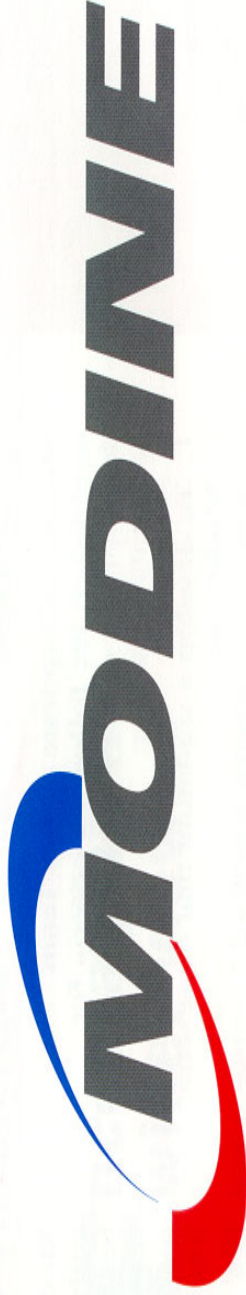


Concept Studies for Multi Radiator Cooling System

J.Nies B.Stephan W.Zobel

2nd Kuli User Meeting October 1999 / Steyr



Content

- ⌋ Introduction
- ⌋ External Flow Model
- ⌋ Internal Flow Model
- ⌋ Results
- ⌋ Conclusions

Introduction

- What is a multi radiator radial cooling system?
Any system where the cores are grouped around a radial fan
- Components of a multi radiator cooling system investigated here are:
 - 3 radiators
 - 1 'condensor'
 - 1 charge air cooler
 - 1 oil-water heat exchanger or 1 oil-air heat exchanger
 - 1 radial fan
 - n resistances

Introduction

Charge Air Cooler CAC

Air out

Air out

Radial Fan

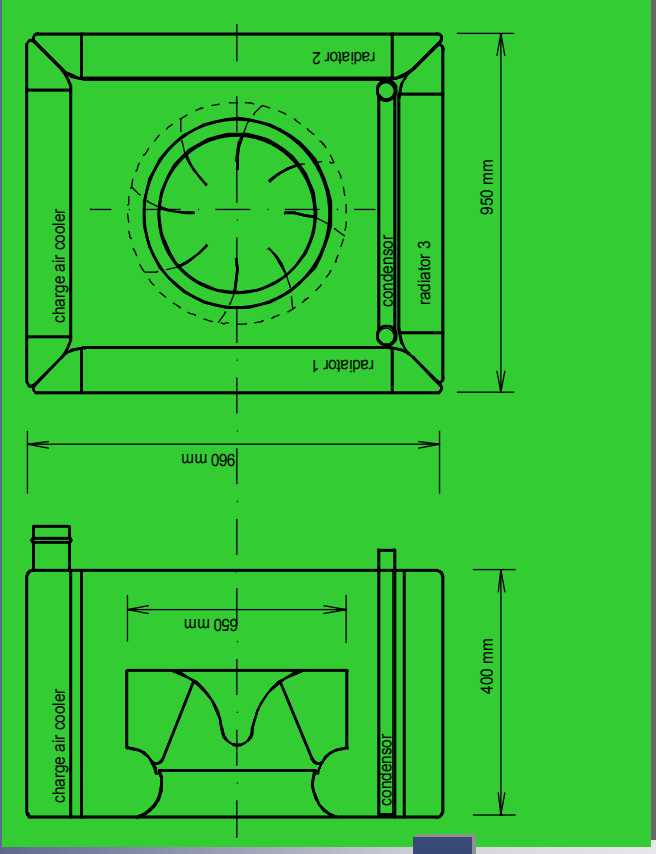
Air in

Air out

Radiators

Air out

Multi radiator radial cooling system



Introduction

- Multi radiator cooling systems allow several possibilities to connect the radiators
- Oil-Water heat exchanger can be implemented at different locations in the internal flow
- Condensor can be placed in front of any core
- Different fin tube combinations can be used for flow balancing
- Sensitivity of the system to area resistances

Content

⌋ **Introduction**

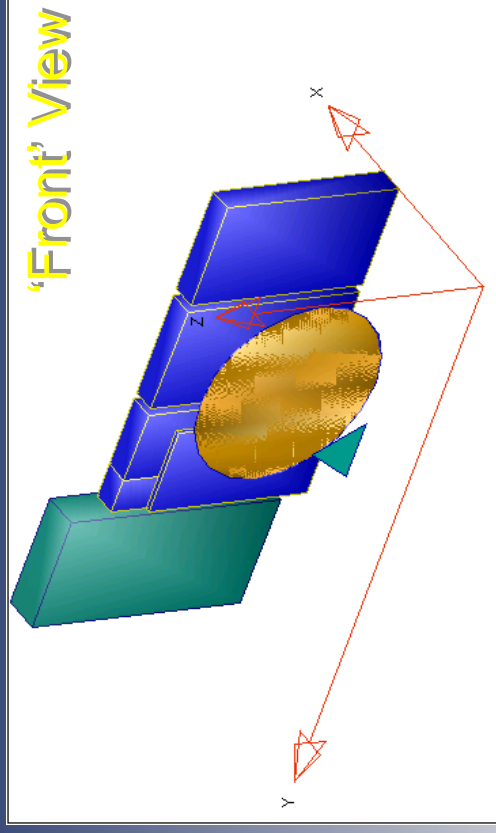
⌋ **External Flow Model**

⌋ **Internal Flow Model**

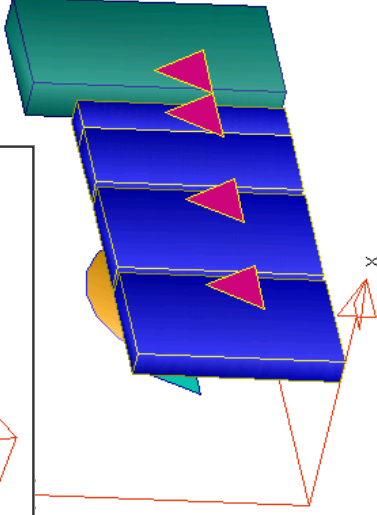
⌋ **Results**

⌋ **Conclusions**

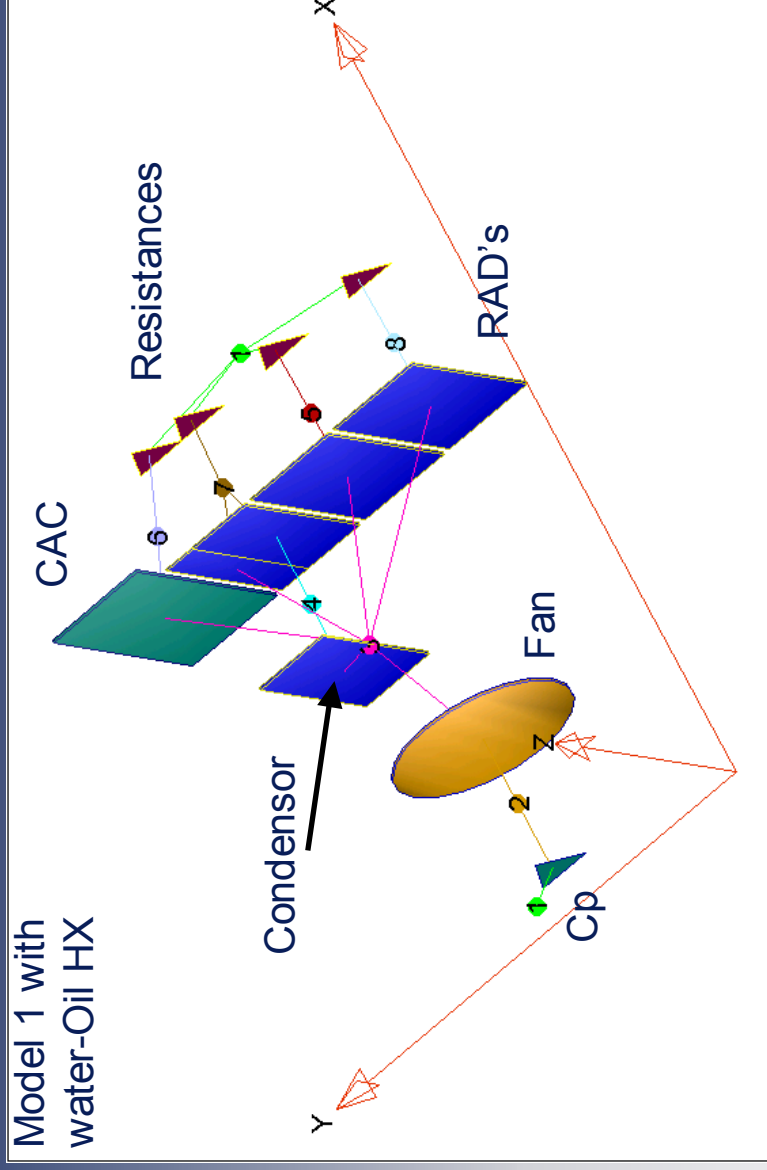
External Flow Model



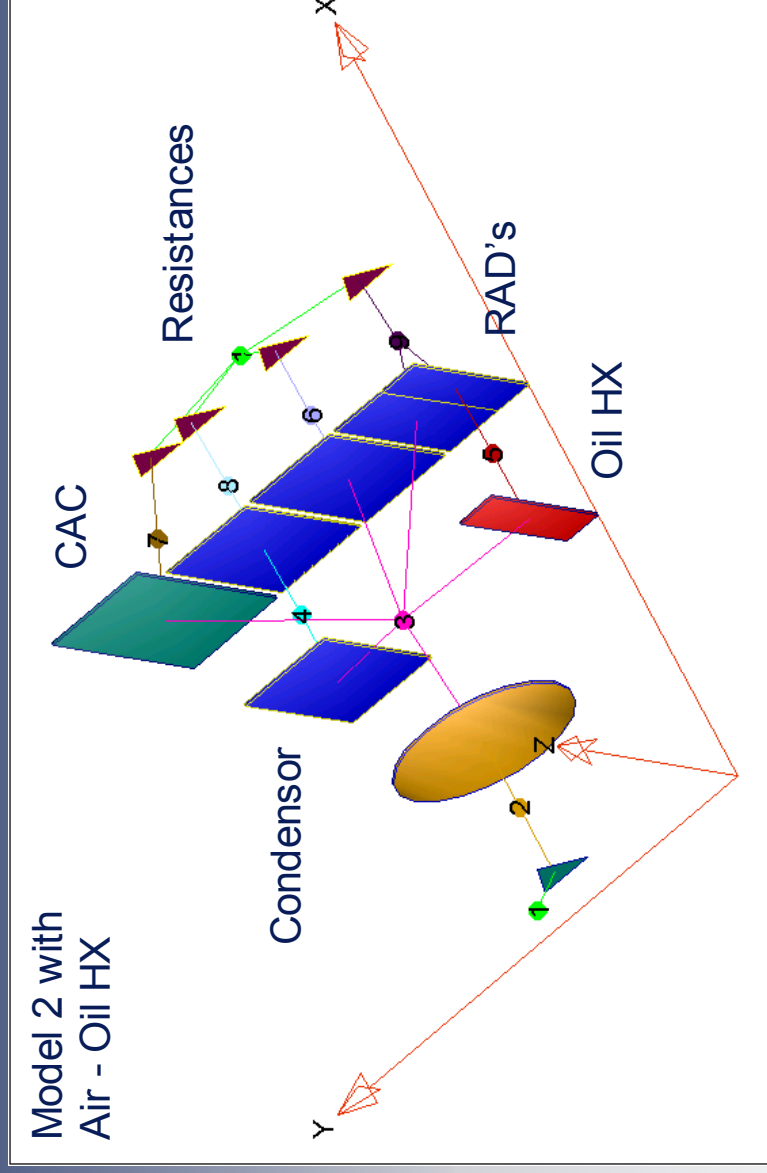
“Rear” View



External Flow Model



External Flow Model



External Flow Model

- The 'condensor' is simulated as a radiator with
 - a prescribed heat rejection into the air flow
 - an air side pressure drop identical to the fin tube combination of the real condensor
- The radiator behind the condensor is divided into two parts to simulate the smaller cross section area of the condensor
- The built in resistances are taken from known and similar applications (or CFD)
- Recirculation or inhomogenous flow distribution over the core areas are not taken into account

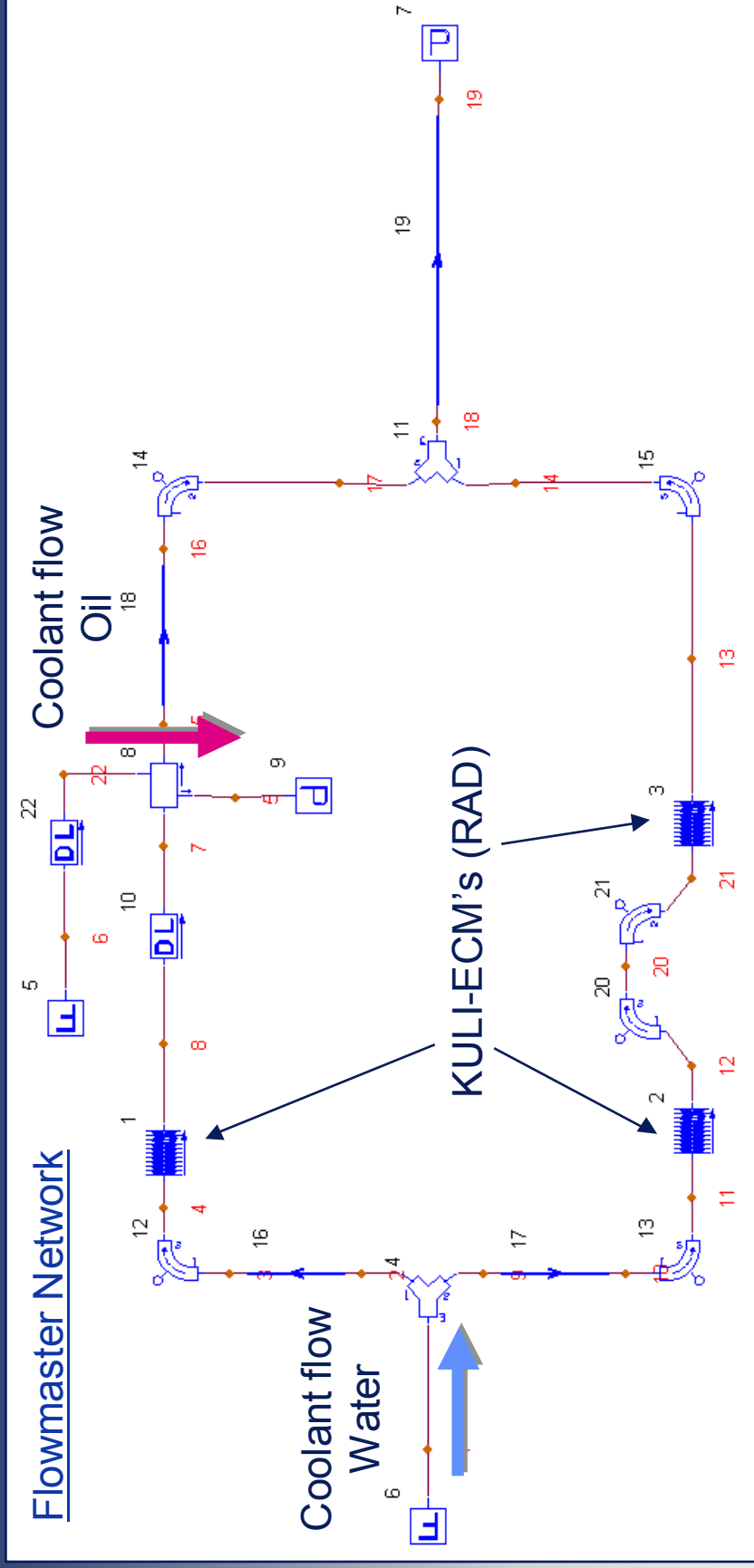
Content

- ⌋ **Introduction**
- ⌋ **External Flow Model**
- ⌋ **Internal Flow Model**
- ⌋ **Results**
- ⌋ **Conclusions**

Internal Flow Model

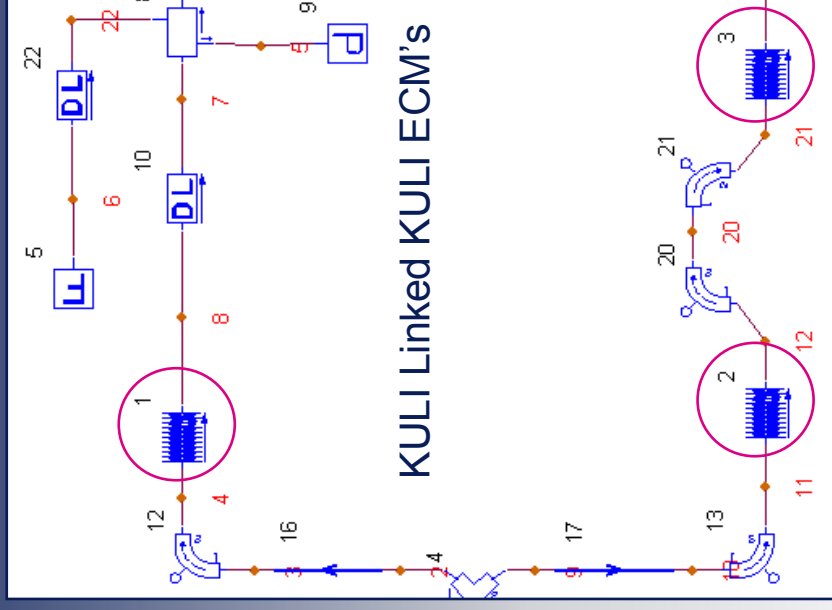
- The internal flows are simulated using Flowmaster 2
- The simplified network is set up out of:
 - Flow/Pressure Sources for the coolant fluids
 - Pipes and junctions
 - KULI- ECM's
 - Heat exchanger thermal (water-oil HX)
 - Discrete loss (water-oil HX)
- Steady state analysis with heat transfer

Internal Flow Model



Internal Flow Model

Isystems									
Allgem. Daten		Komponenten		Simul.-Param.		Innere Kreisl.			
Kenng.	Breite [mm]	Höhe [mm]	Tiefe [mm]	Pos X [mm]	Pos Y [mm]	Pos Z [mm]	FMID		
1.WK	355	675	86	500	0	0	1	3	2
2.WK	355	675	86	500	400	0			
3.WK	355	675	86	500	800	0			
4.WK	343	615	16	400	800	0			
2.LLK	392	760	129	500	1200	0			
1.ML	664	664	0	300	600	325			
1.FW	203	100	10	500	-600	300			
2.FW	465	465	10	700	0	325			
3.FW	440	440	10	750	400	325			
4.FW	465	465	10	700	800	325			
5.FW	435	435	10	750	1200	200			
6.FW	497	497	10	80	300	200			
7.FW	497	497	10	140	300	150			
8.FW	2086	200	10	350	-300	300			
1.CP	1	1	1	10	600	325			
2.CP	1	1	1	1000	600	300			



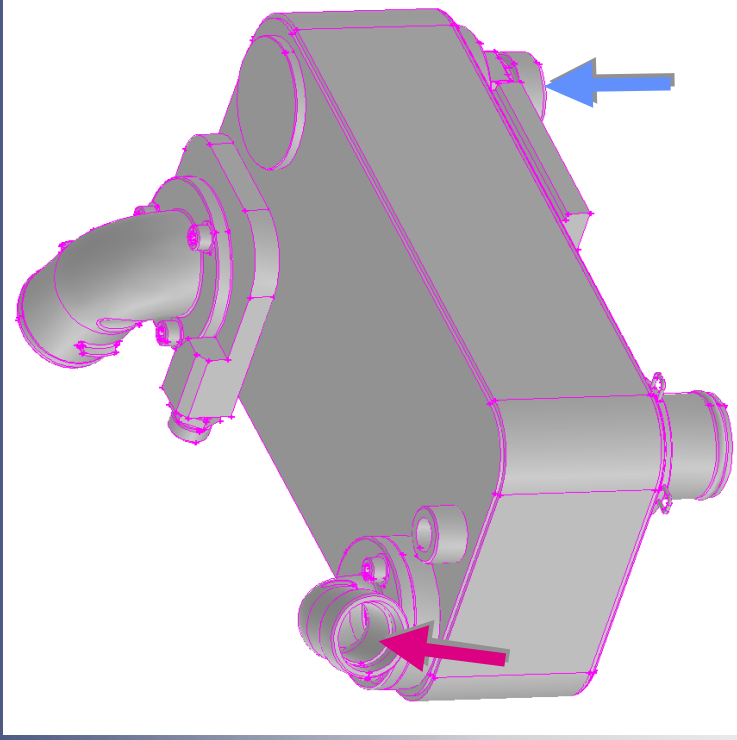
Internal Flow Model

- Boundary conditions for internal flows are defined in Flowmaster
- Heat exchanger characteristics (ECM) are defined in KULI

The screenshot displays the Flowmaster software interface. The main window is titled 'Innerer Kreislauf' (Inner Loop). The 'Kreislauf Nr.' (Loop No.) is set to 2, which is circled in red. The 'Komponenten' (Components) tab is selected, showing a list of components including 'WAK vor WAK+KOND', 'glys_b.dat', and 'Mischverhältnis [Vol%]' with a value of 50. The 'Status Durchsatz' (Status Flow Rate) and 'Status Temperatur' (Status Temperature) fields are also visible. In the background, a schematic diagram of a flow system is shown, featuring a central heat exchanger (labeled 2) connected to various pipes and components, with nodes numbered 1 through 21.

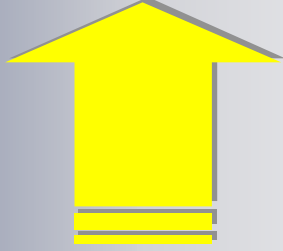
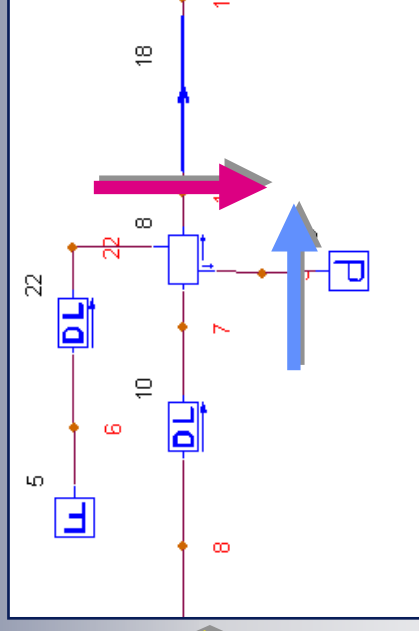
Internal Flow Model

- Water - Oil HX Model in Flowmaster



Input:

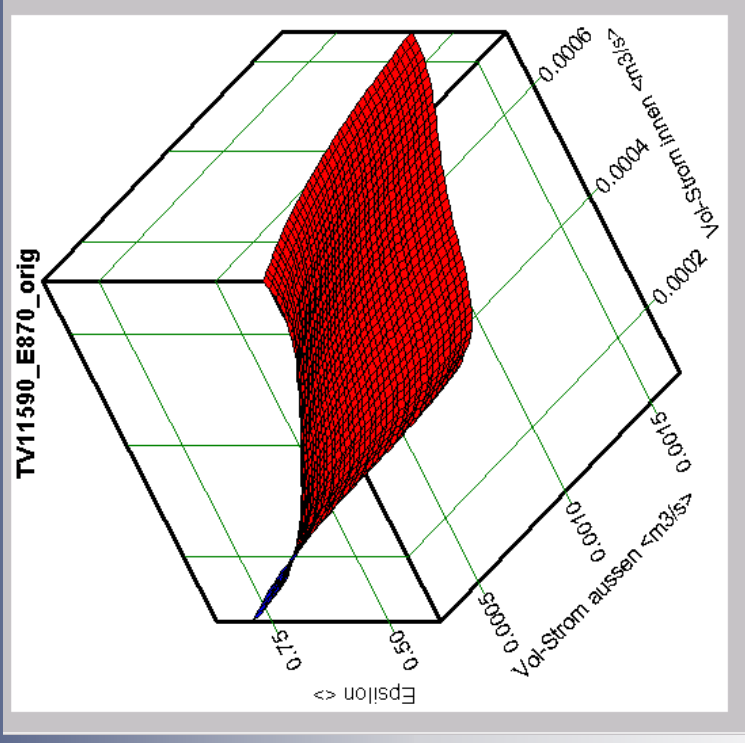
- Curves: Pressure loss vs. volumetric flow (i/o)
- Surface: Effectiveness vs. volumetric flows



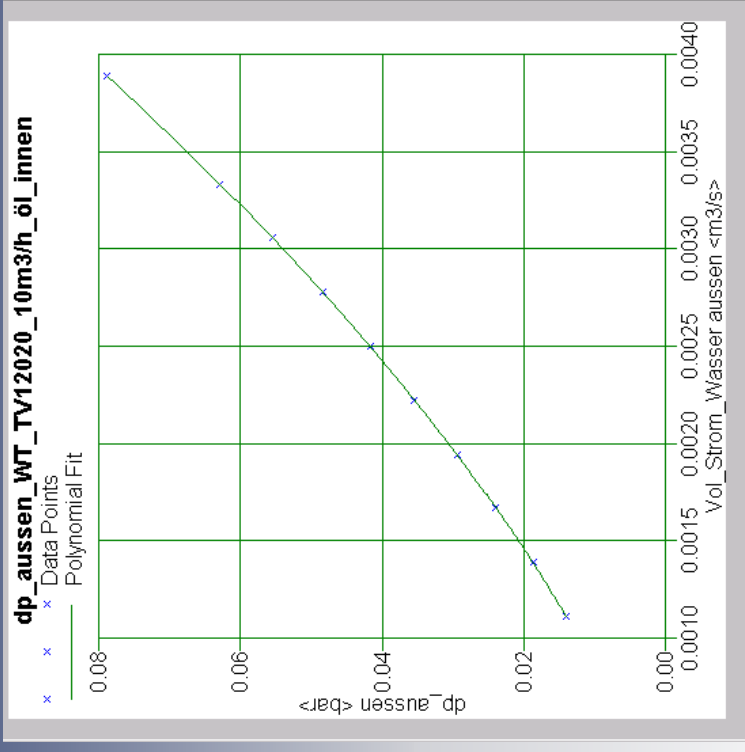
Internal Flow Model

- Water - Oil HX Model in Flowmaster

Effectiveness vs. volumetric flows



Pressure loss vs. Volumetric flow (i/o)



- Water - Oil HX Data from Modine Component Calculation Program

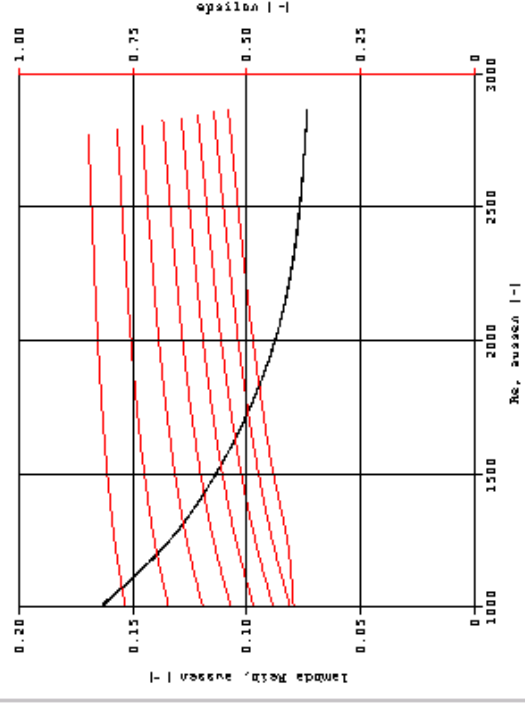
Physikalische Daten	
Umgebung	
Umgebungsbedingung der Luft	
Druck (abs.) [bar]:	1.0
Temperatur [°C]:	21.0
Feuchte [%]:	40.0
abs. [kg/kg]:	0.00624885
Innenseite	
Fluid:	Shell VITREA 100 (SAE 30) Fluideigenschaften
Eintrittstemperatur [°C]:	140.0
Foulingfaktor [m²K/kW]:	0.0
Volumen-/Massenstrome durch Leerzeichen getrennt eingeben (max. 10 Punkte) in [m³/h]	1.000 2.000 3.000 4.000 5.000 6.000 7.000 8.000 9.000 10.000
☒ Seite der Nutzleistung	
Aussenseite	
Fluid:	60% Wasser / 40% Glycol Fluideigenschaften
Eintrittstemperatur [°C]:	110.0
Foulingfaktor [m²K/kW]:	0.0
Volumen-/Massenstrome durch Leerzeichen getrennt eingeben (max. 10 Punkte) in [m³/h]	0.250 0.500 0.750 1.000 1.500 2.000 2.500 3.000 3.500
☐ Seite der Nutzleistung	
OK Cancel	

Internal Flow Model

Water - Oil HX Data from Modine Component Calculation Program

Wärmeaustauscher - [vi12020 #3]										
Benutzerbemerkung: DataSet for Flowmaster Input										
Datensatz: TV12020 KKZ: E947										
Versuchsbericht: VB10963 Zeichnungsnummer: 1521962.15										
Datensatzinfo: SBK a.Hilfsw.150el/16Wa-Pass.oberste u. unterste Wa-Pass.blind gel.										
1.00m³/h	2.00m³/h	3.00m³/h	4.00m³/h	5.00m³/h	6.00m³/h	7.00m³/h	8.00m³/h	9.00m³/h	10.00m³/h	1/a
wm [l/m³s]	Re i	alpha i[kW/m²K]	etaR i	a* ϵ A [l/kW/K]	lam					
51 0.20	5.2749e+001	1.868	0.8306	5.8219	9.204					
52 0.20	5.2184e+001	1.856	0.8314	5.7880	9.225					
53 0.20	5.1726e+001	1.846	0.8321	5.7602	9.242					
54 0.20	5.1347e+001	1.838	0.8327	5.7369	9.257					
55 0.23	6.6205e+001	2.131	0.8120	6.5794	8.953					
56 0.23	6.5315e+001	2.119	0.8128	6.5450	8.967					
57 0.23	6.4577e+001	2.109	0.8135	6.5158	8.979					
58 0.23	6.3950e+001	2.100	0.8142	6.4907	8.989					
59 0.23	6.2938e+001	2.086	0.8151	6.4494	9.006					
60 0.23	6.2153e+001	2.074	0.8159	6.4167	9.019					
61 0.23	6.1523e+001	2.065	0.8166	6.3900	9.029					
62 0.23	6.1005e+001	2.057	0.8171	6.3677	9.0388					
63 0.23	6.0570e+001	2.051	0.8176	6.3488	9.0464					
64 0.27	7.5818e+001	2.306	0.8003	7.0745	8.8124					
65 0.27	7.4915e+001	2.294	0.8011	7.0411	8.8248					

Plot #17



Internal Flow Model

•Boundary condition input for the coolant flows

The screenshot displays the MODINE software interface. The top portion shows a schematic diagram of a coolant flow system with various components like pumps, valves, and heat exchangers, connected by pipes. A red circle highlights a specific component labeled '6'. The bottom portion is a detailed parameter input window for this component, titled 'SOURCE:FLOW'.

Component Input Window Details:

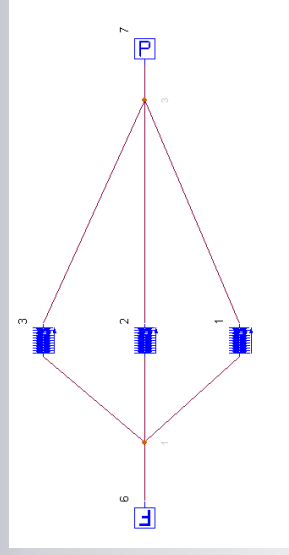
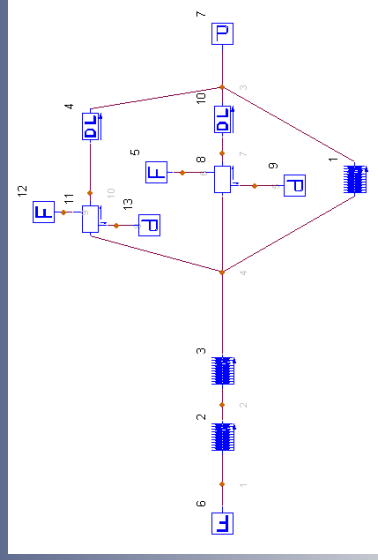
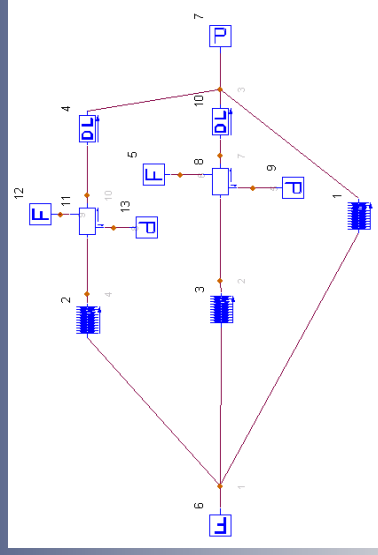
- Component Number:** 6
- Collection:**
 - 10: discrete loss
 - 9: source:pressure
 - 8: heat-exchanger: thermal
 - 7: source:pressure
 - 6: source:flow
 - 5: source:flow
 - 4: junction: $\alpha_1 = \alpha_2 = \alpha_3$
 - 3: ecm - 2 arms: kuli component: enter your type: enter your
- Parameters:**
 - Fluid Type:** Gas Type
 - Gas Type:** * Not Set *
 - Vol. Liquid Flow Rate:** 0.009 m³/s
 - Volumetric Gas Flow Rate:** * Not Set * m³/s
 - Constant Gas Mass Flow Rate:** * Not Set * kg/s
 - Constant Temperature:** 100 deg C
 - Noise Data:**
 - Vol. Flow Rate v Time:** * Not Set *
 - Gas Mass Flow Rate v Time:** * Not Set *
 - Temperature v Time:** * Not Set *

Content

- ◌ **Introduction**
- ◌ **External Flow Model**
- ◌ **Internal Flow Model**
- ◌ **Results**
- ◌ **Conclusions**

Results

Several simplified concepts for inner flow design were simulated and a best configuration for the given operating points was identified



And more...

Parameters to vary:

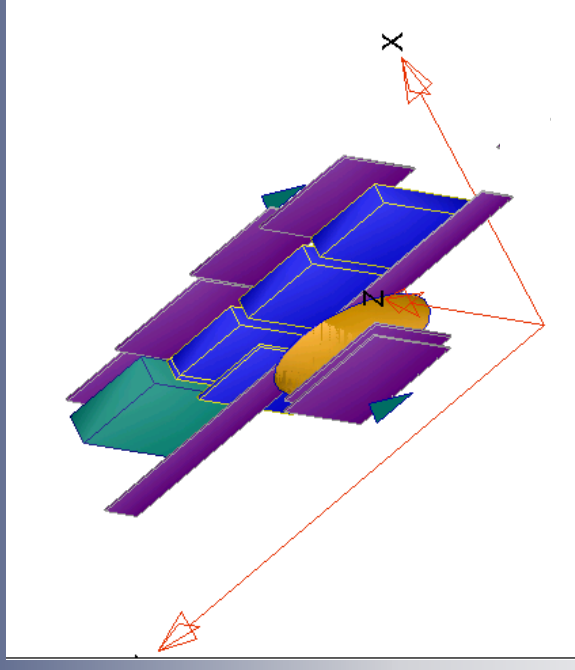
- serial / parallel
- No. of Oil HX
- Location of Oil HX
- Single/Multi flow to adjust flow distribution

Results

external flow configuration modeled in KULLI can be varied by:

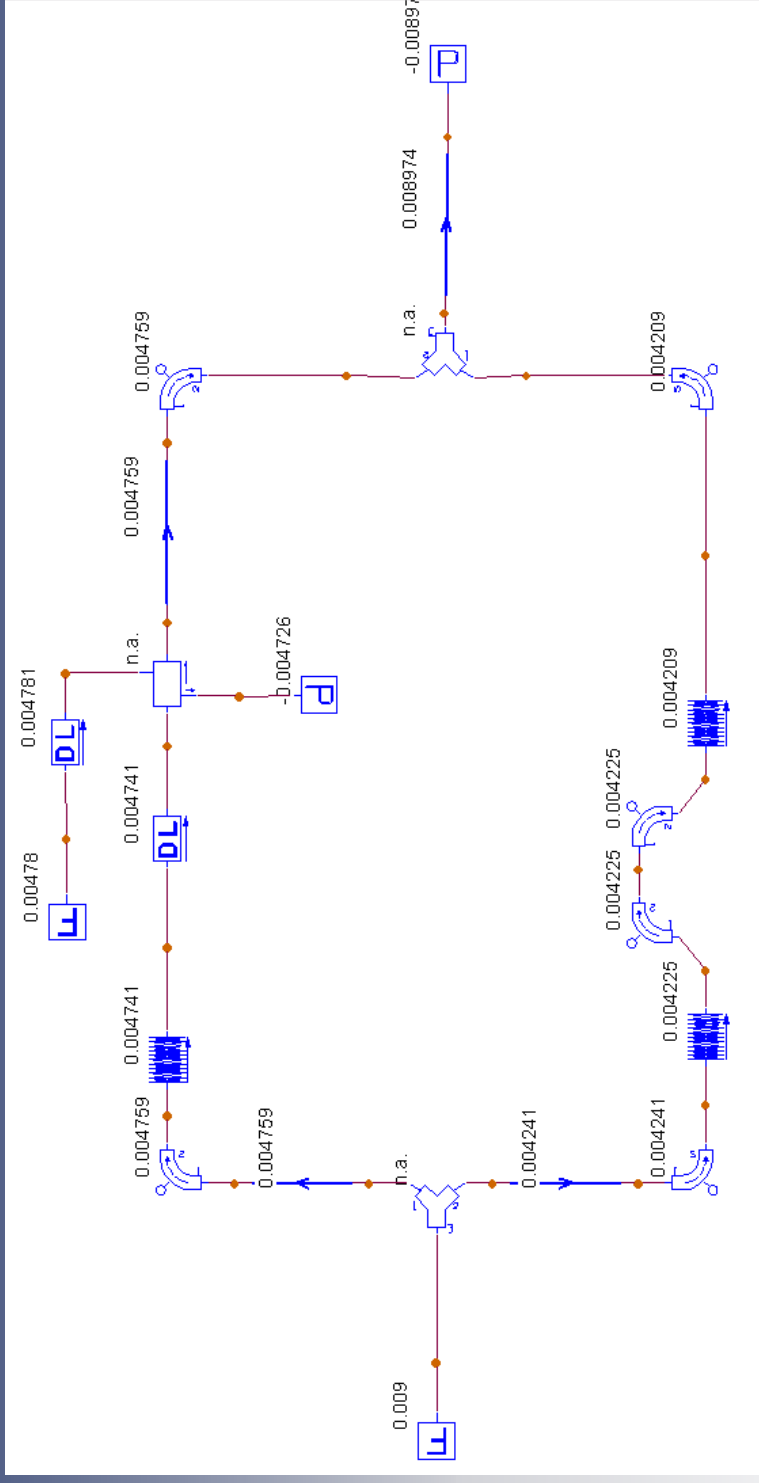
- location of the condensor/oil HX
- air fin density to balance mass flow
- definitions of the resistances
- fan rpm's
- (core and fan size)

It turned out, that the definitions of the resistances are mostly empirical but system performance is sensitive to these inputs



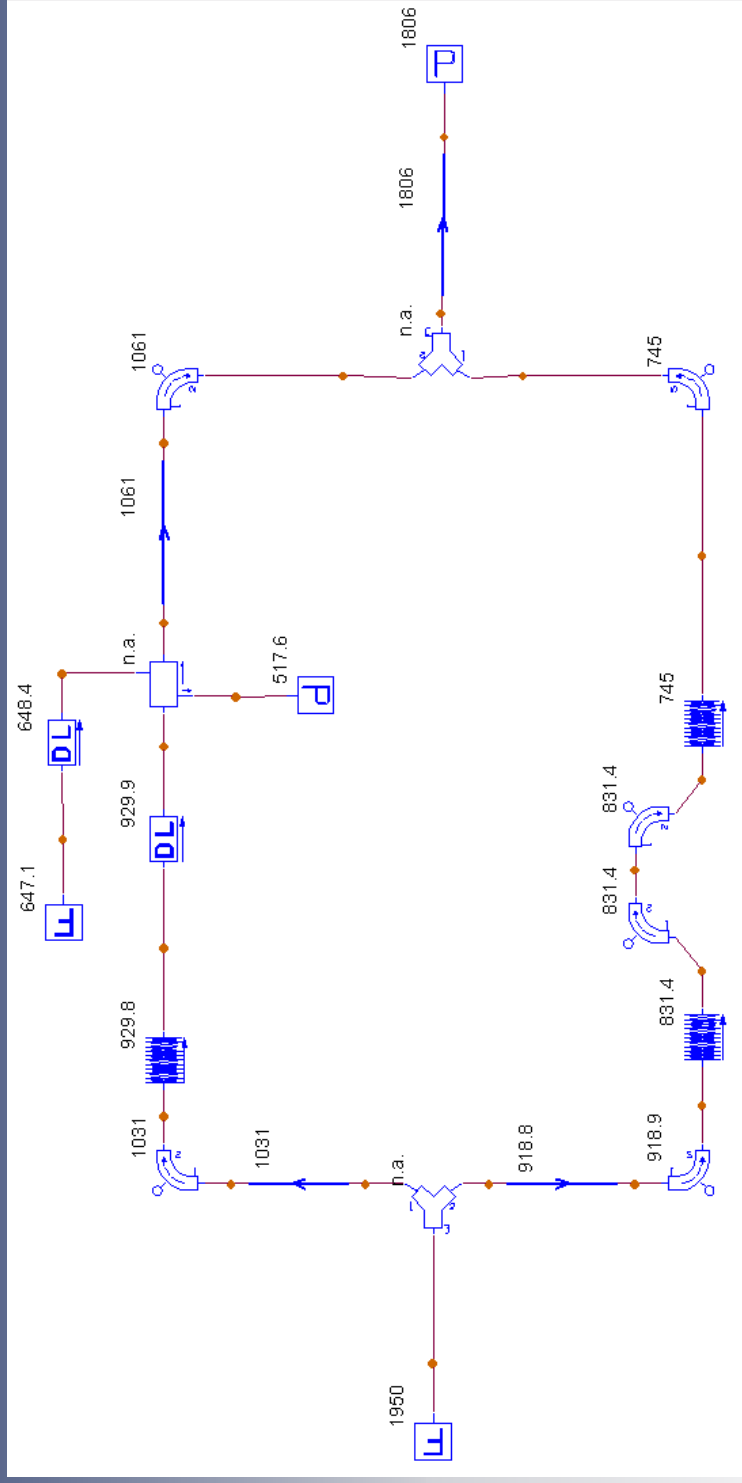
Results

Internal flow results in Flowmaster: Volumetric flow in m³/h



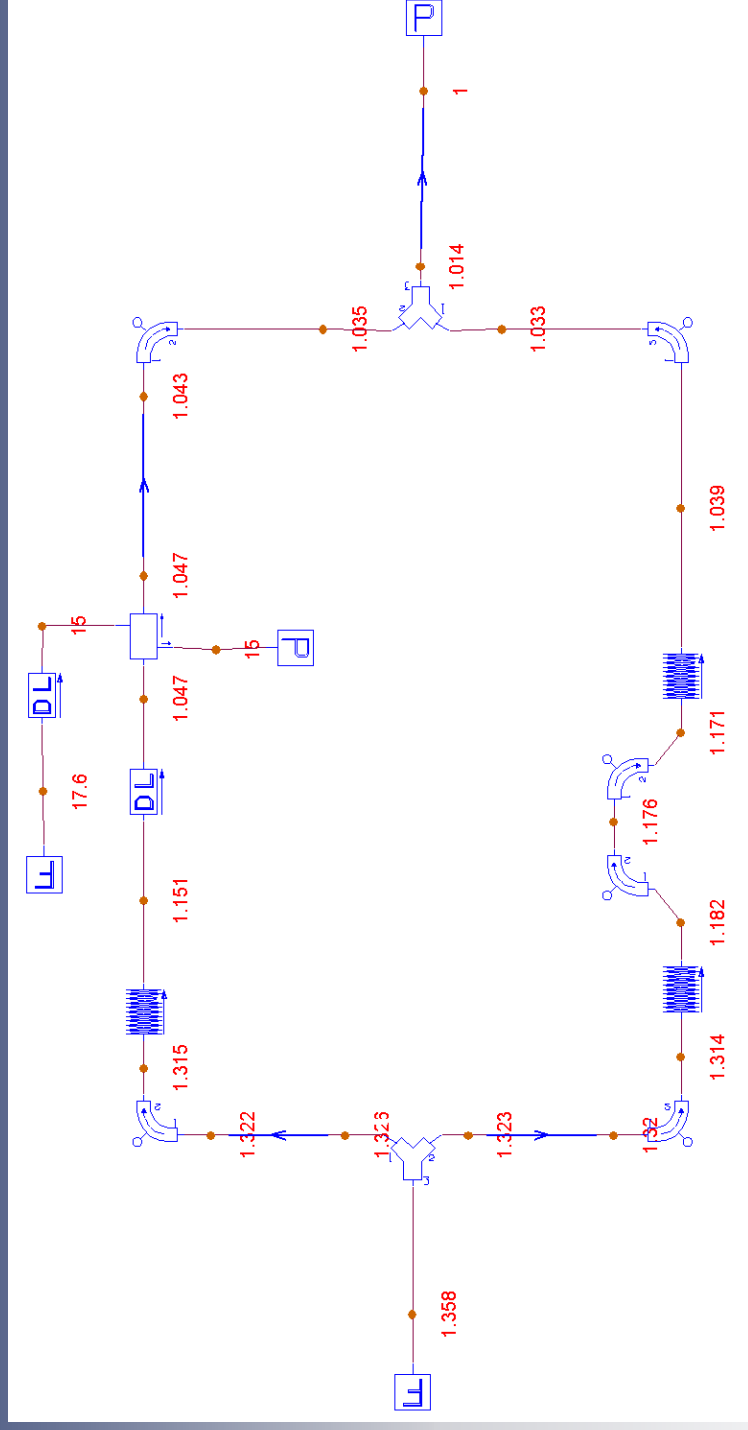
Results

Internal flow results in Flowmaster: Total heat flow in kW



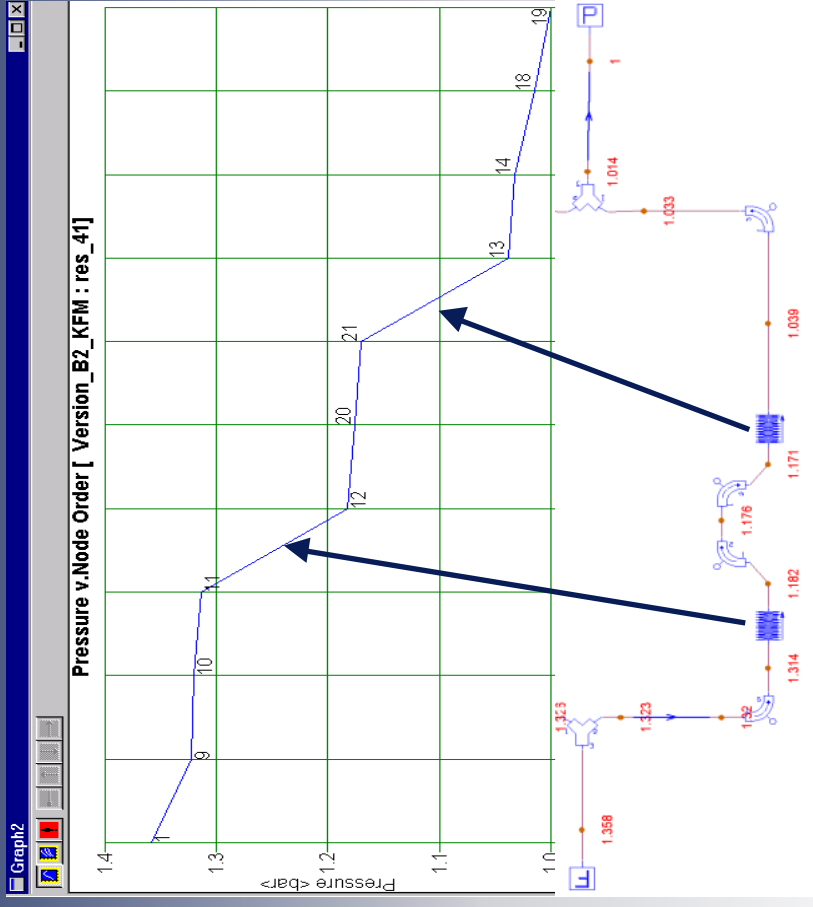
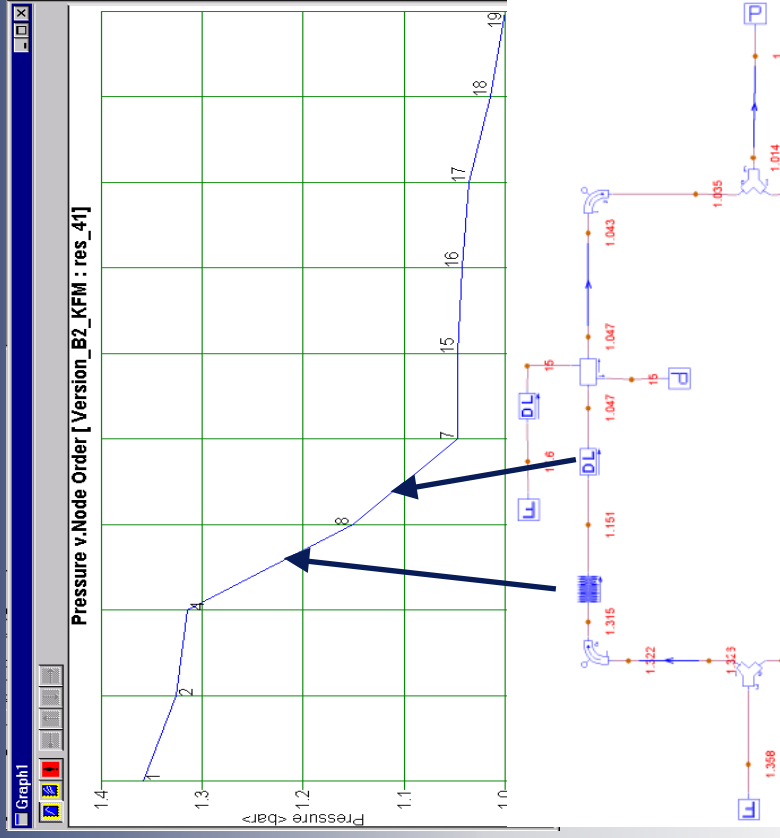
Results

Internal flow results in Flowmaster: Pressure node values in bar



Results

Internal flow results in Flowmaster: Node values



Content



Introduction



External Flow Model



Internal Flow Model



Results



Conclusions

Conclusions

- A multi radiator cooling system was investigated using KULI for the external flow and Flowmaster for the internal flow
- Several concepts for inner flow connections were compared
- Parameters for internal and external flow which can be varied were identified
 - These parameters and the constraints (operating point) can be subject to an optimization routine
- The resistances need fine tuning using experiments or CFD
- Transient Analysis are planned

Kuli - Flowmaster functionality meets the demands of cooling system design engineers in the concept phase and reduces the amount of measurements

END

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???

