions for
Component Connections
and Heat Exchangers

Open Circuit
(Definition of inlet
properties)



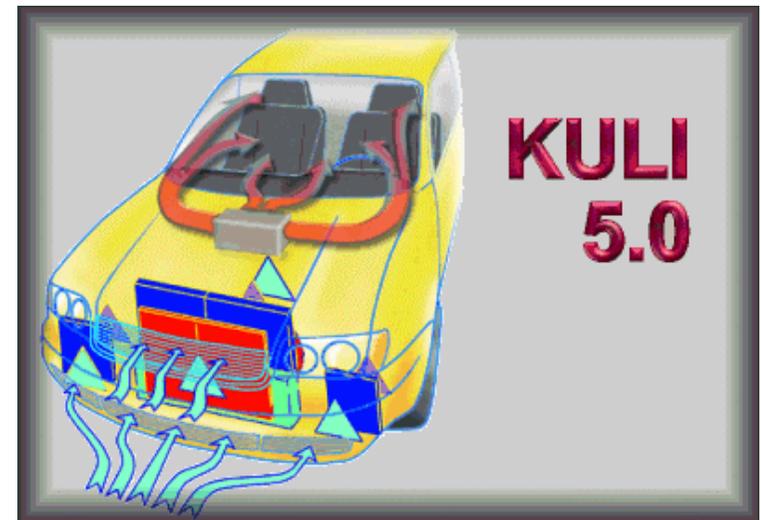
Closed Circuit
(Circuit
equalization)

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



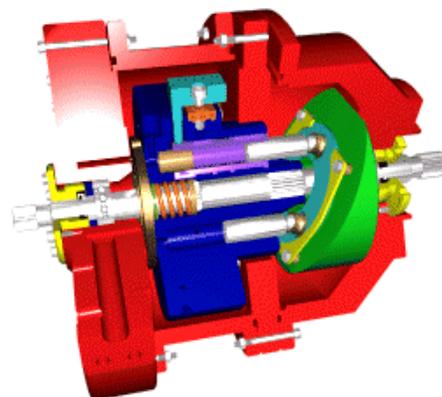
Overview

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



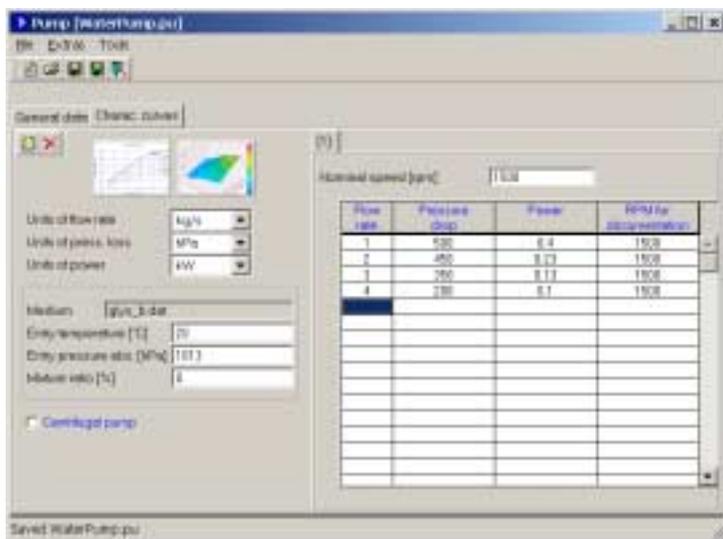
KULI Fluid

Pumps,
Compressors

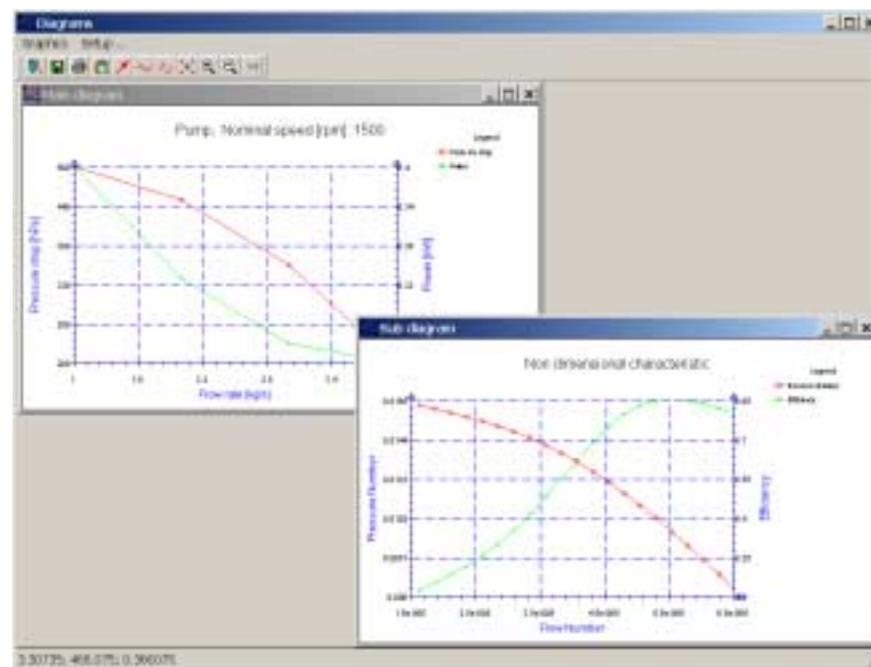


Non Dimensional
Characteristic

Input Data (measured
performance curve)

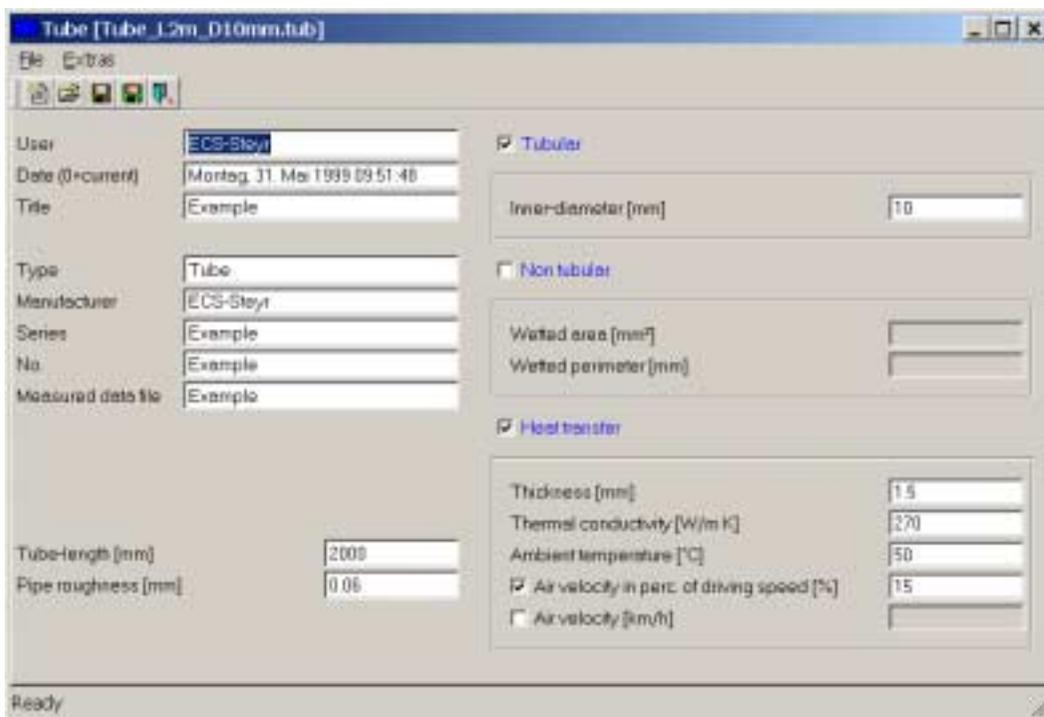
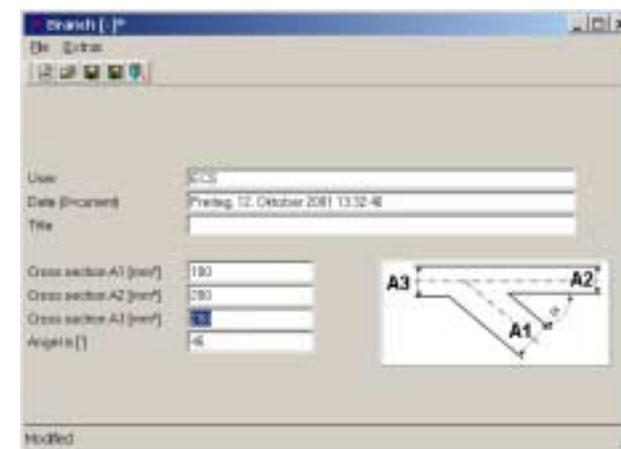


Transformation



KULI Fluid

Tubes,
Bends, Manifolds



Input Data (based only on
geometric information)

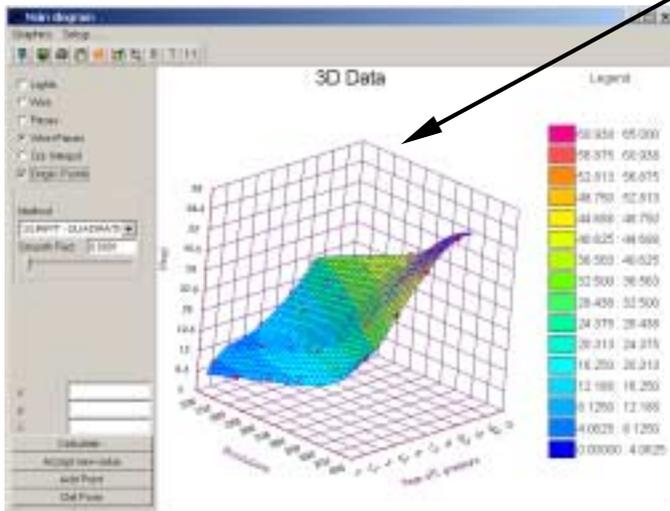


KULI Fluid

Heat, Pressure
and Flow Sources

2D or 3D Input Data

Visualization of
Input Data



Heat [engine\heat\Rejection\heat]

Type of map: Heat

User: ECS Comments: [Auto Generated from C:\erheckl\kain_0\kai_0\kai_0\Tutor\Modell]

Date (Document): Donnerstag, 27. September 28

3D Data visualization icon

First entry: Type: Revolutions, Unit: 1/rev

Second entry: Type: Mean of press, Unit: bar

Output: Type: Heat, Unit: kW

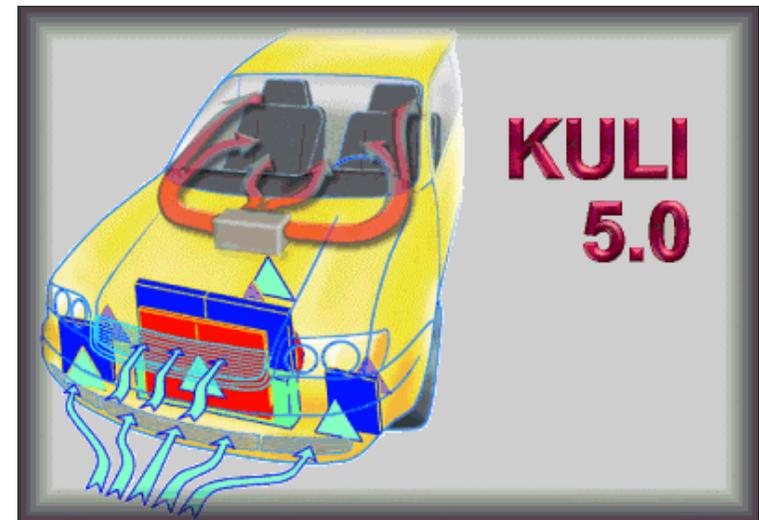
Revolutions [1/rev]	Mean of press [bar]	Heat [kW]
1500	1.5	7.5
1500	6.1	15
1500	8.8	22.5
1500	18.9	30
2000	0.8	7.5
2000	3.2	15
2000	7.1	22.5
2000	9.4	30
2500	1	11.25
2500	7	18.75
2500	7.7	30
2500	18.1	37.5
3000	1.1	15
3000	2.7	22.5
3000	5.7	30
3000	11.2	45
3500	1.7	22.5
3500	4.4	33.75
3500	7.7	45
3500	18.5	52.5
4000	1.3	30

Method: SURFIT - QUADRATIC
SmoothFact: 0.0001

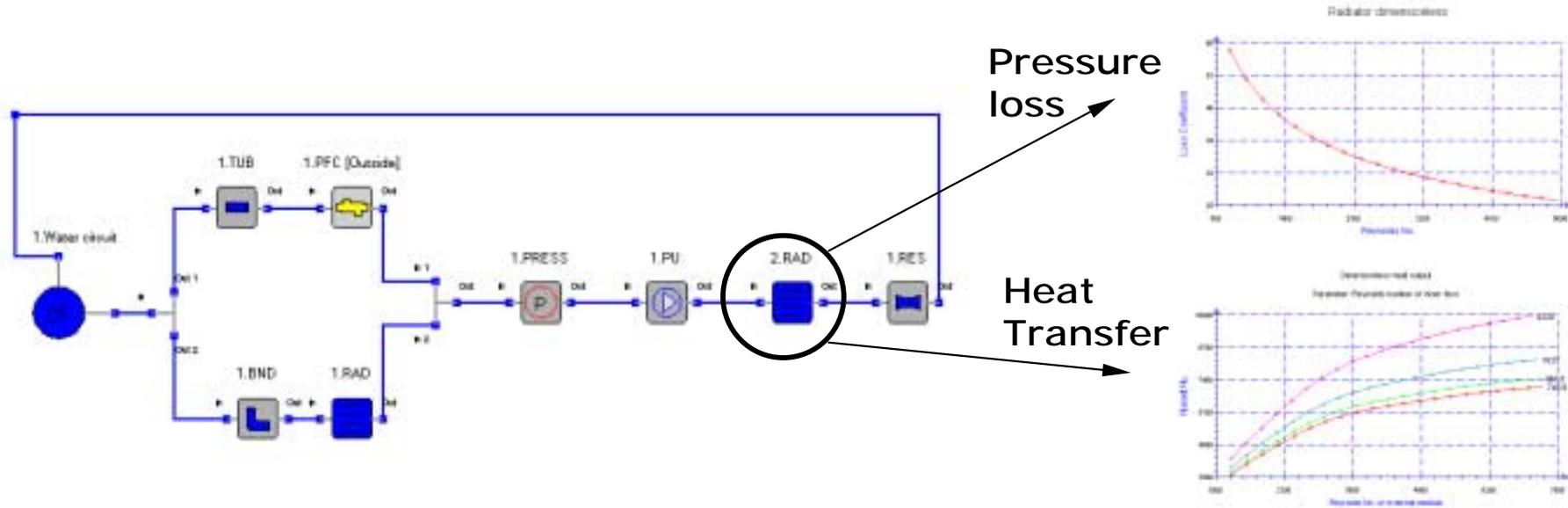
Input and Output unit definition

Overview

- Demands for a KULI Fluid Circuit
- KULI Fluid Components
- **Technical Specification**
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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

$$\vec{m} = \begin{Bmatrix} \dot{m}_1 \\ \dot{m}_2 \\ \dots \\ \dot{m}_j \end{Bmatrix}$$

$$\vec{p} = \begin{Bmatrix} p_1^{in} \\ p_1^{in} \\ \dots \\ p_j^{in} \end{Bmatrix}$$

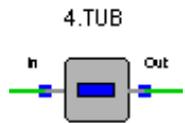
Mass Flow, Pressure Distribution

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

Enthalpy (Temperature) Distribution

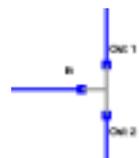
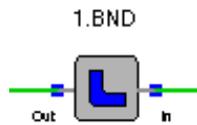
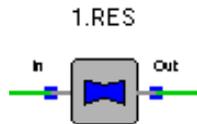
Specification

Tubes, Resistances, Bends, Manifolds

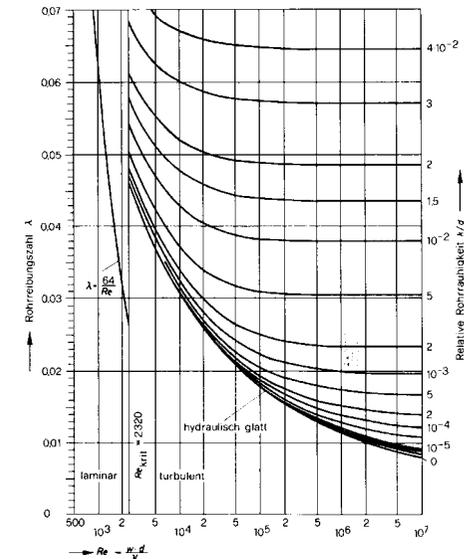


Pressure Loss Calculation

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



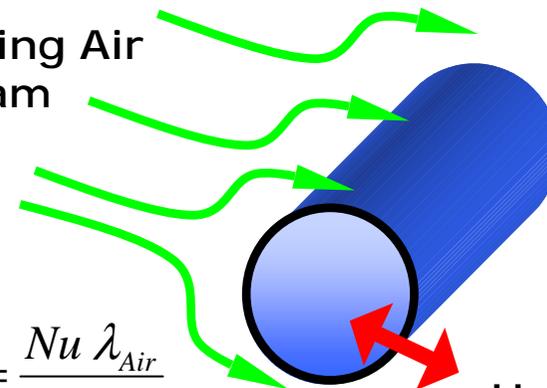
Heat Transfer Calculation



Colebrook Diagram

Leading Air Stream

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

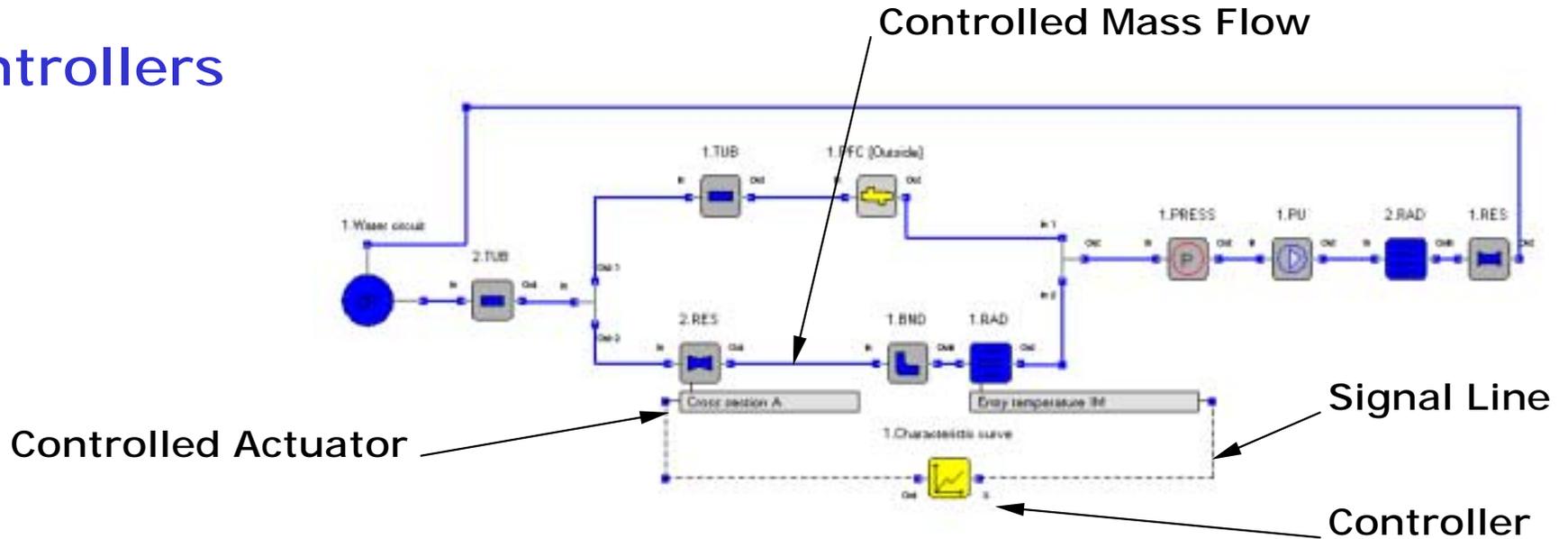


Theorie:
Cross leading air flow

Heat flow

Specification

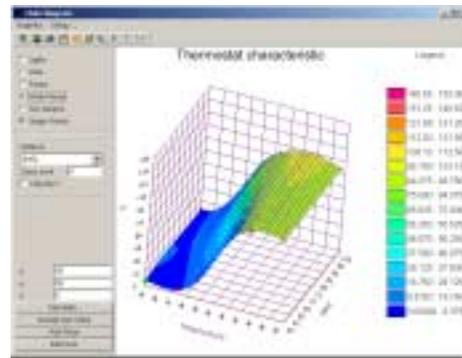
Controllers



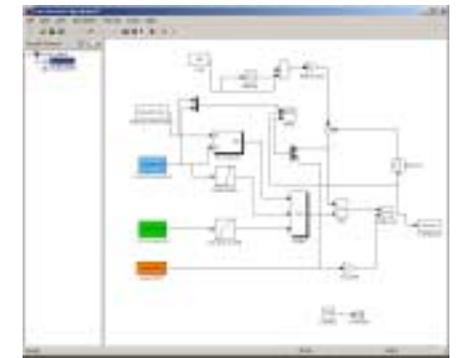
Controller Characteristic



2D Characteristic Line



3D Map

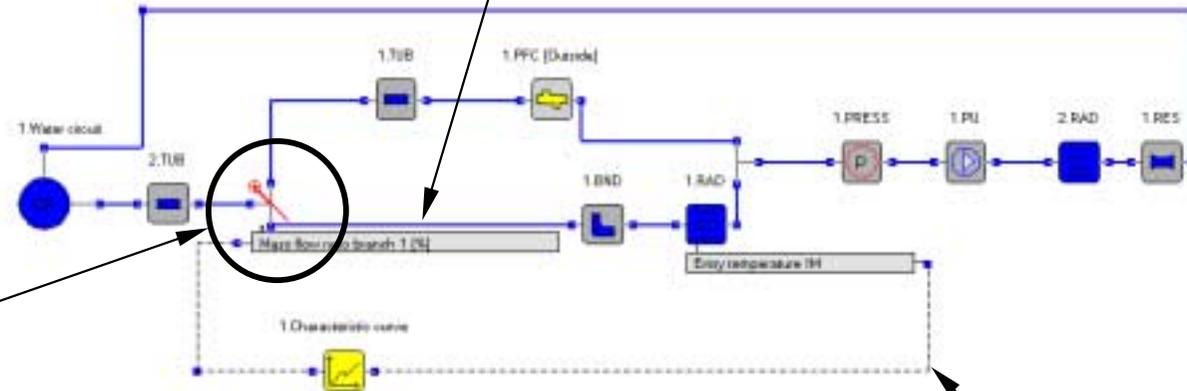


MATLAB/SIMULINK

Specification

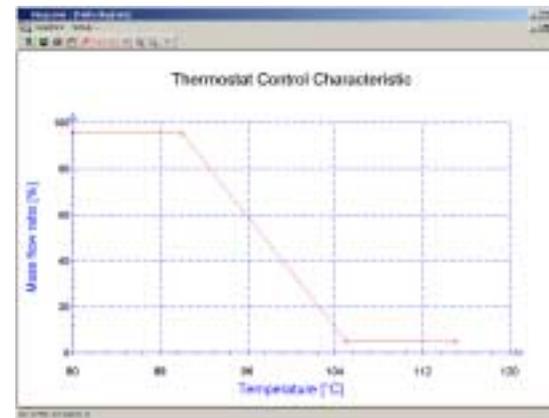
Valves, Controlled Valves

Controlled Mass Flow Ratio



Branched Valve with Controlled Mass Flow Ratio

Controller Characteristic

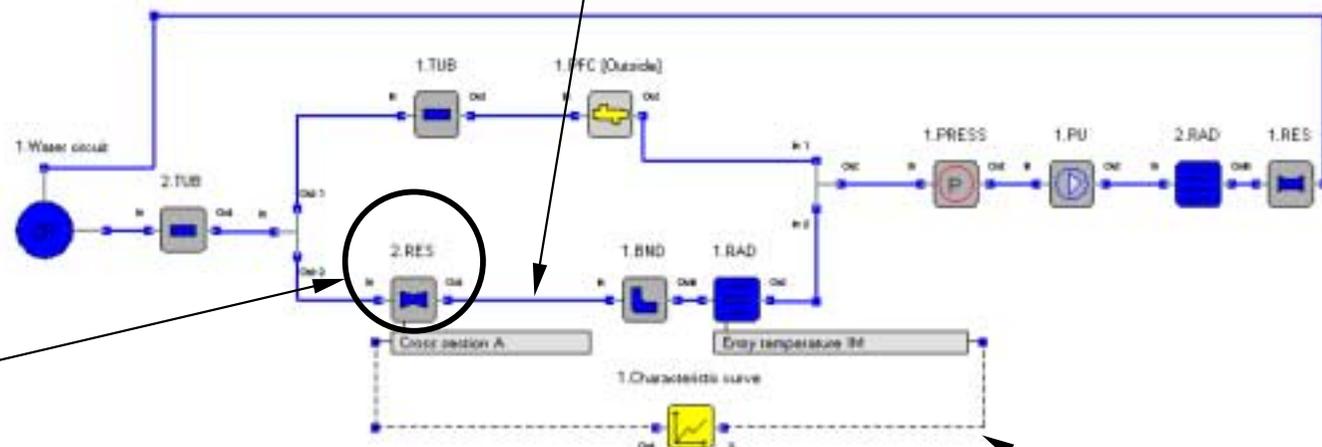


Signal Line

Specification

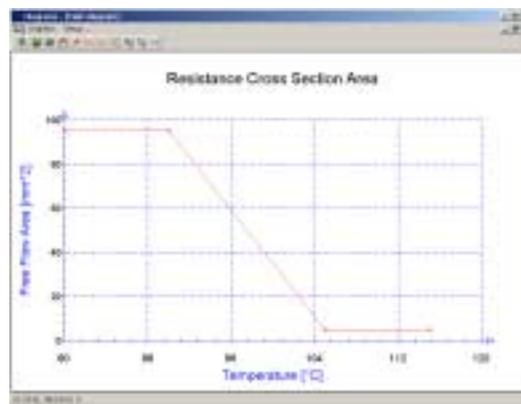
Controlled Resistances

Controlled Mass Flow



Controlled Cross Sectional Area

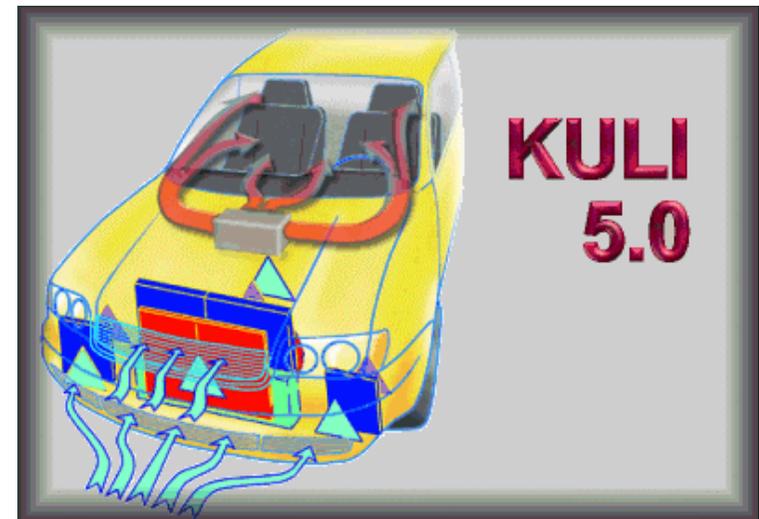
Controller Characteristic



Signal Line

Overview

- Demands for a KULI Fluid Circuit
- KULI Fluid Components
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- **Graphical User Interface**
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GUI

Component Toolbars
(dockable)

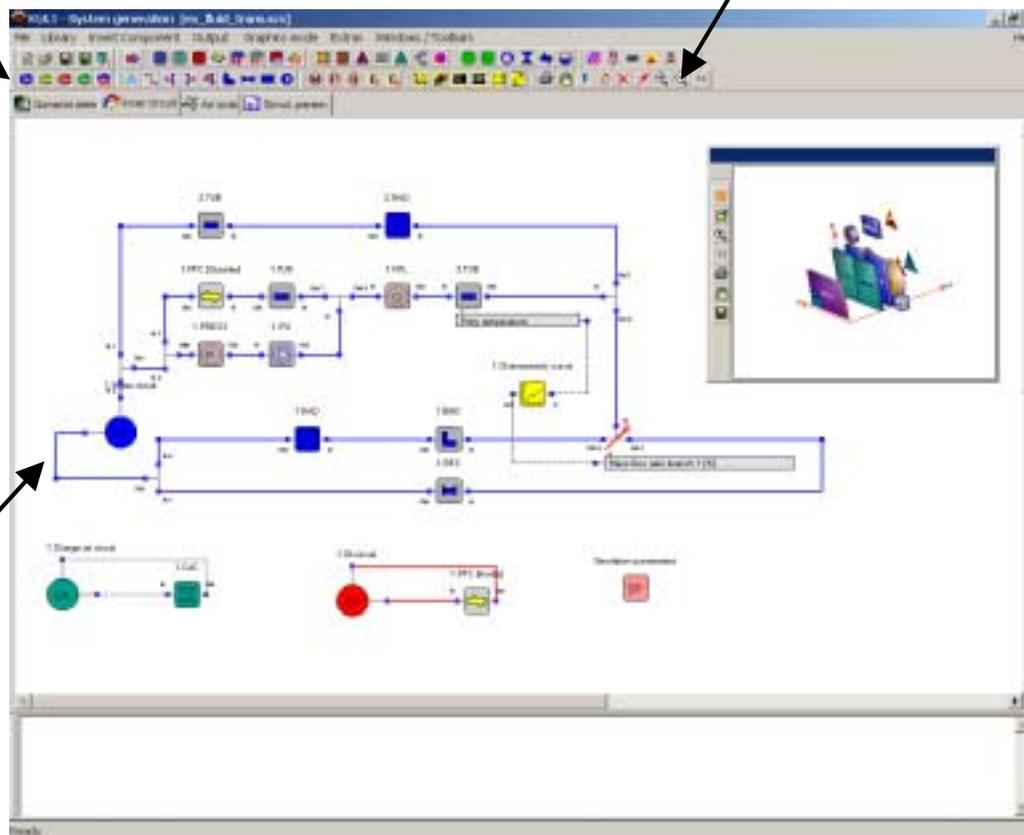
Zooming, Editing Tools

2D Fluid Network
View

3D Air Network
View

Complex
Connector Lines

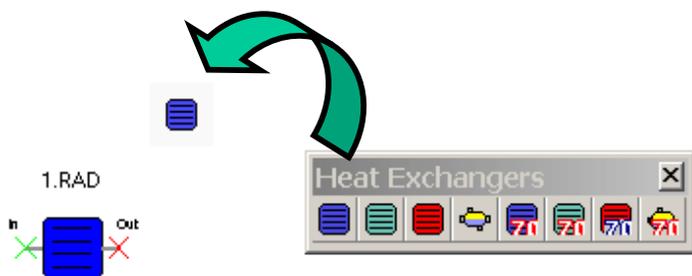
Unrestricted
Component
Arrangement



GUI

Handling

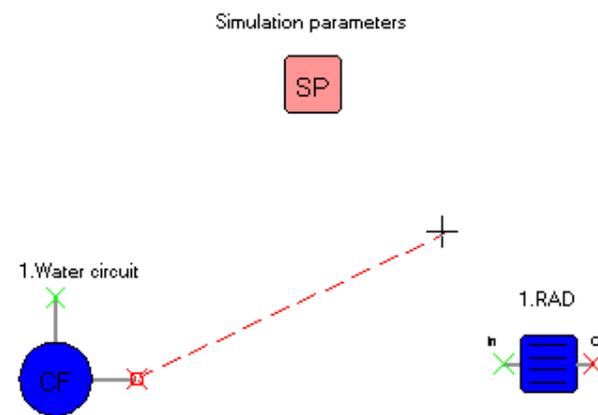
Insert Components from the Component Toolbars



Sensitive Menu

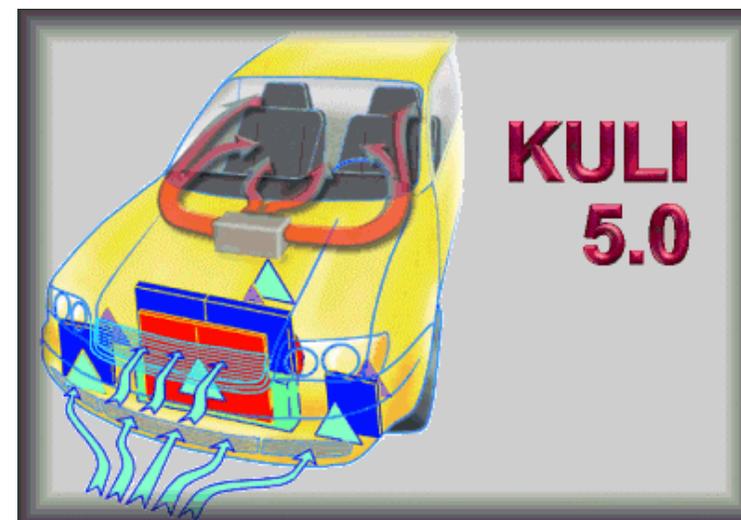


Connect Components only by Clicking



Overview

- Demands for a KULI Fluid Circuit
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- Further Development

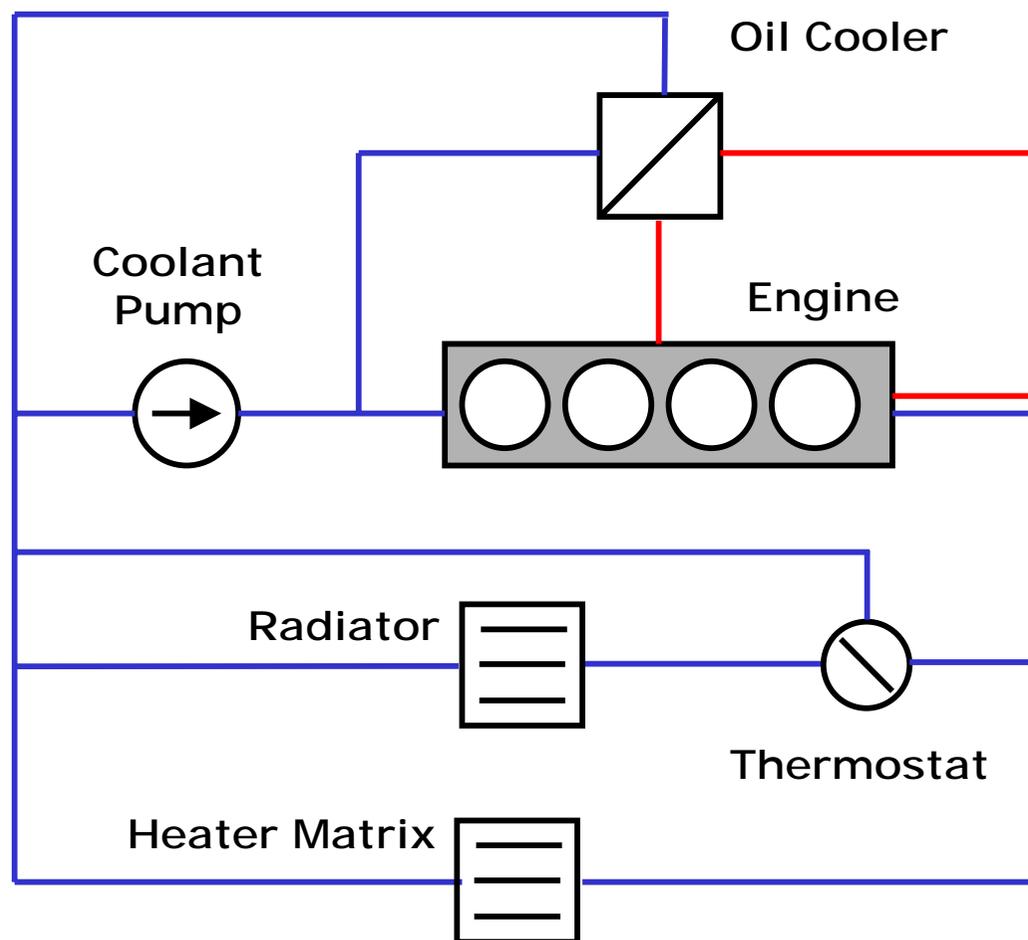


Application

System Layout

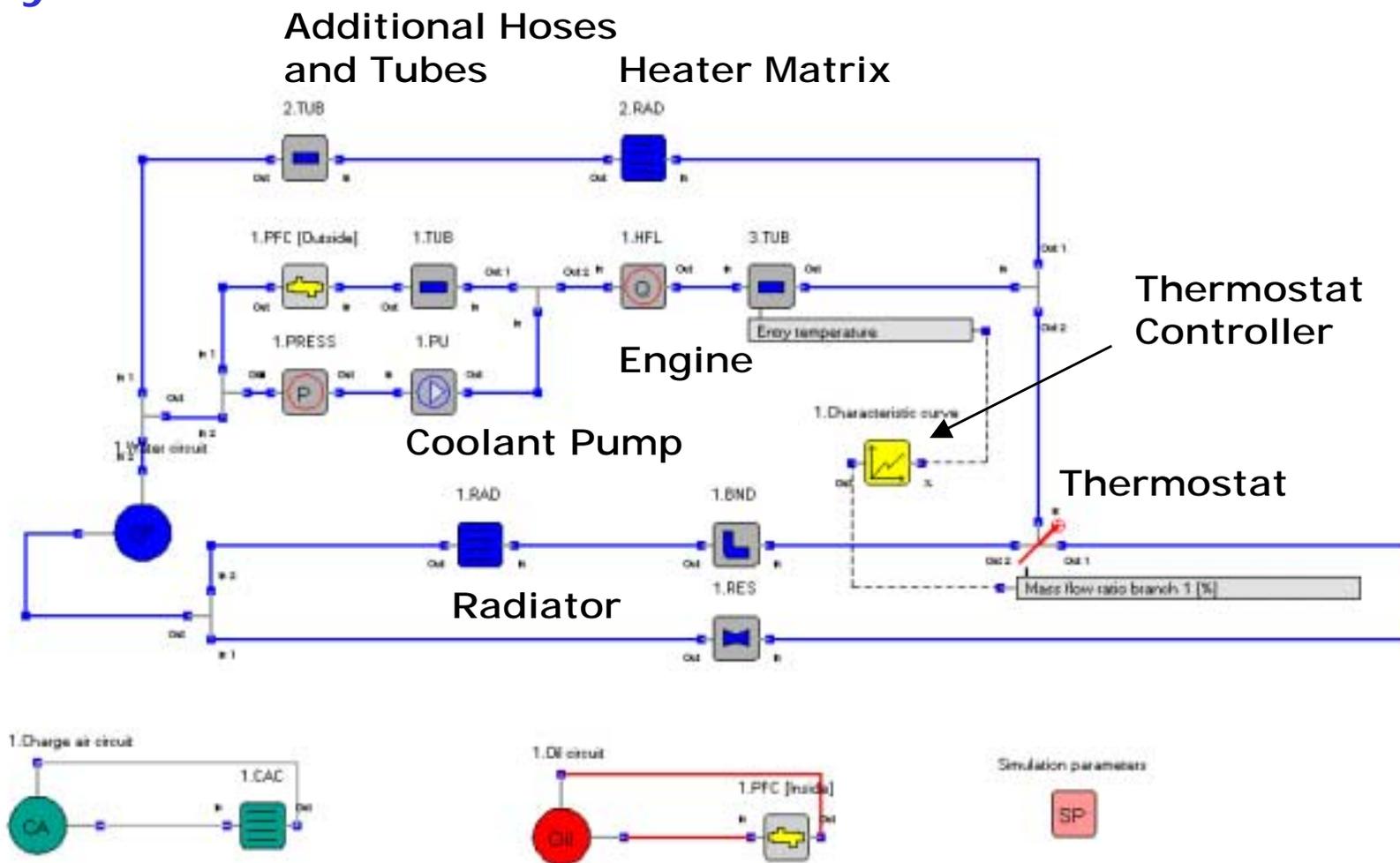


- Oil Circuit
- Coolant Circuit



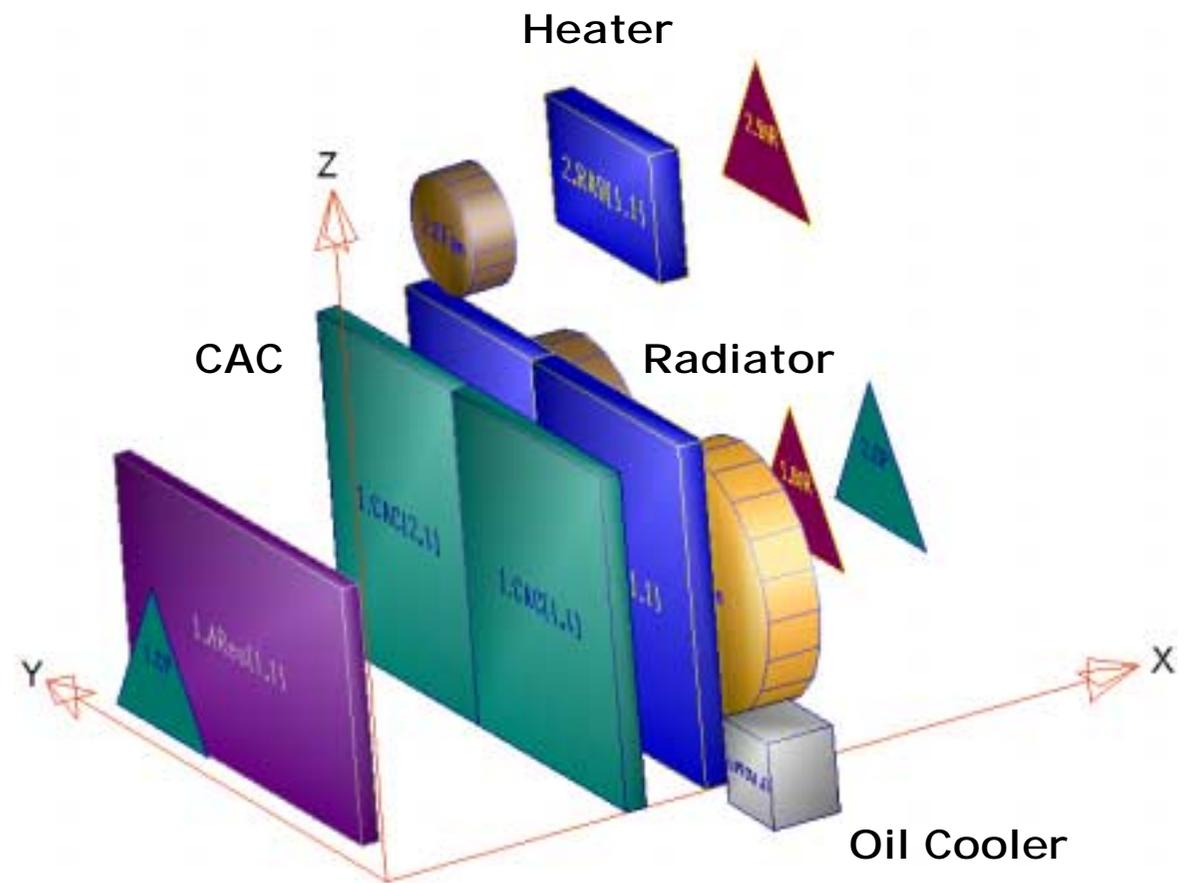
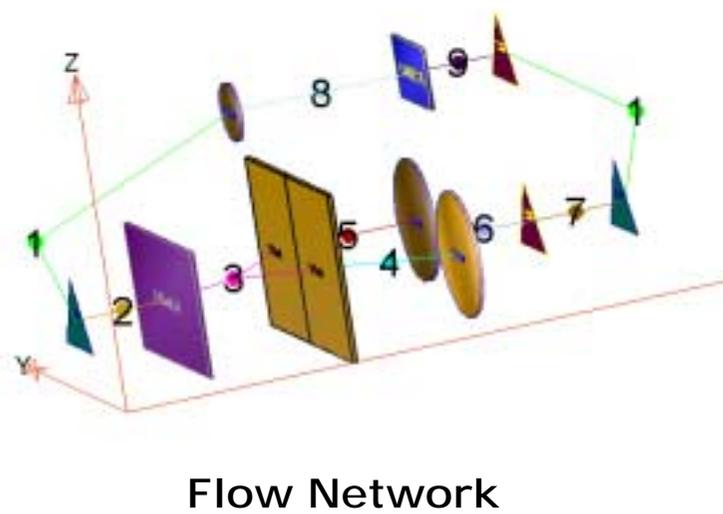
Application

KULI Layout



Application

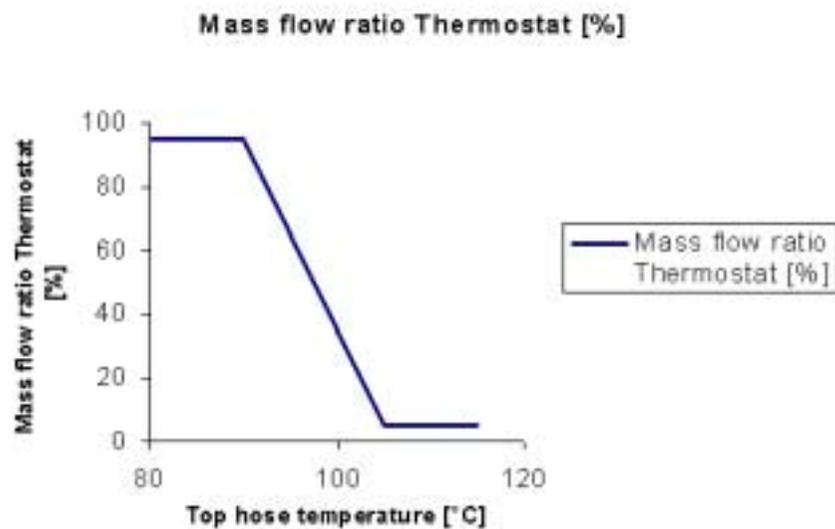
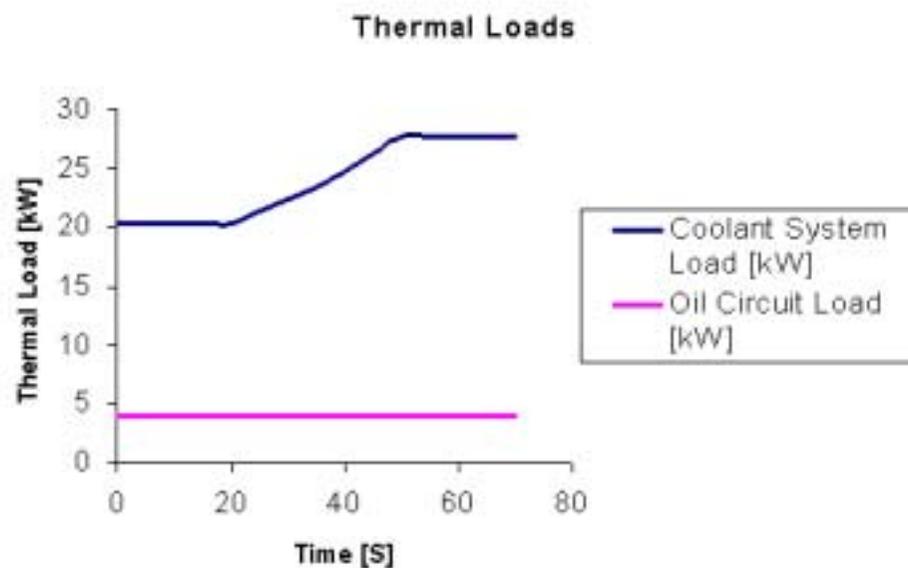
Air Flow Layout



Application

Simulation Parameters

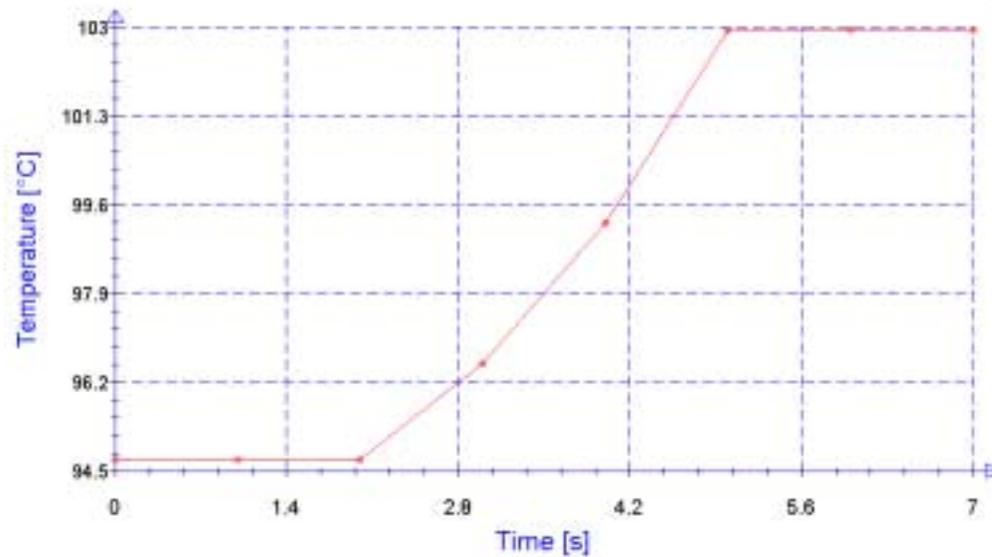
Constant Driving Speed: 40 km/h
 Constant Engine Speed: 2500 1/min
 Ambient Temperature: 20°C



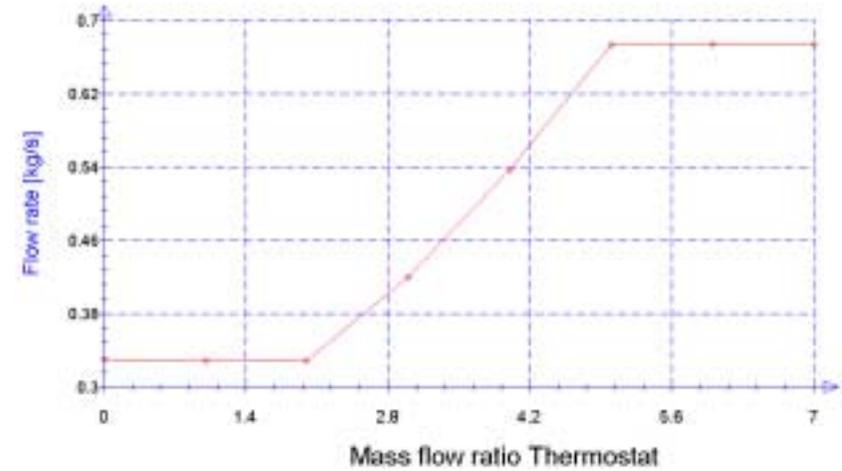
Application

Results

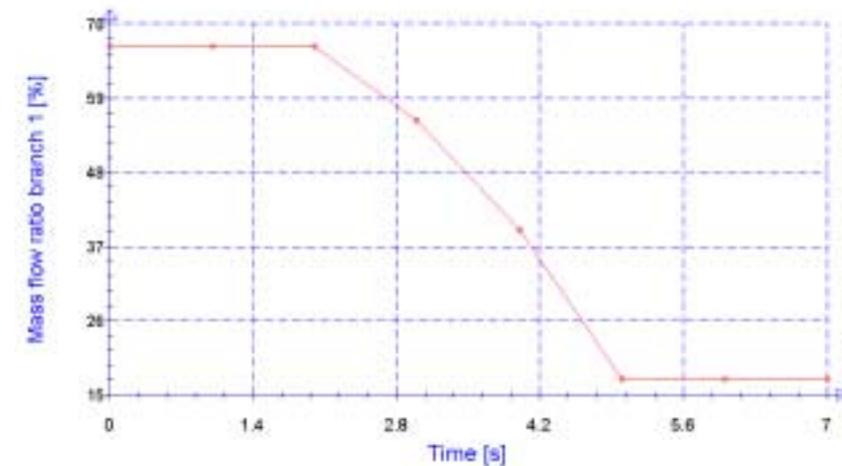
Radiator top hose temperature



Radiator Mass Flow Rate



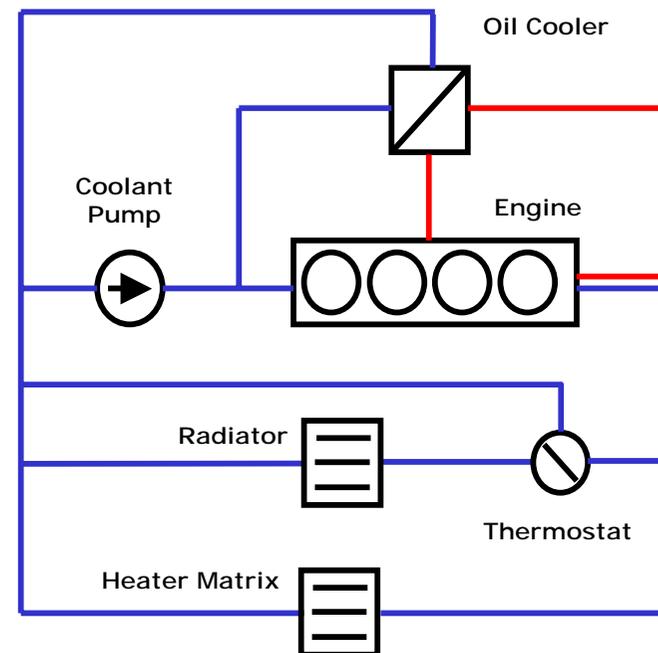
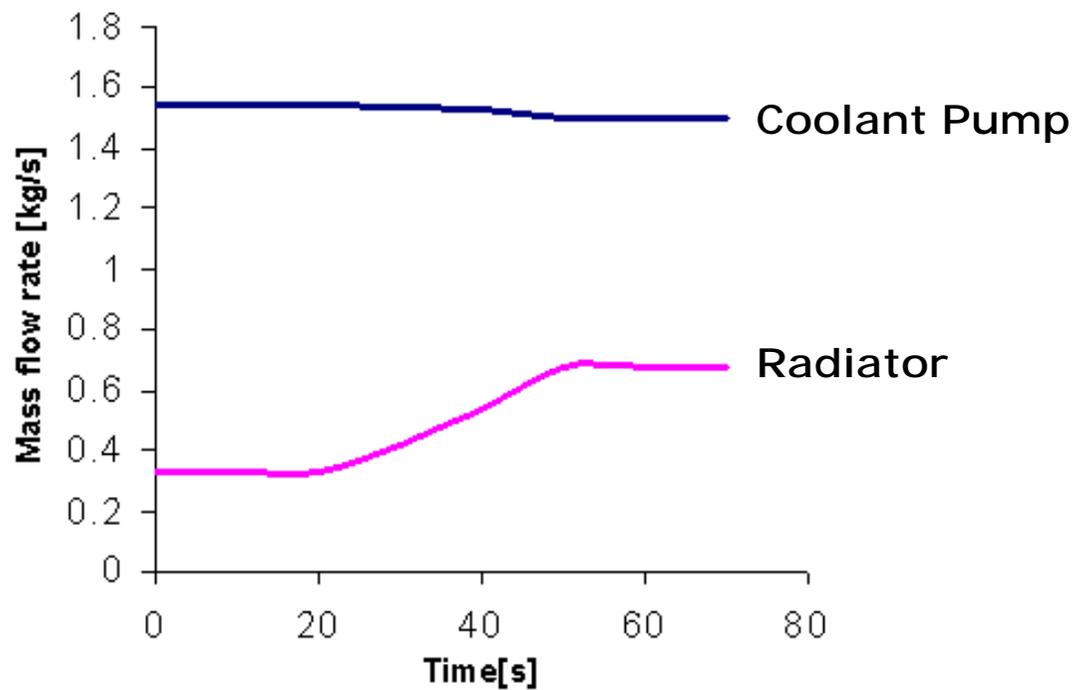
Mass flow ratio Thermostat



Application

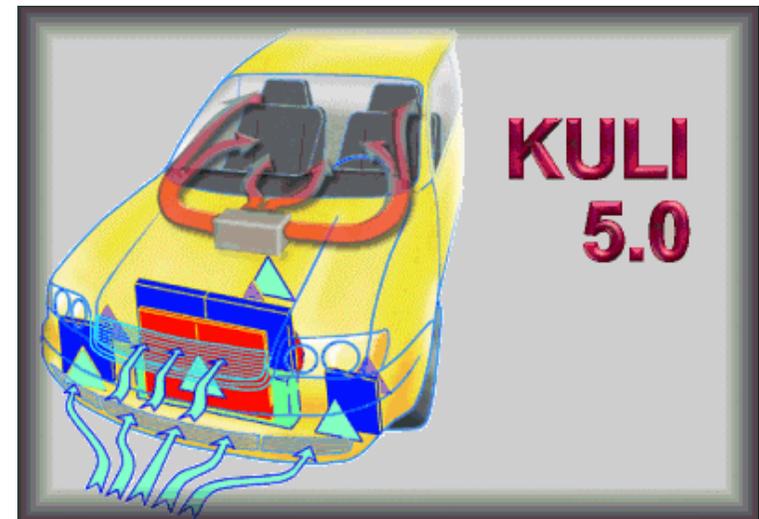
Results

Mass flow rates



Overview

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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**