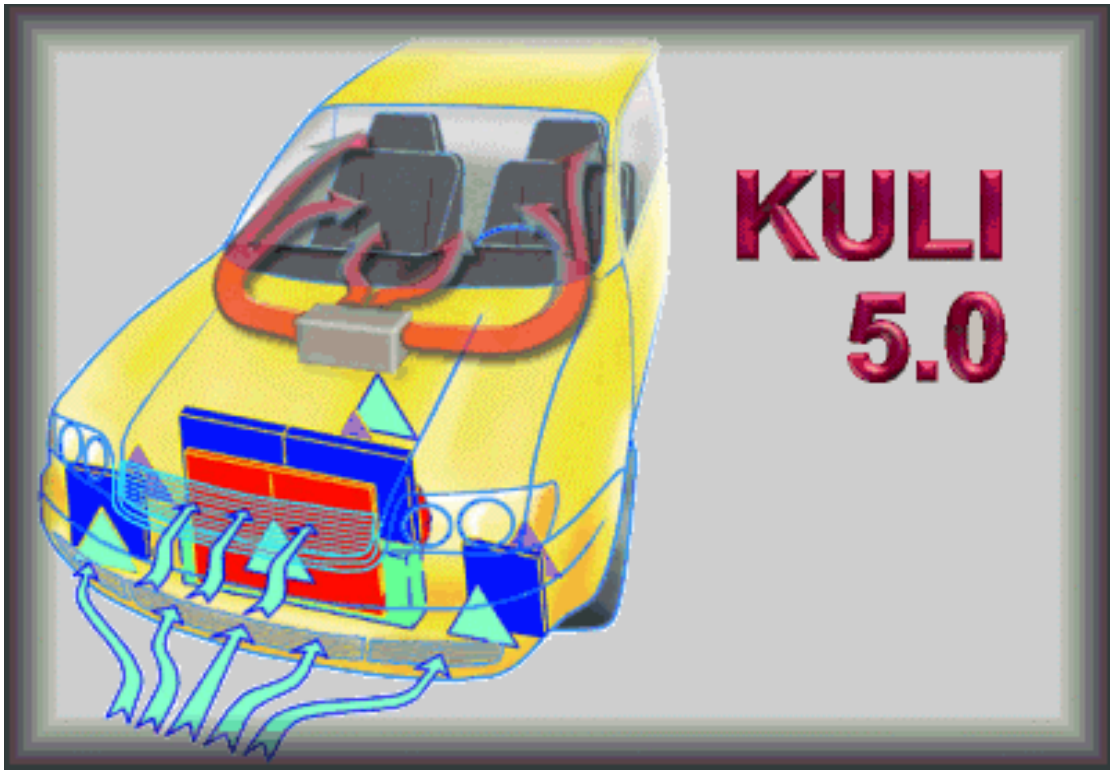
KULI AC



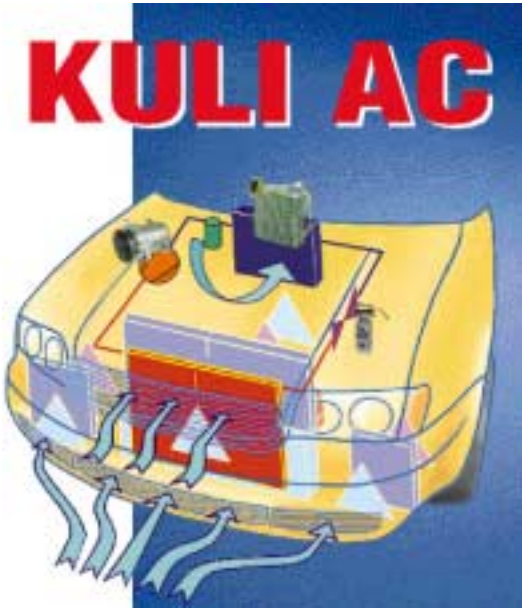
Analysis of A/C Systems

- Branched Refrigerant Networks
- Advanced Storage Models
- Internal Heat Exchanger
- Carbon Dioxide

Thomas Anzenberger, ECS Steyr

Overview

- Overview KULI AC
- KULI AC, new Components
- Technical Specification
- Practical Application
- Further Development



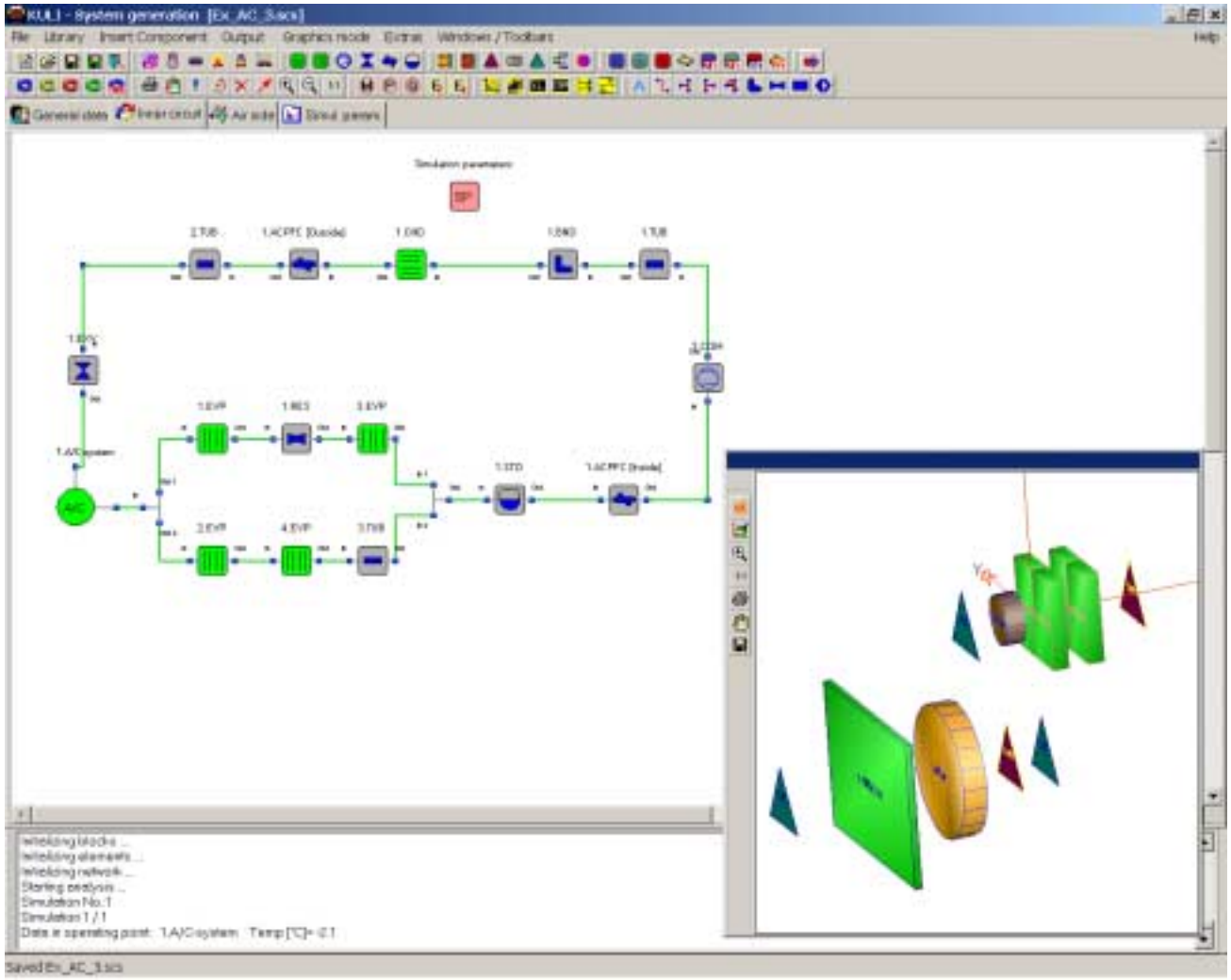
Why A/C Simulation ?

KULI A/C

Component Toolbars

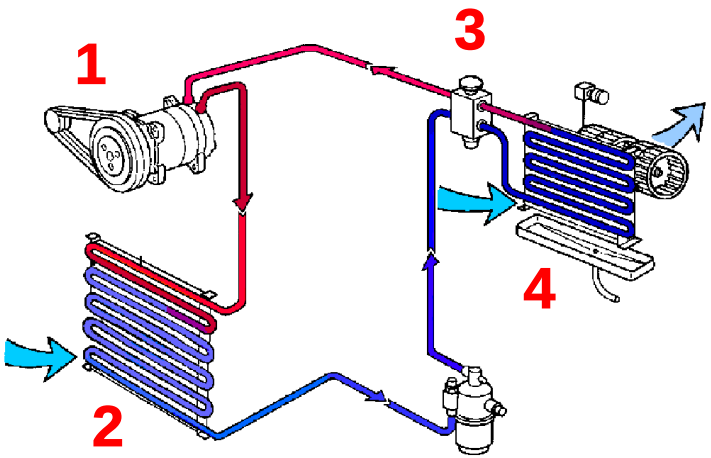
Refrigerant Circuit Layout

Message Window



3D Air Network View

Refrigerant Circuit

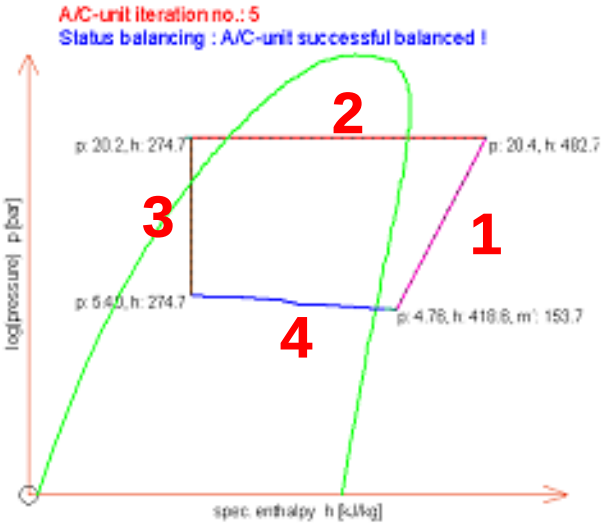


1 Compressor

2 Condenser

3 Expansion Device

4 Evaporator

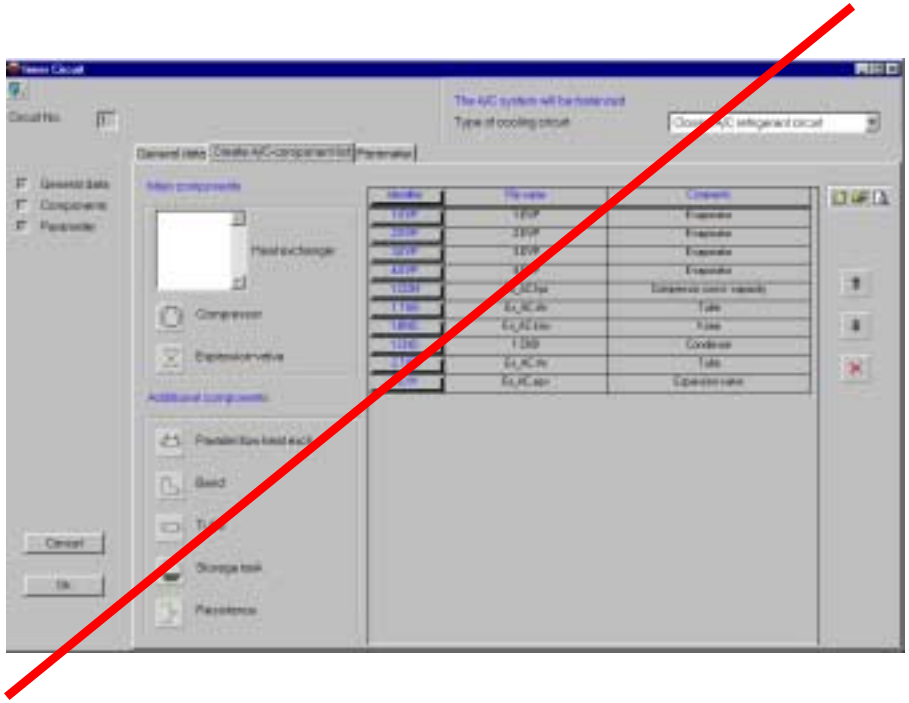


Geometric Model

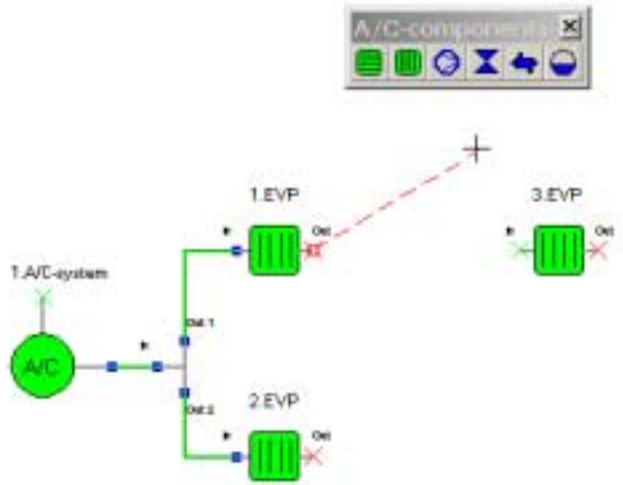
Analysis Results

Simulation

Refrigerant Circuit

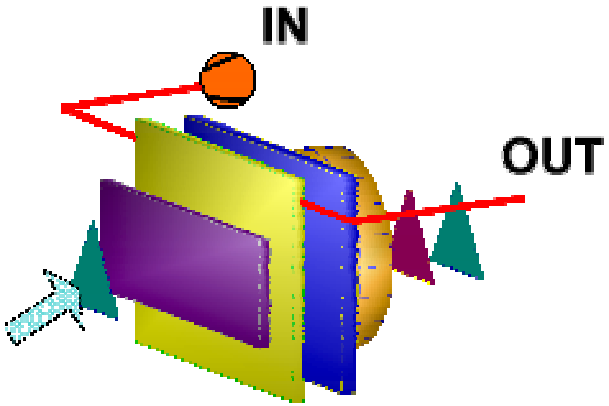


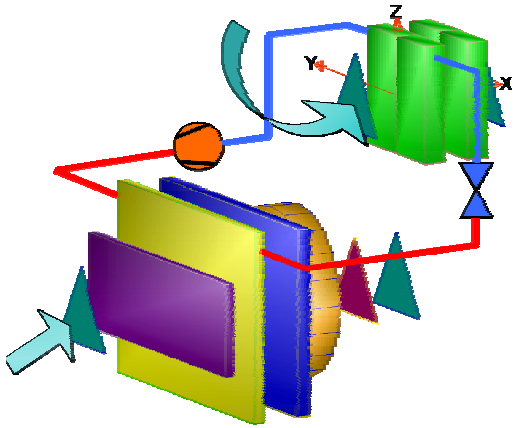
Old: Component Table

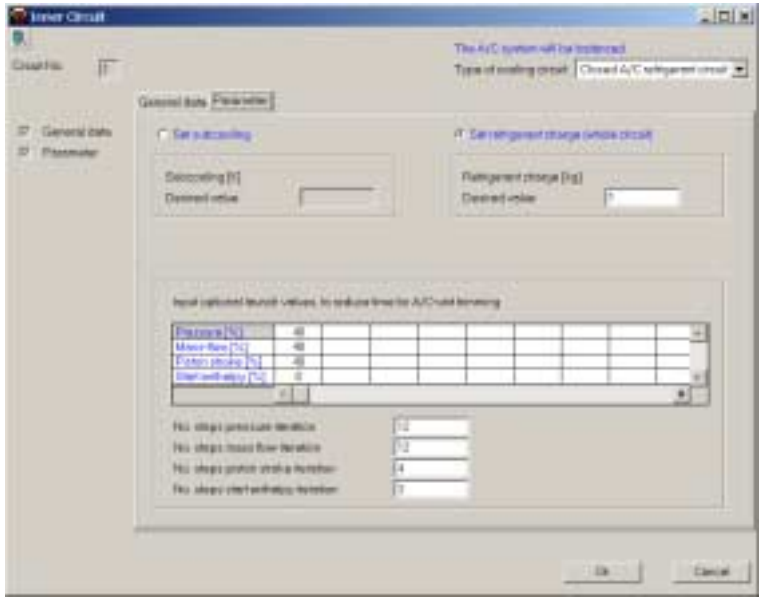


New: Component Connection by Clicking

Refrigerant Circuits





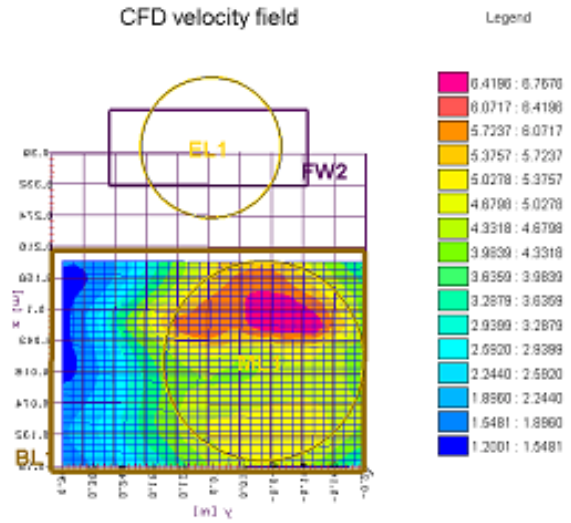


Open: Inlet properties

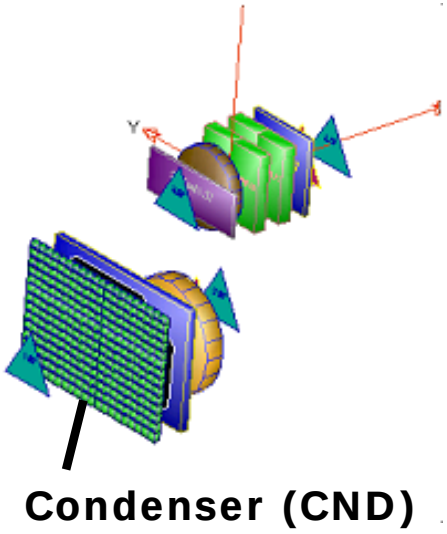
Closed: Equalization

Air Flow

Inhomogeneous Velocity Distribution

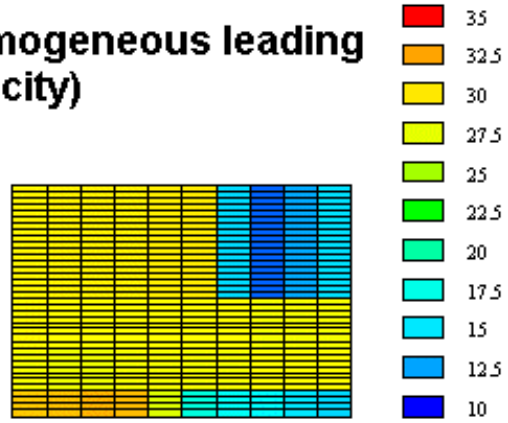


Resistance Matrix



CND Performance [W]

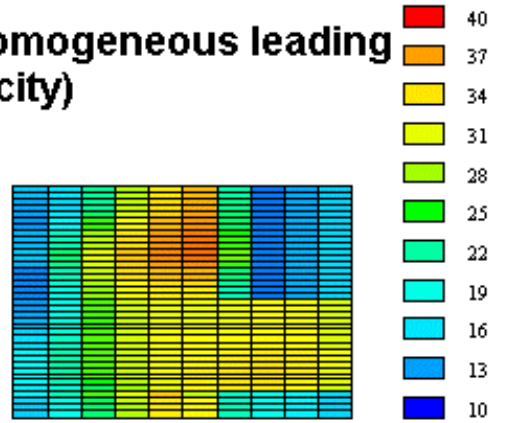
(homogeneous leading velocity)



Difference

CND Performance with CFD [W]

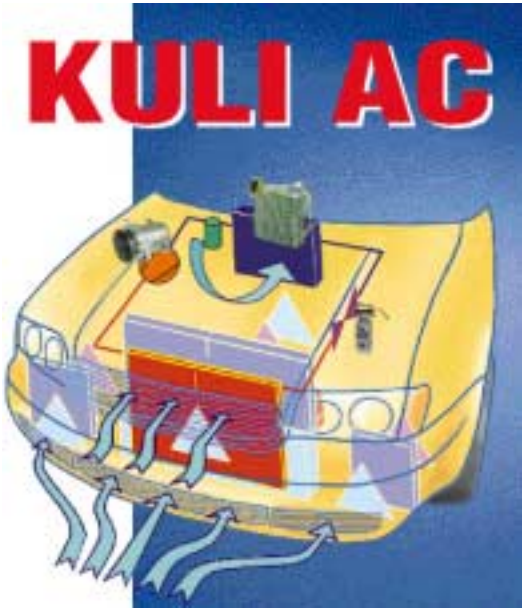
(inhomogeneous leading velocity)



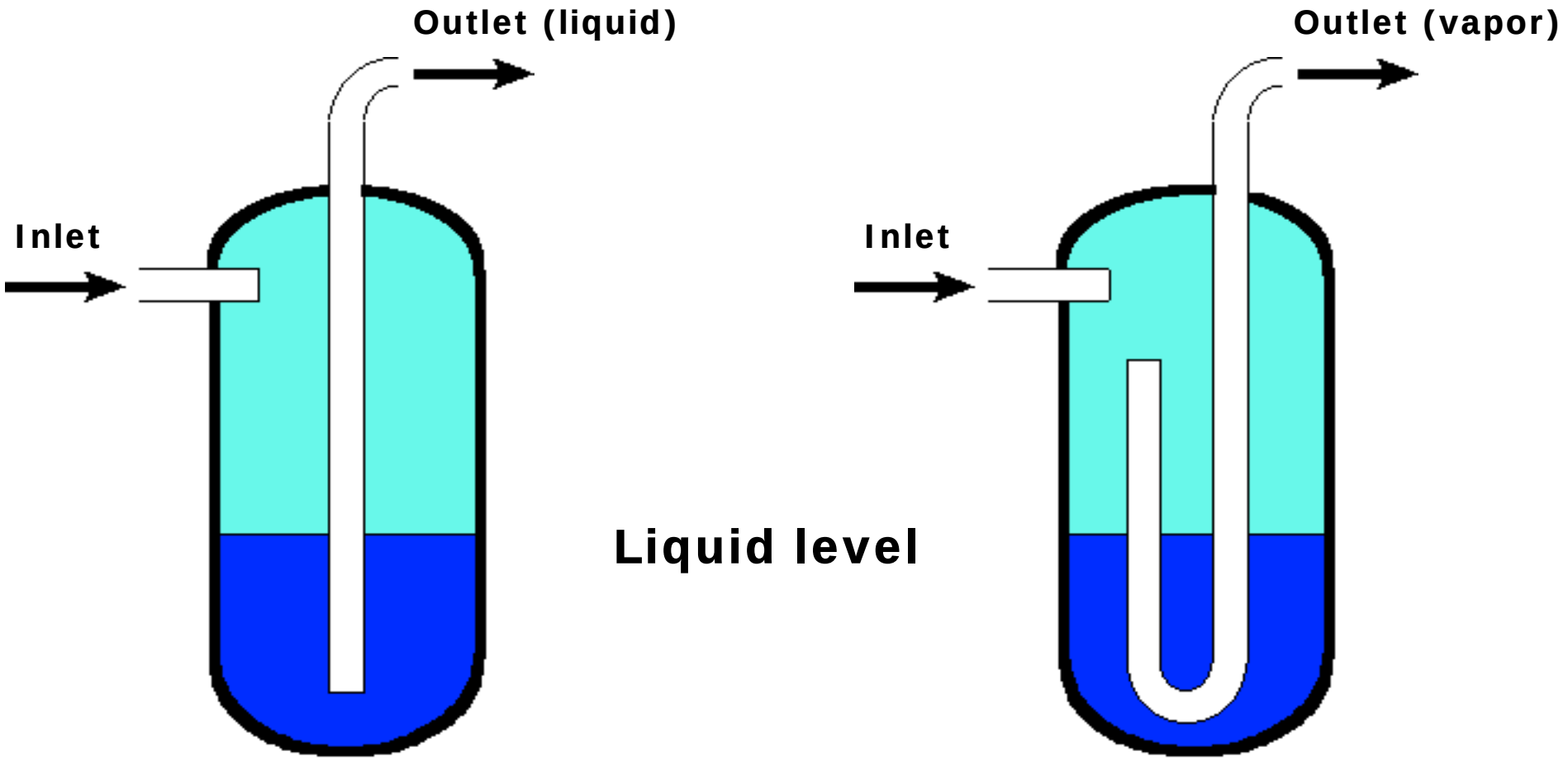
CFD-Interface: Consider Inhomogeneous Velocity Distributions

Overview

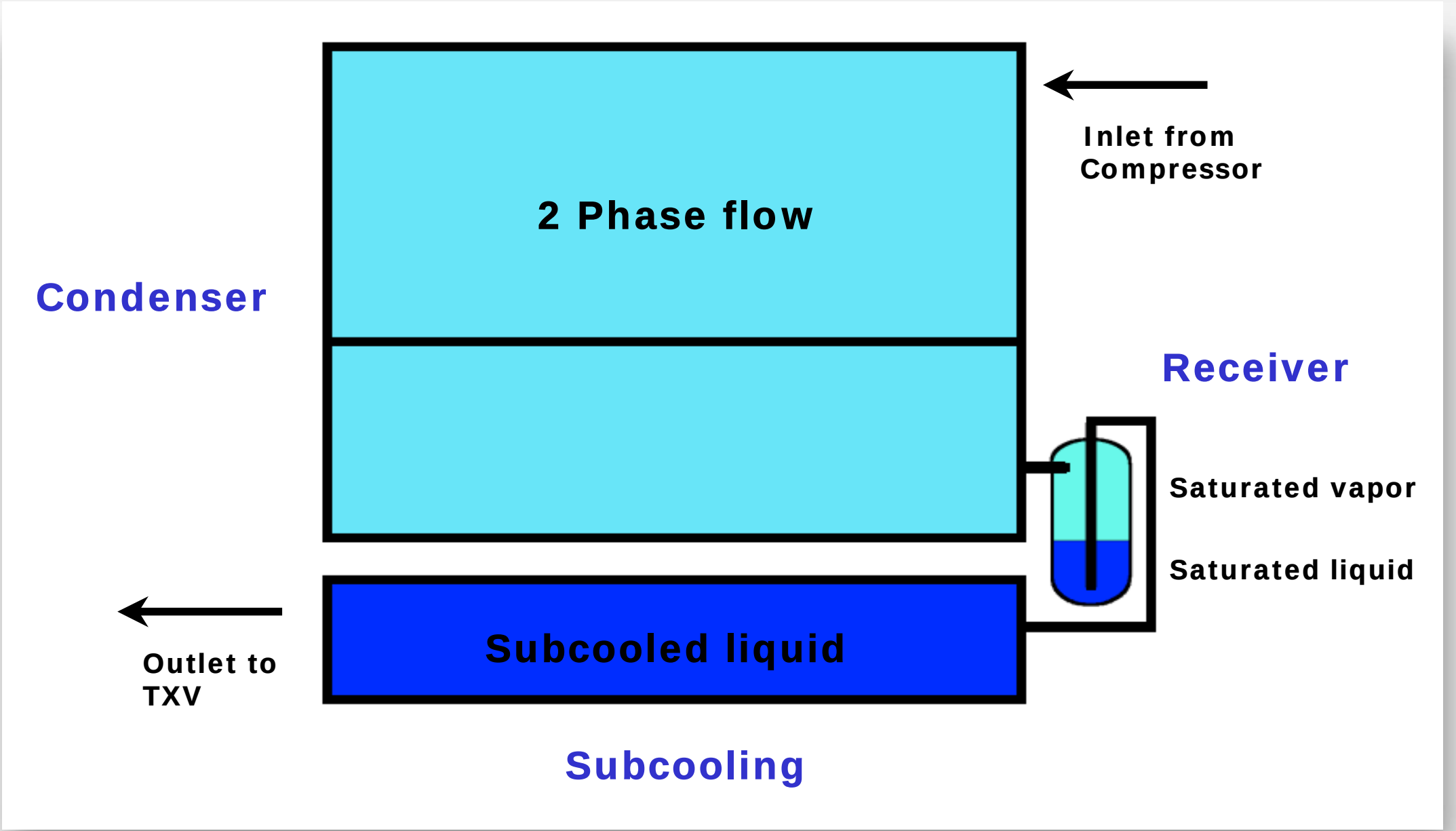
- Overview KULI AC
- **KULI AC, new Components**
- Technical Specification
- Practical Application
- Further Development



Storage Model

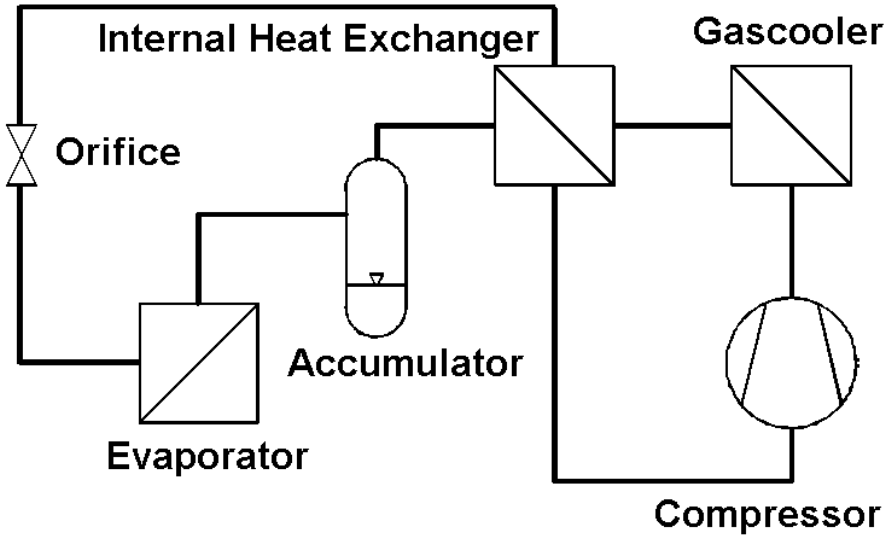


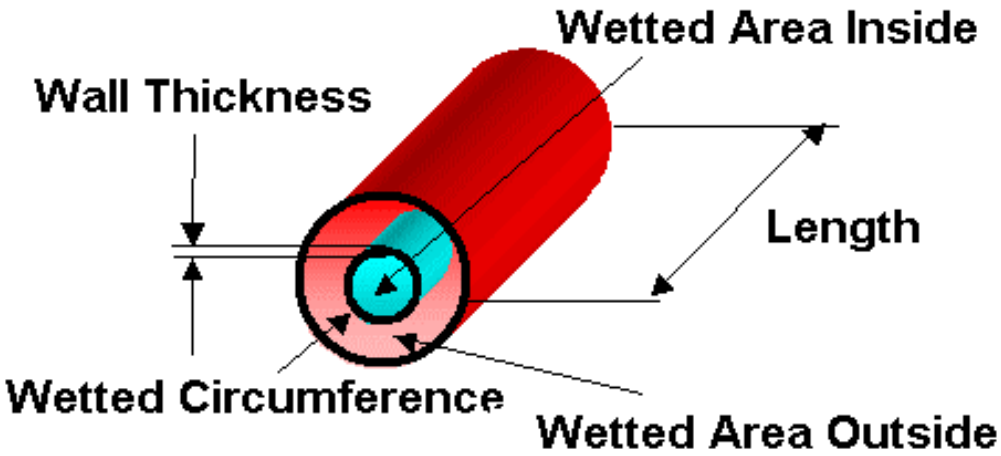
Integrated Receiver



PFC (SLHX)

Internal Heat Exchanger (SLHX)



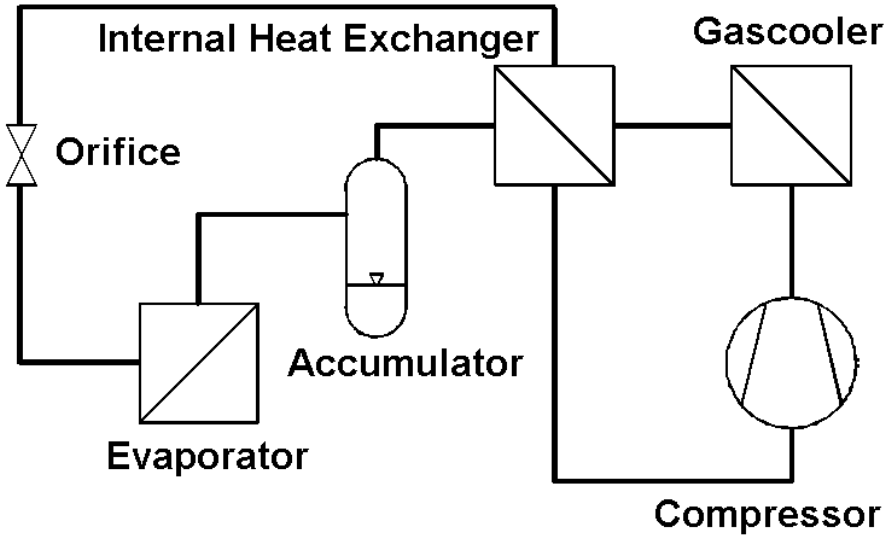


CO_2 Refrigerant Circuit

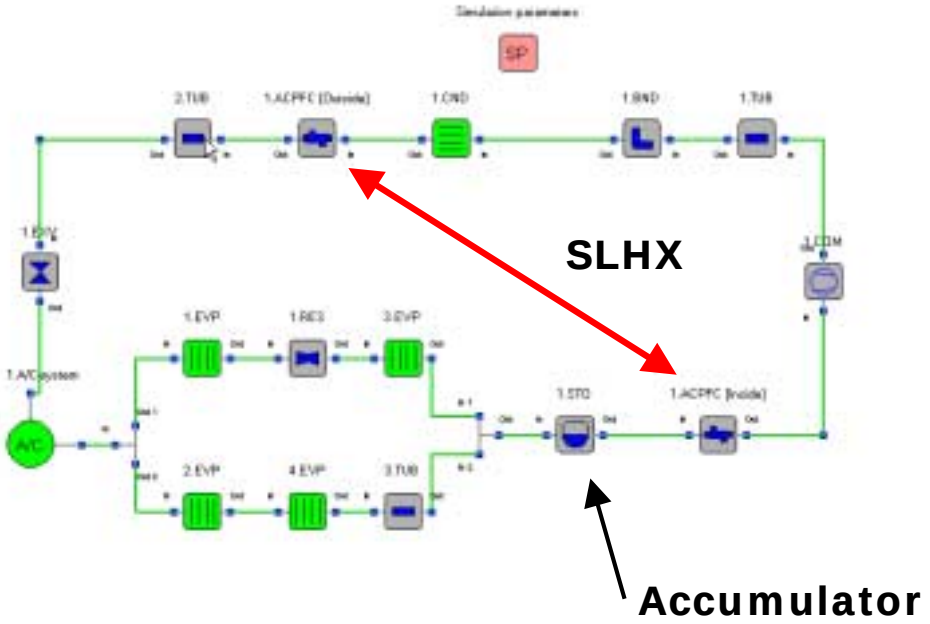
Geometric Based Model

PFC (SLHX)

Internal Heat Exchanger (SLHX)



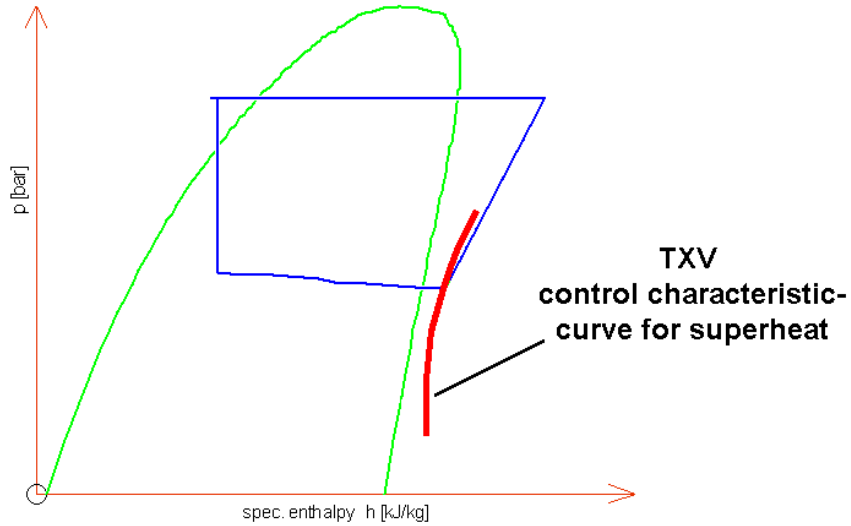
CO_2 Refrigerant Circuit Layout

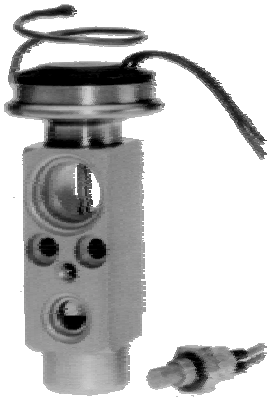


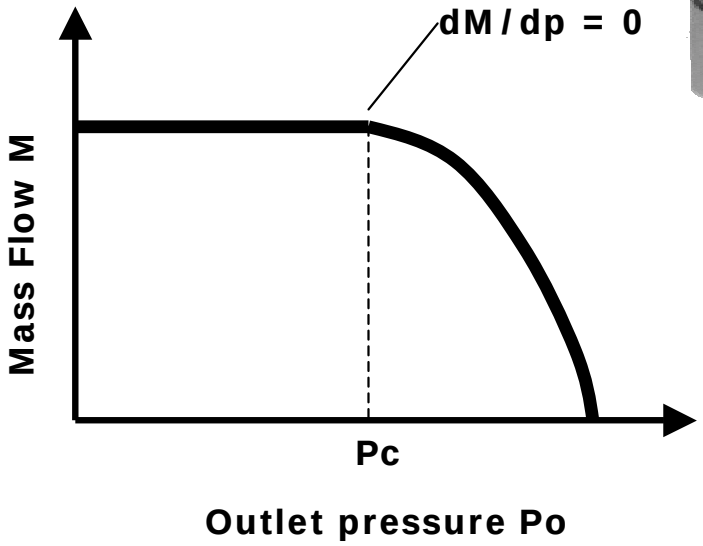
KULI Layout

Expansion Device

- Thermostatic Controlled Expansion Valve (TXV)
- Uncontrolled Orifice





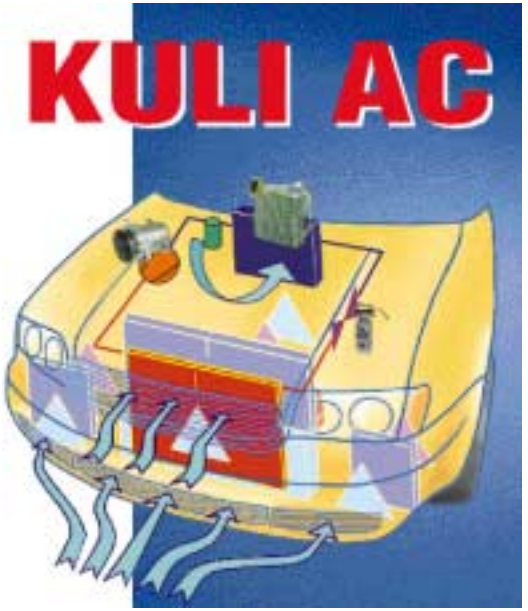


TXV: Characteristic Curve for Superheat

Orifice: Critical Mass Flow Calculation

Overview

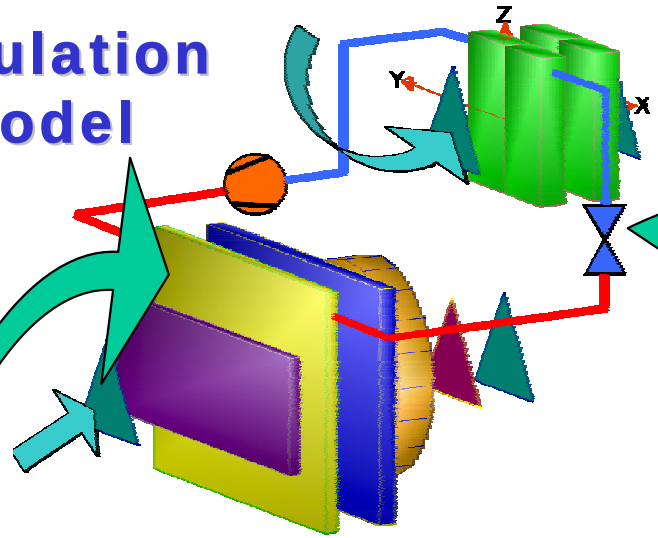
- Overview KULI AC
- KULI AC, new Components
- **Technical Specification**
- Practical Application
- Further Development



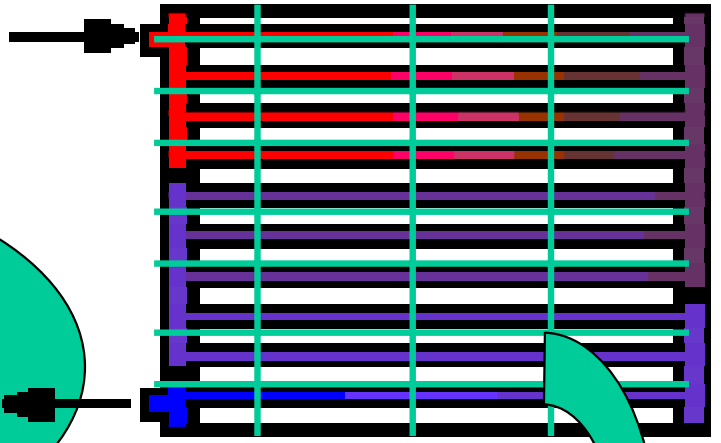
Heat Exchanger

Heat Exchanger Model

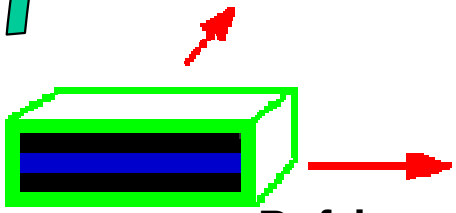
Simulation Model



Solver



Air Out



Refrigerant Out

Refrigerant In

Air In

$$dp_{\mathrm{Re}\ frigerant} = f\ (\text{Air Inlet, Refrigerant Inlet})$$

$$dh_{\mathrm{Re}\ frigerent} = f\ (\text{Air Inlet, Refrigerant Inlet})$$

$$dt_{Air} = f\ (\text{Air Inlet, Refrigerant Inlet})$$

$$dx_{Air} = f\ (\text{Air Inlet, Refrigerant Inlet})$$

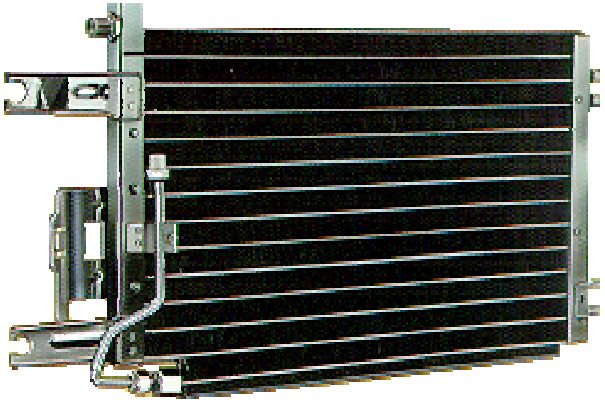
Return Results

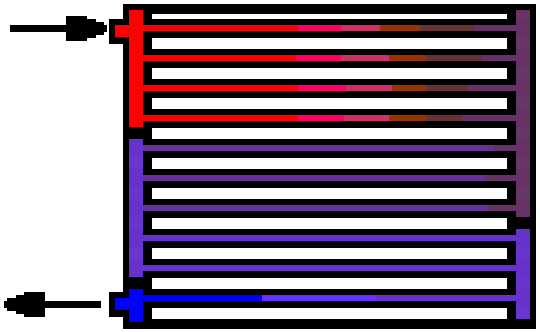
Element - Analysis

Dividing into Single Elements

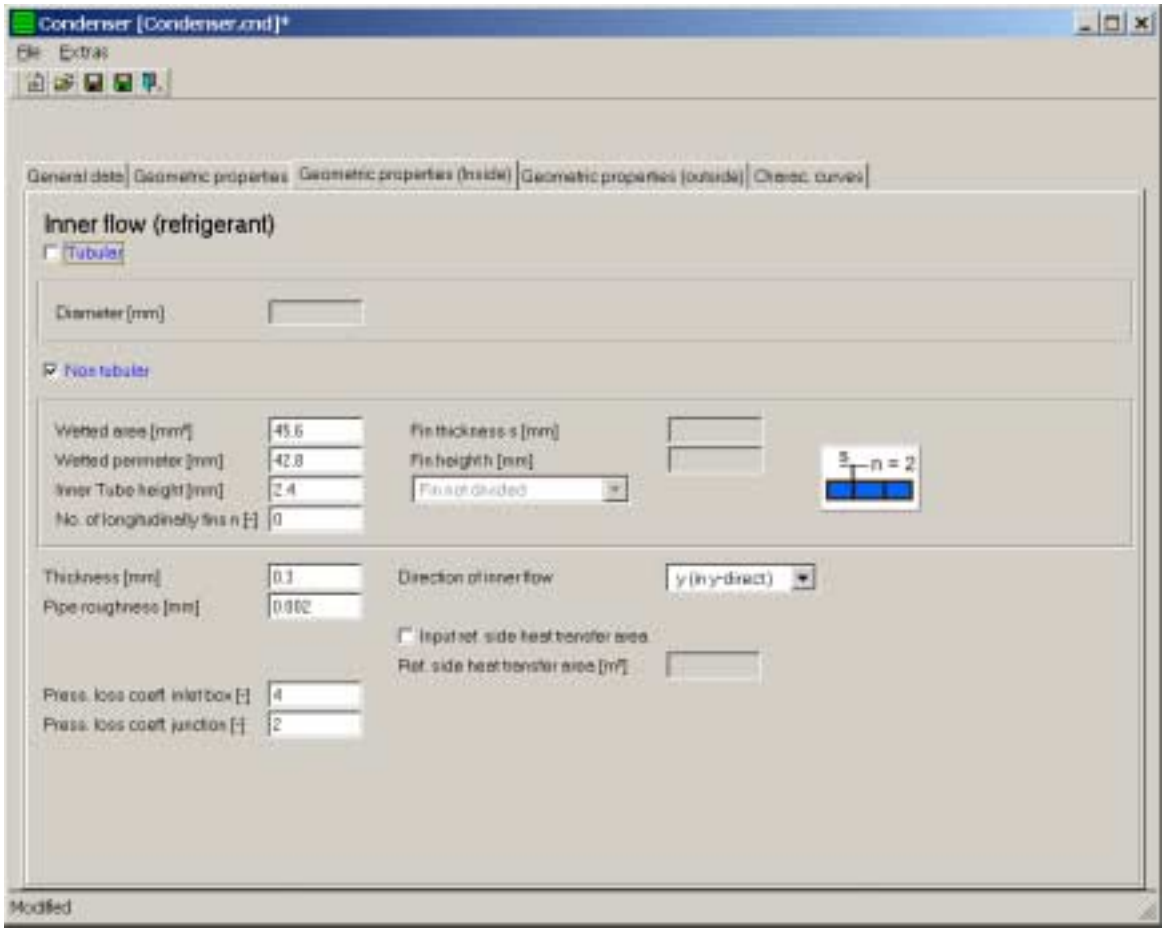
Condenser / Evaporator

Hardware

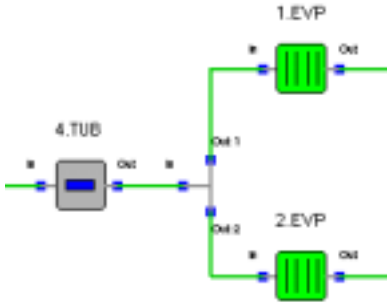


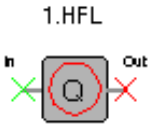


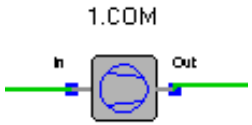
Simulation Model: Based on Geometric Properties

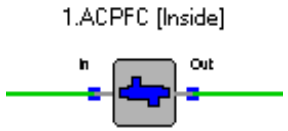


Components





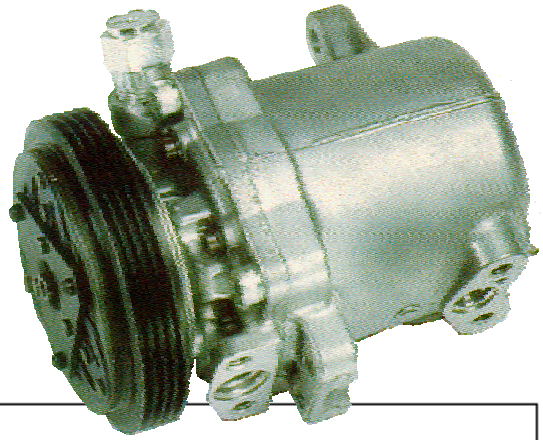


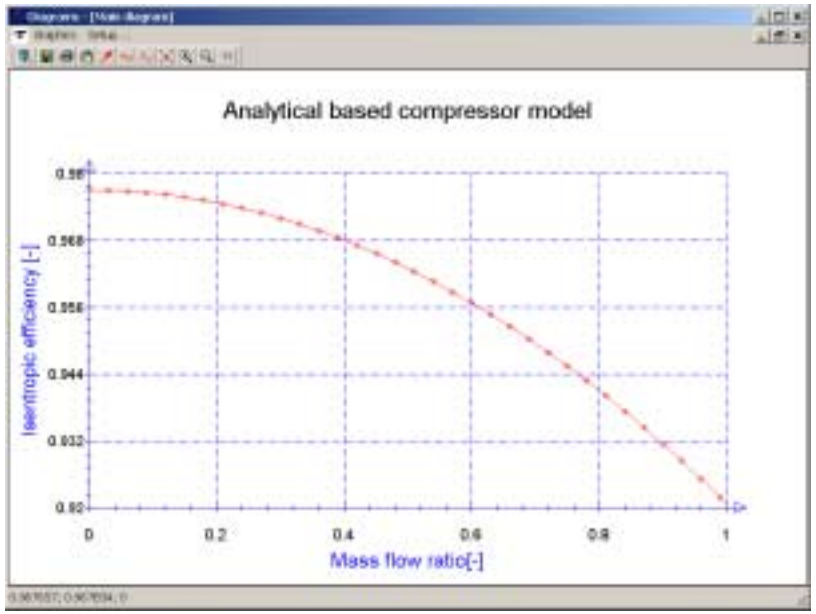


- **Tubes, Bends, Manifolds**
- **Heat Sources**
- **SLHX (Parallel Flow)**
- **Compressor (Controlled / Uncontrolled)**
- **TXV, Orifice**
- **Condenser / Evaporator**
- **User-Defined External Component (using COM Interface)**

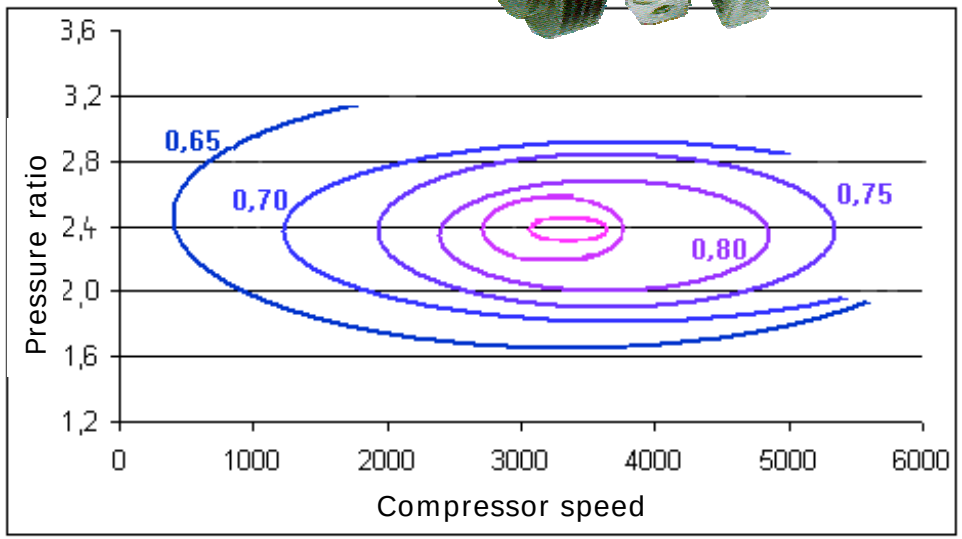
Compressor

- Based on Characteristic Curves
- Based on an Analytical Model



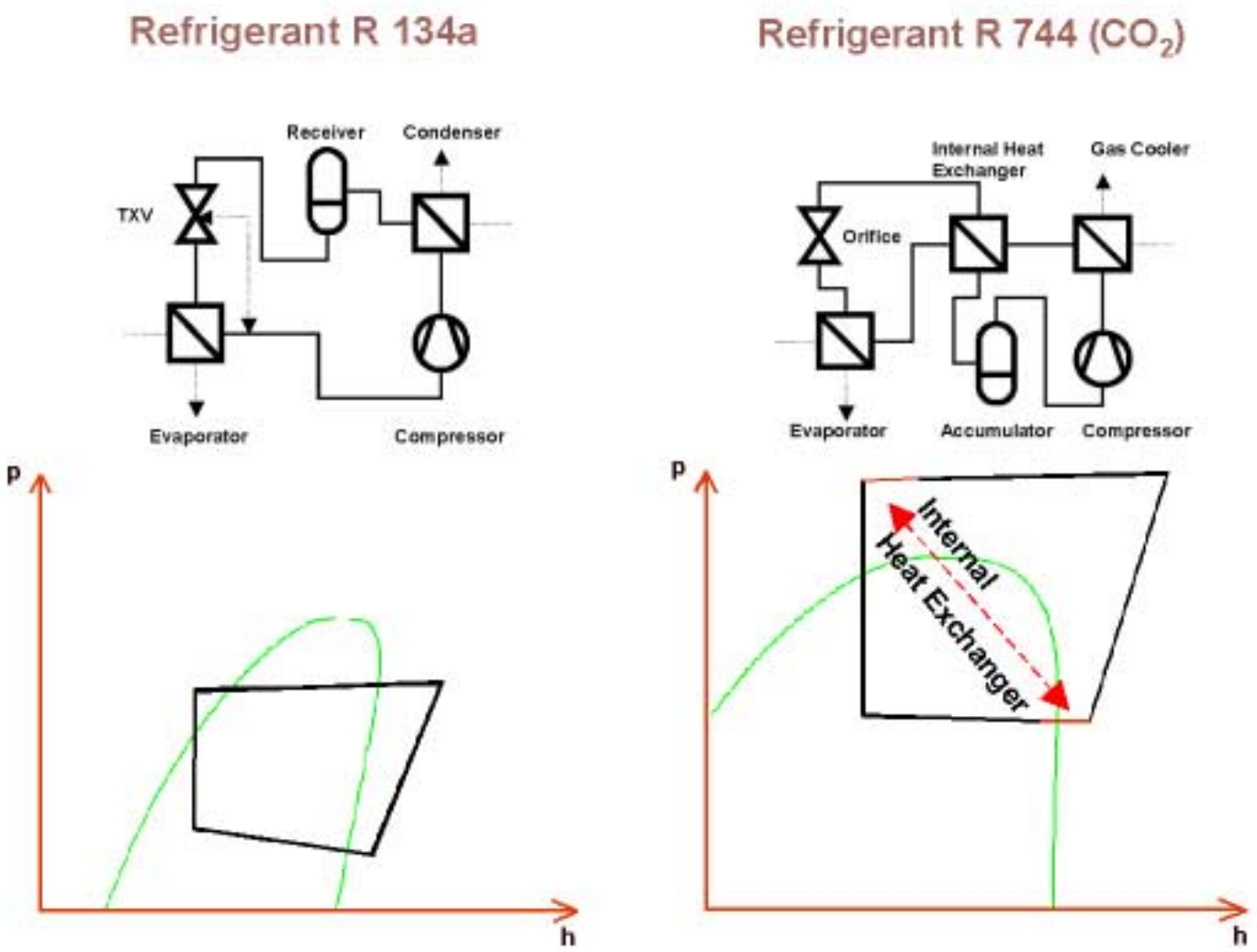


Isentropic Efficiency Formula



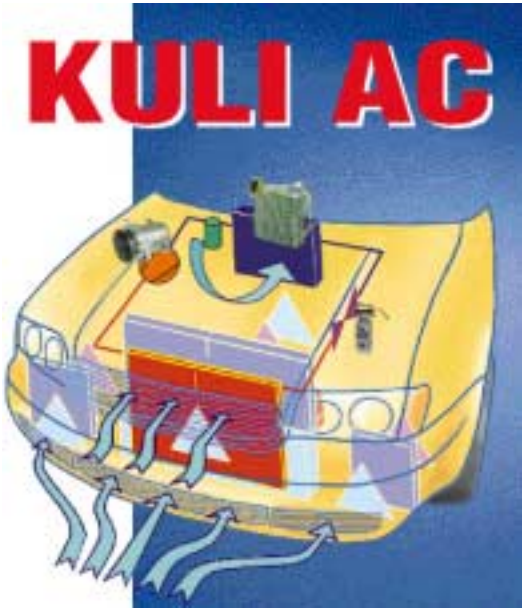
Measured Isentropic Efficiency Map

Comparison R134a-CO_2



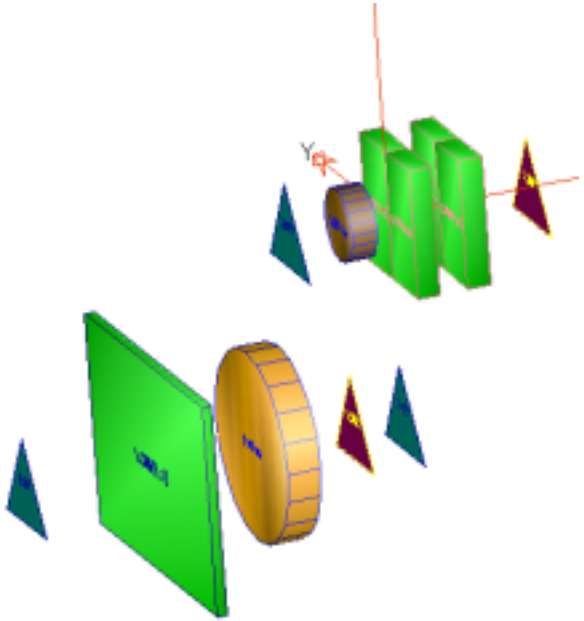
Overview

- Overview KULI AC
- KULI AC, new Components
- Technical Specification
- **Practical Application**
- Further Development



Application

General Data



- 1000-3500 RPM Compressor Speed
- R744 Refrigerant (CO_2)
- Orifice with Accumulator and SLHX
- Ambient Temperature 30°C, 40% Humidity
- Compressor with Outlet-Pressure Control

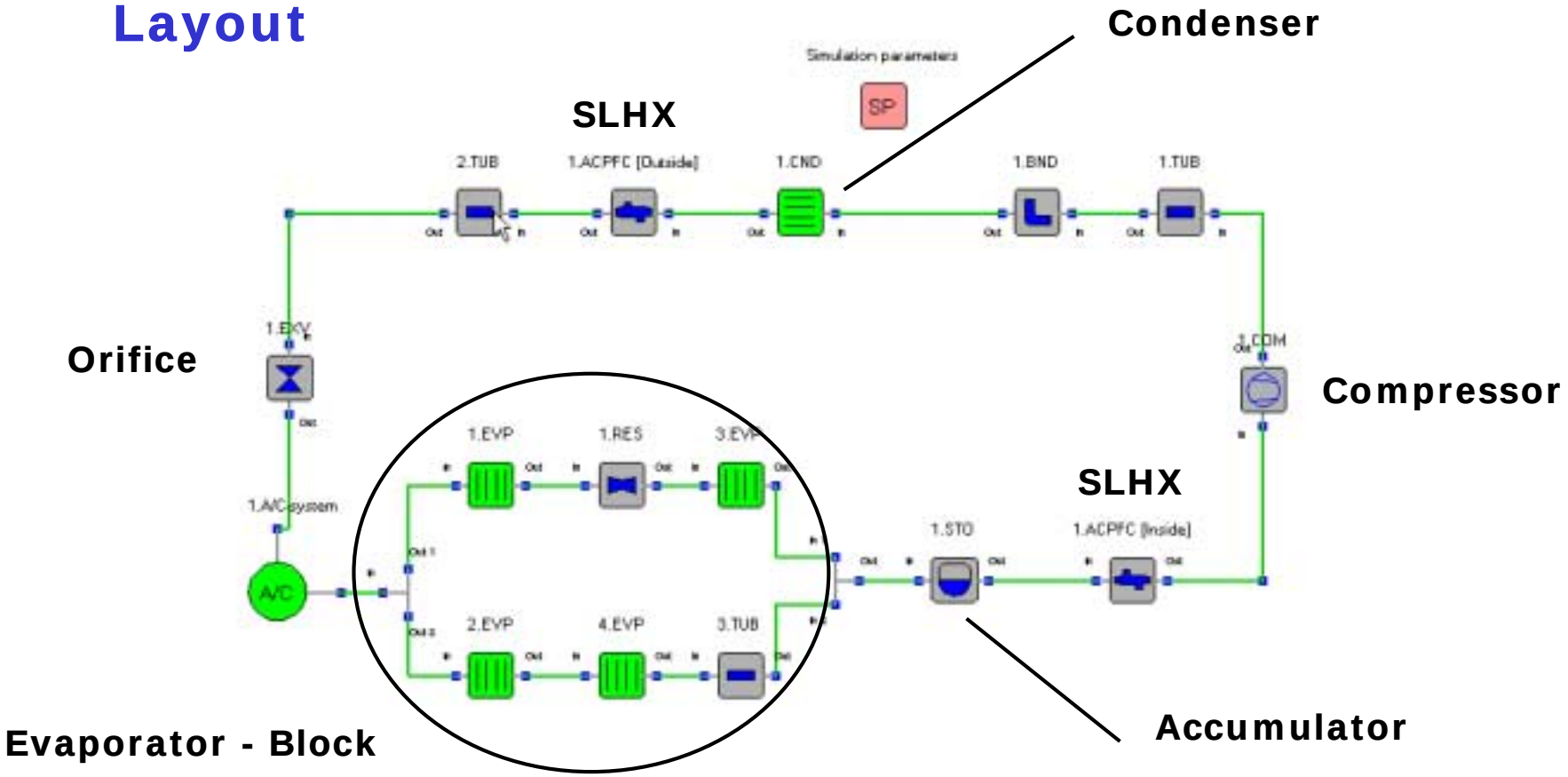
Application

Geometric Data

- Condenser: 600x410x20 mm, 4 Pass, 37 Tubes
- Evaporator: 250x250x90 mm, 4 Pass, 36 Tubes (Plate Type)
- Compressor Piston Displacement 30 cm^3
- Orifice Expansion Device (with Accumulator)
- Pipes according their Geometry (length, diameter)

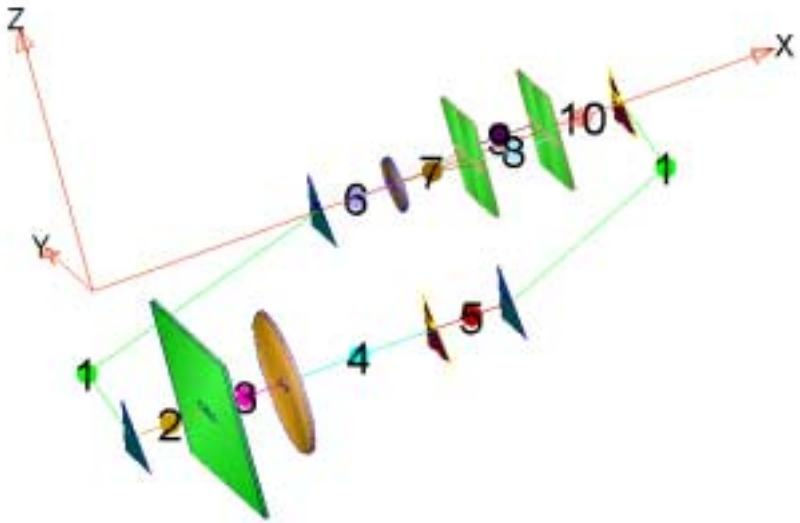
Application

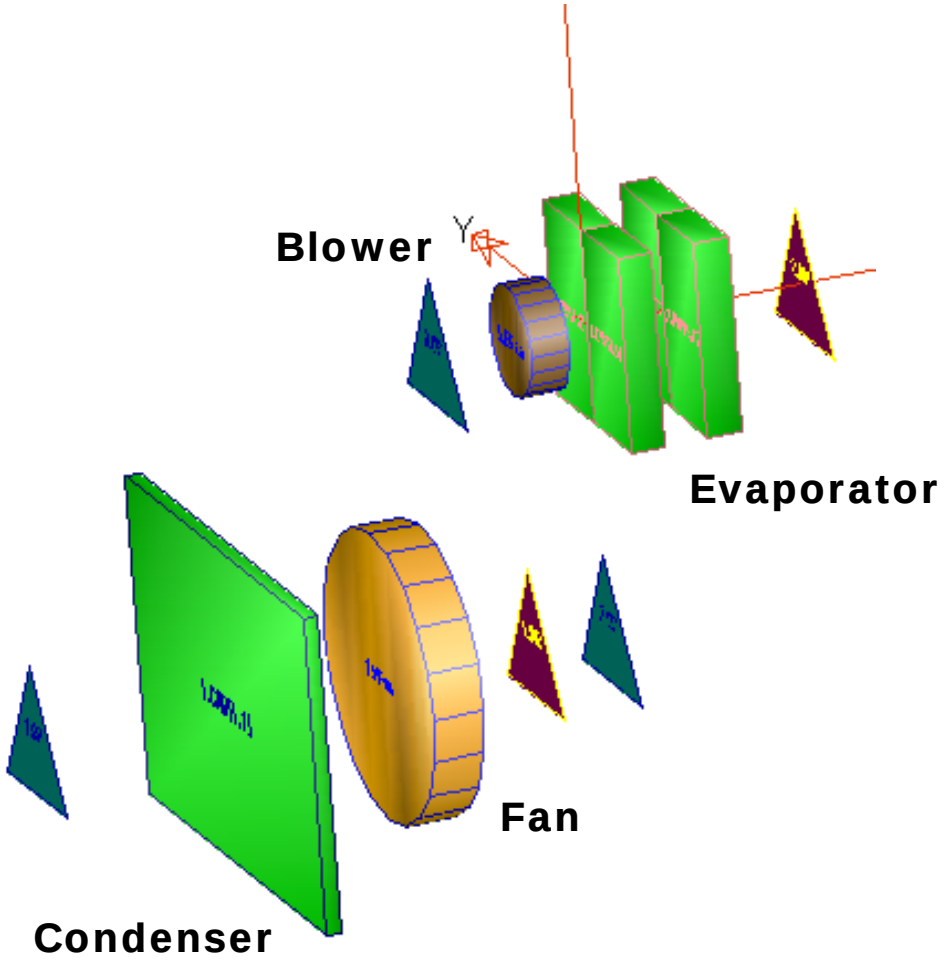
Refrigerant Circuit Layout



Application

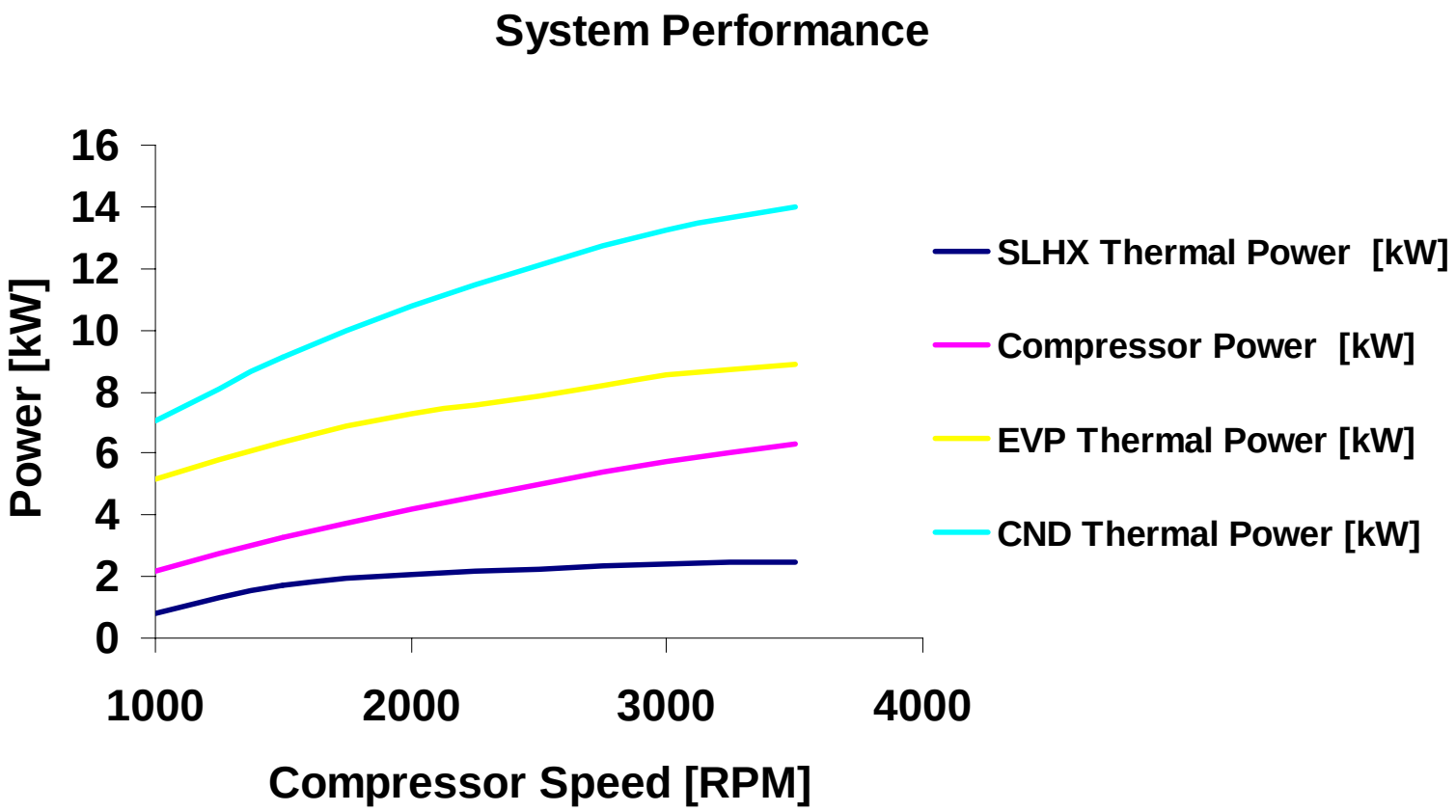
Air Network Layout





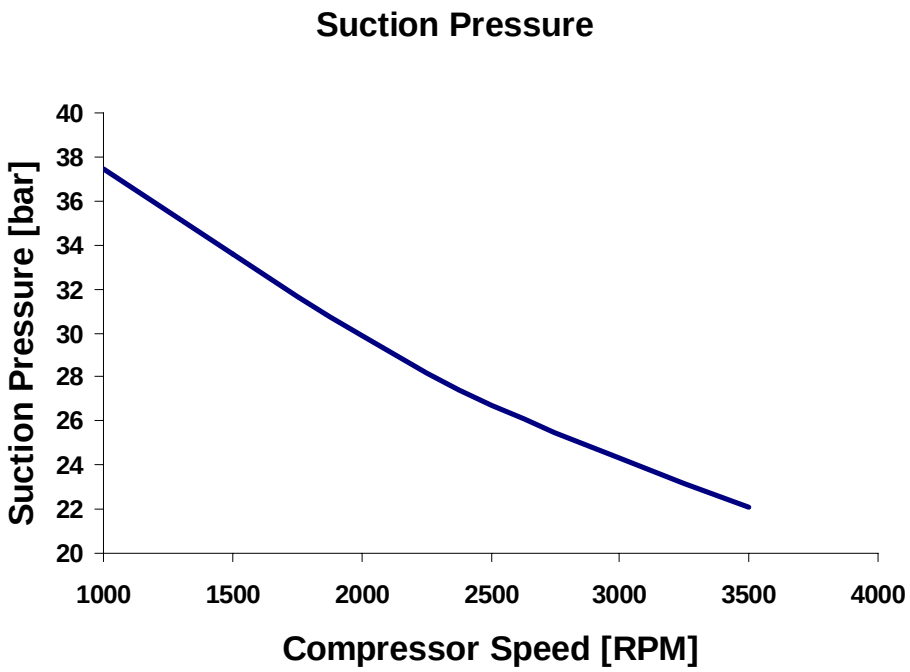
Results

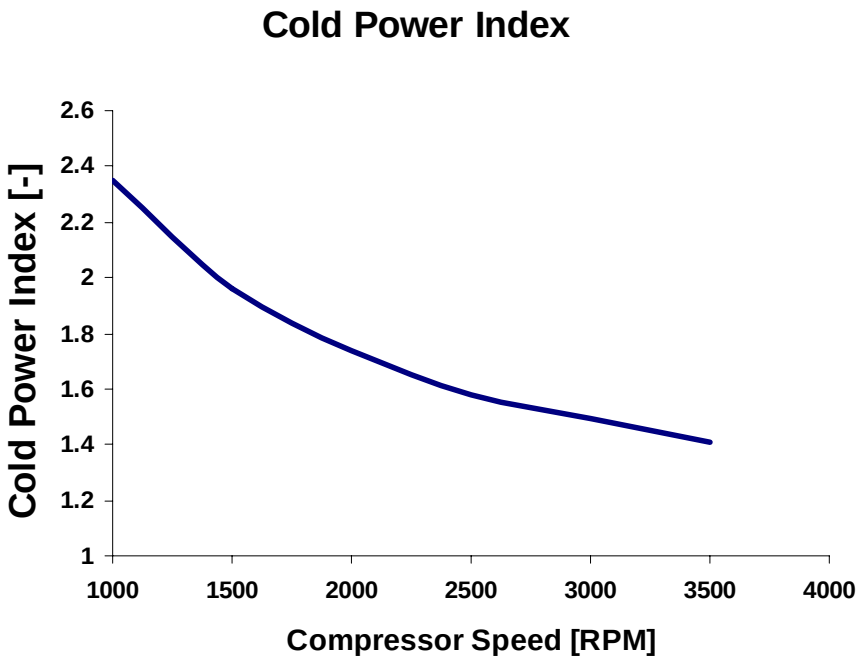
System Performance



Results

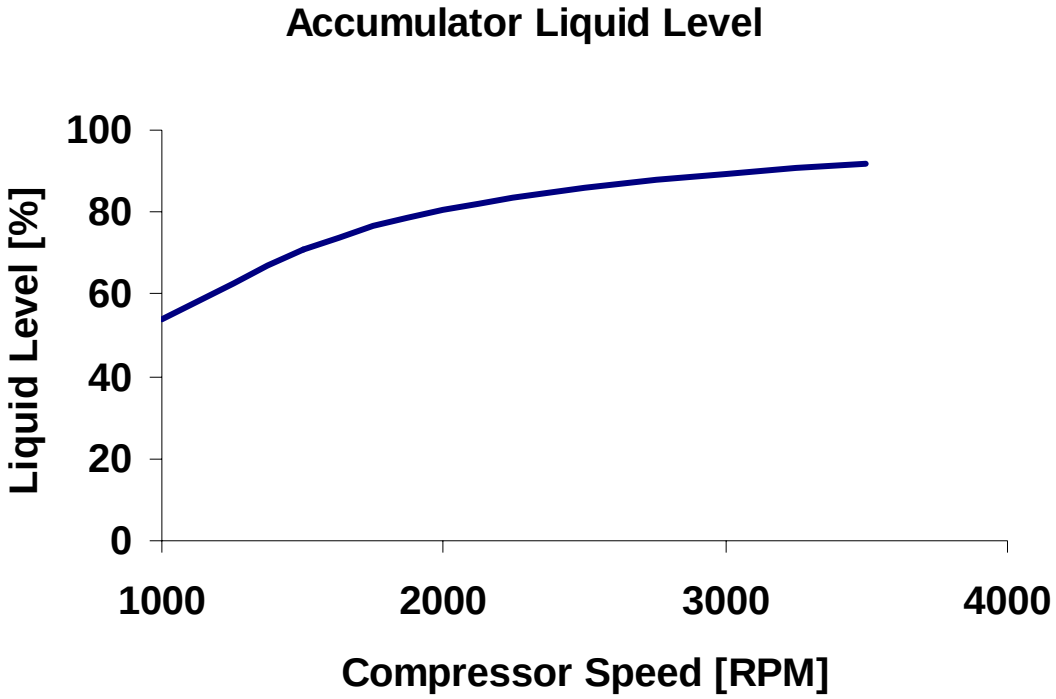
System Performance

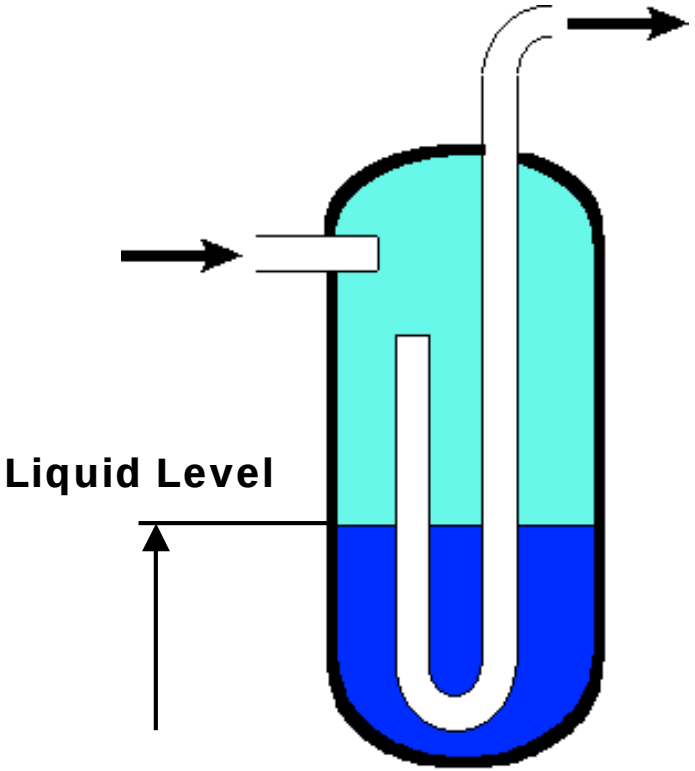




Results

System Performance

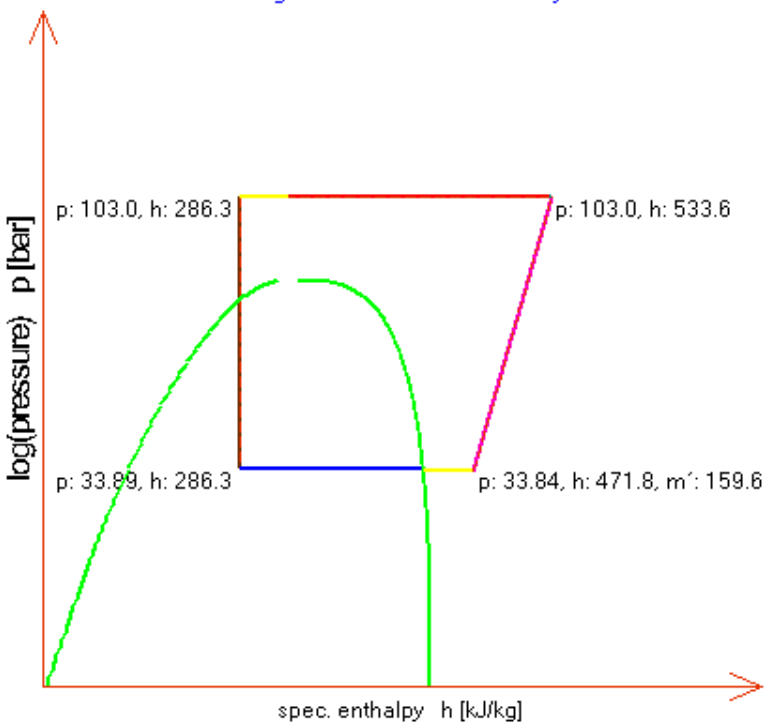




Results

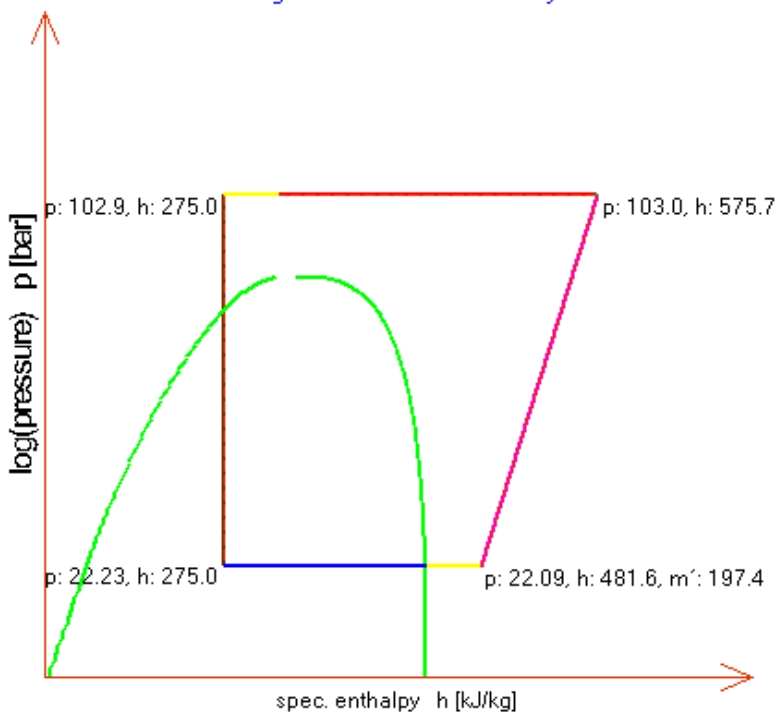
System Performance

A/C-unit iteration no.: 6
Status balancing : A/C-unit successfully balanced !



1500 RPM

A/C-unit iteration no.: 4
Status balancing : A/C-unit successfully balanced !

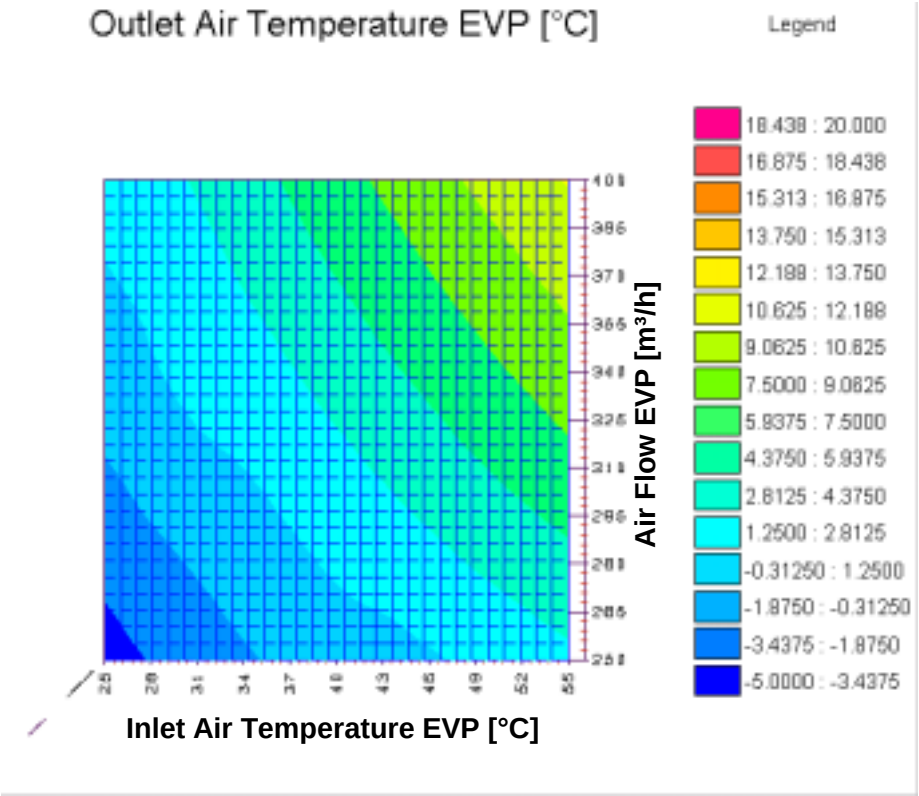


3500 RPM

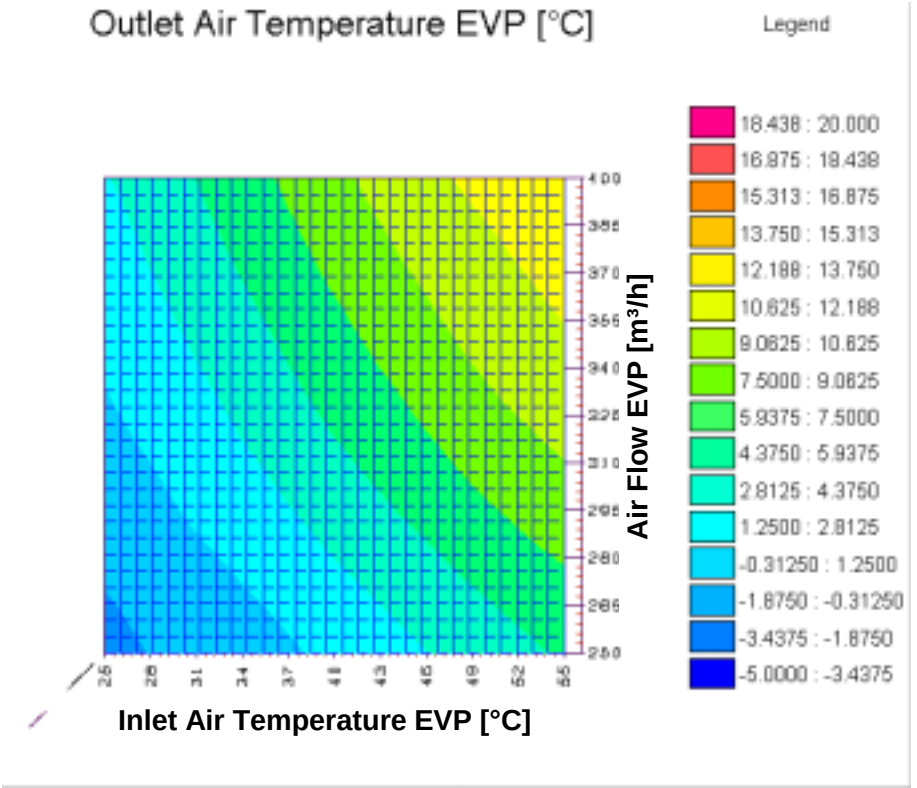
Results

Evaporator Outlet Air Temperature

45°C Ambient Temp.

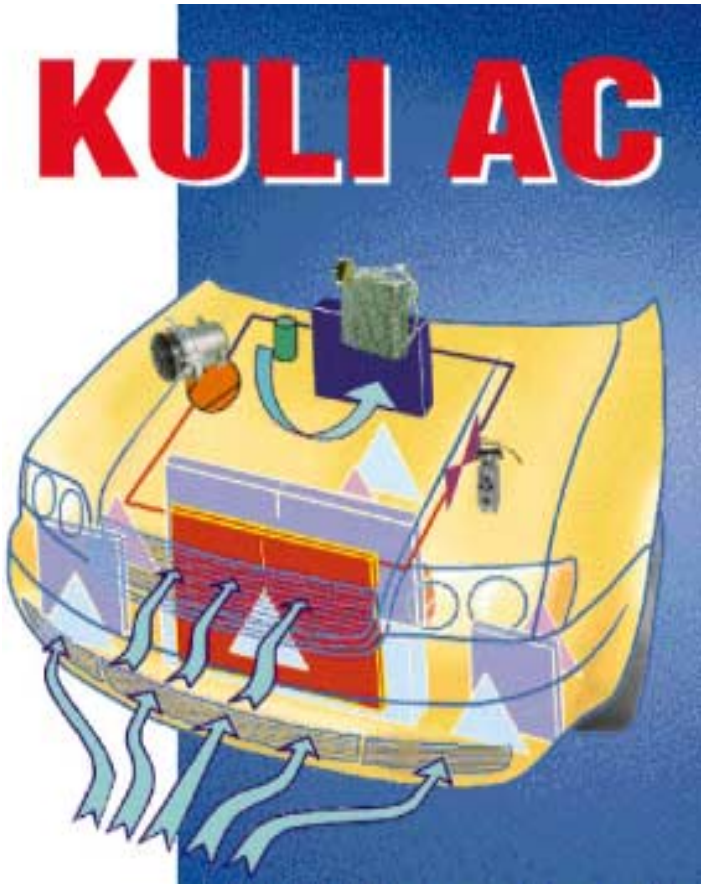


55°C Ambient Temp.



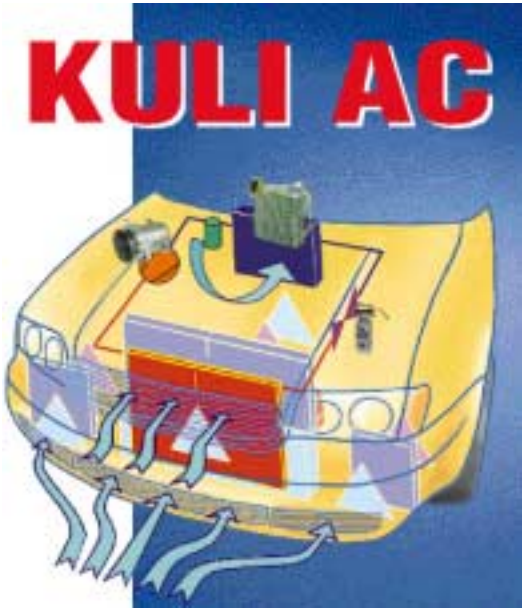
Analysis Results

- Pressures, Temperatures (air / refrigerant)
- Refrigerant Enthalpy, Vapour Quantity
- Mass Flows (air, refrigerant)
- Heat Flows for Evaporator, Condenser, Tubes
- Condensate separation at the Evaporator
- Accumulator Liquid Level
- Required Compressor Power, ….



Overview

- Overview KULI AC
- KULI AC, new Components
- Technical Specification
- Practical Application
- **Further Development**



Further Development

- Continue the Cooperation with TU-Graz (Institut für Wärmetechnik)
- Extended Heat Transfer Models (refrigerant / air)
- Extended Analysis Models for Pressure Loss Calculation
- More Accurate Consideration of the Lubricant Oil
- Improved Analytically-Based Compressor Model
- Graphical User Interface (GUI) Improvements

Summary

- Design of all possible Configurations of the Air and Refrigerant Flow Network
- Special Models for Receiver and Accumulator
- High Pressure Control for CO_2 Circuits
- Analysis Models supplied for R134a and R744 (CO2) Refrigerants
- Possibility to take an Inhomogeneous Velocity Distribution into Consideration (CFD-Interface)

The End

Thank You For Your Attention

Thomas Anzenberger,

and the ECS-Steyr KULI Team