Concept Studies
for
Multi Radiator Cooling System

J.Nies B.Stephan W.Zobel

2nd Kuli User Meeting   October 1999 / Steyr

MODINE

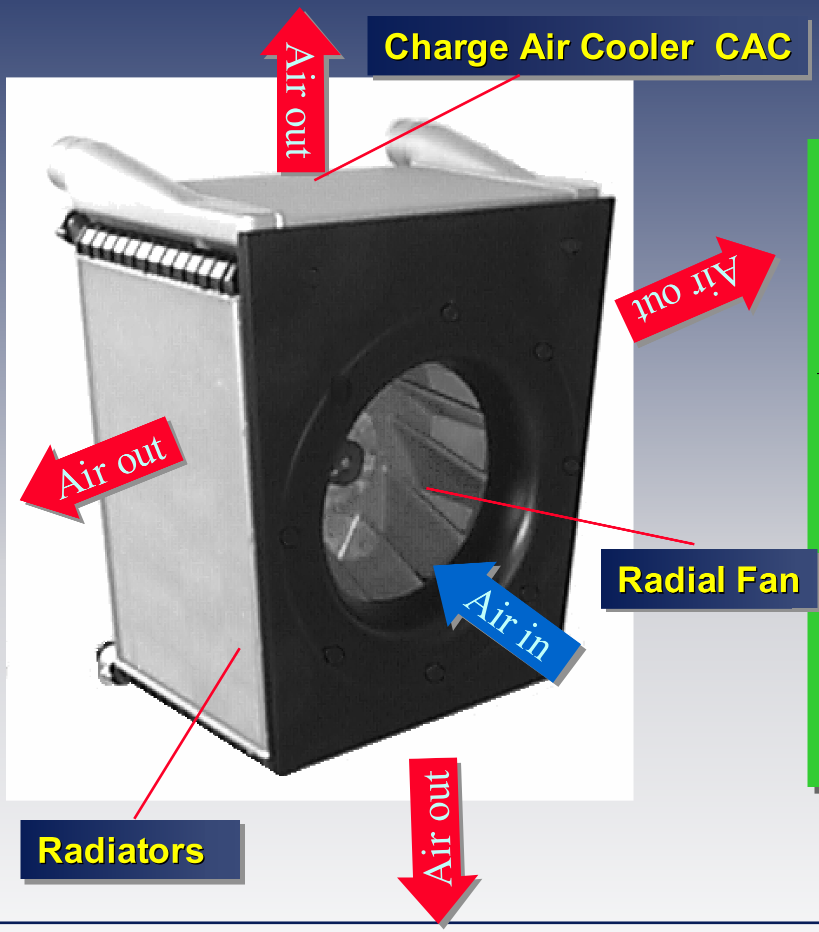
Content

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

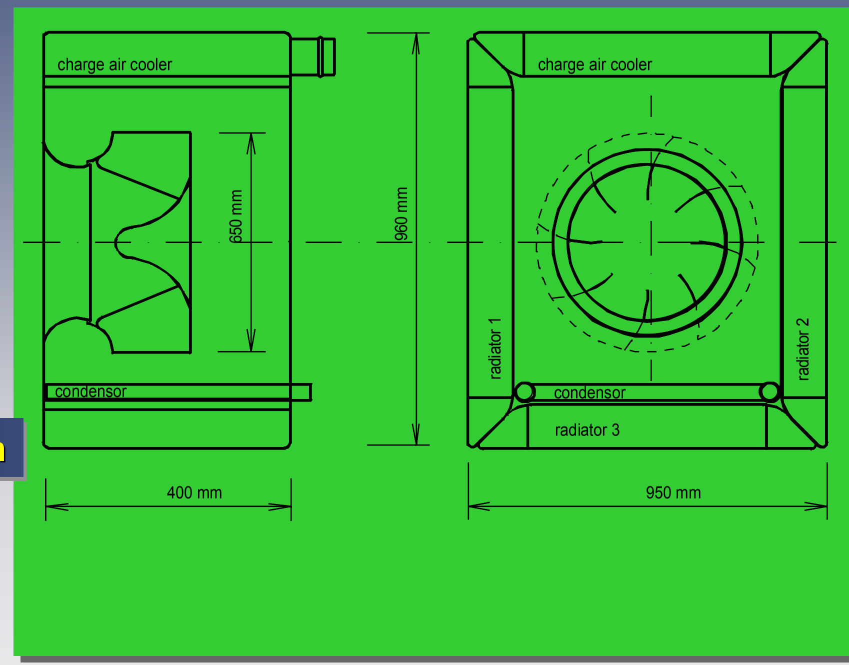
Introduction

- 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



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

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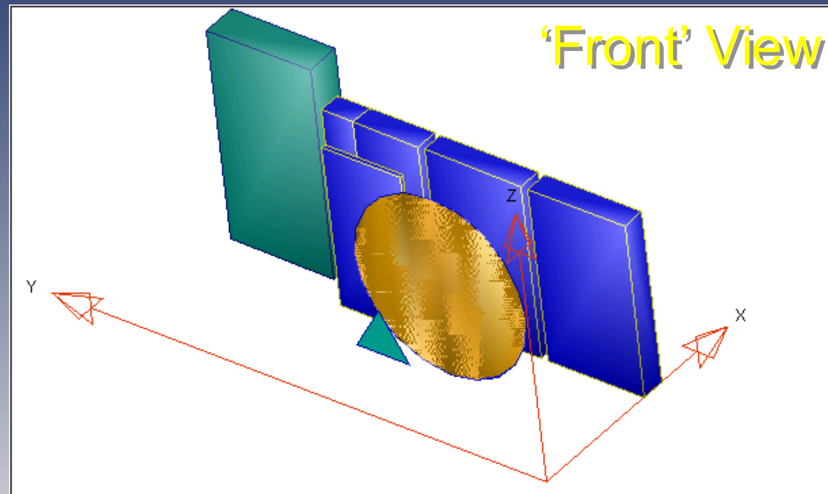
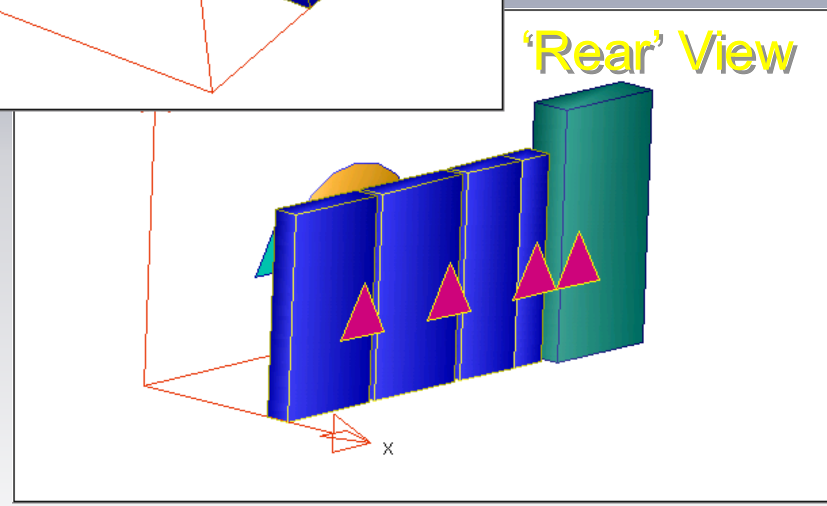
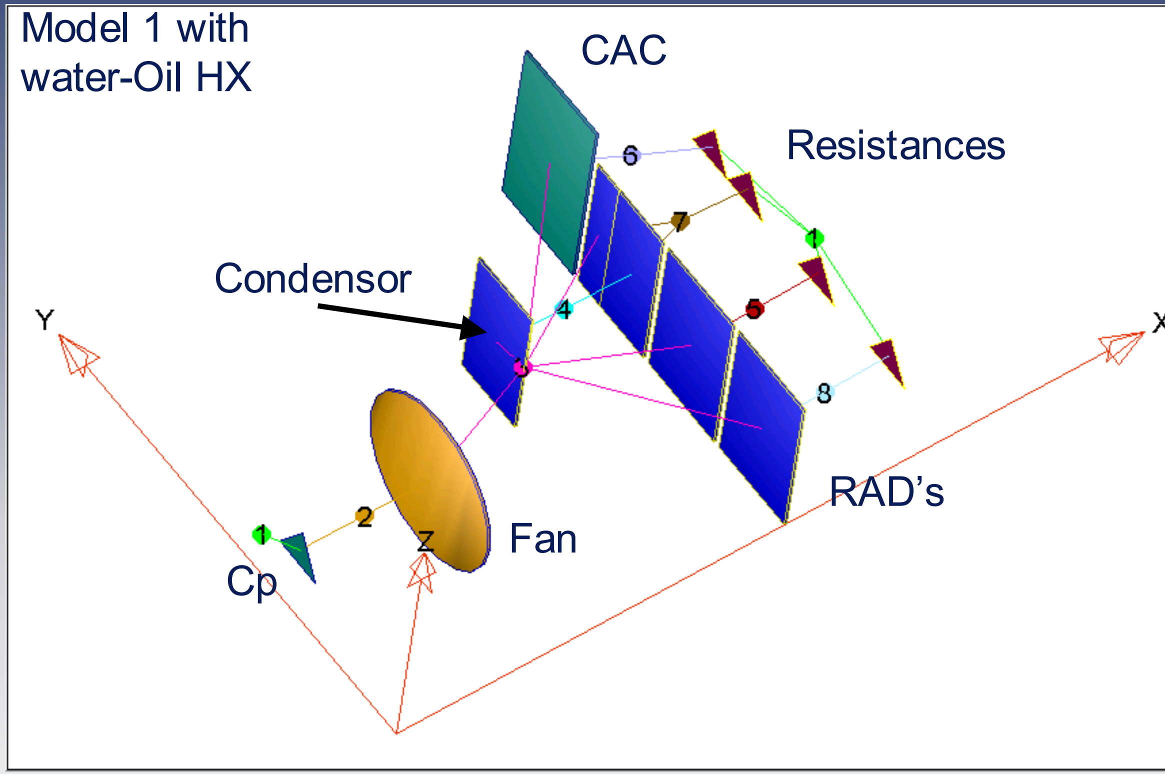
External Flow Model

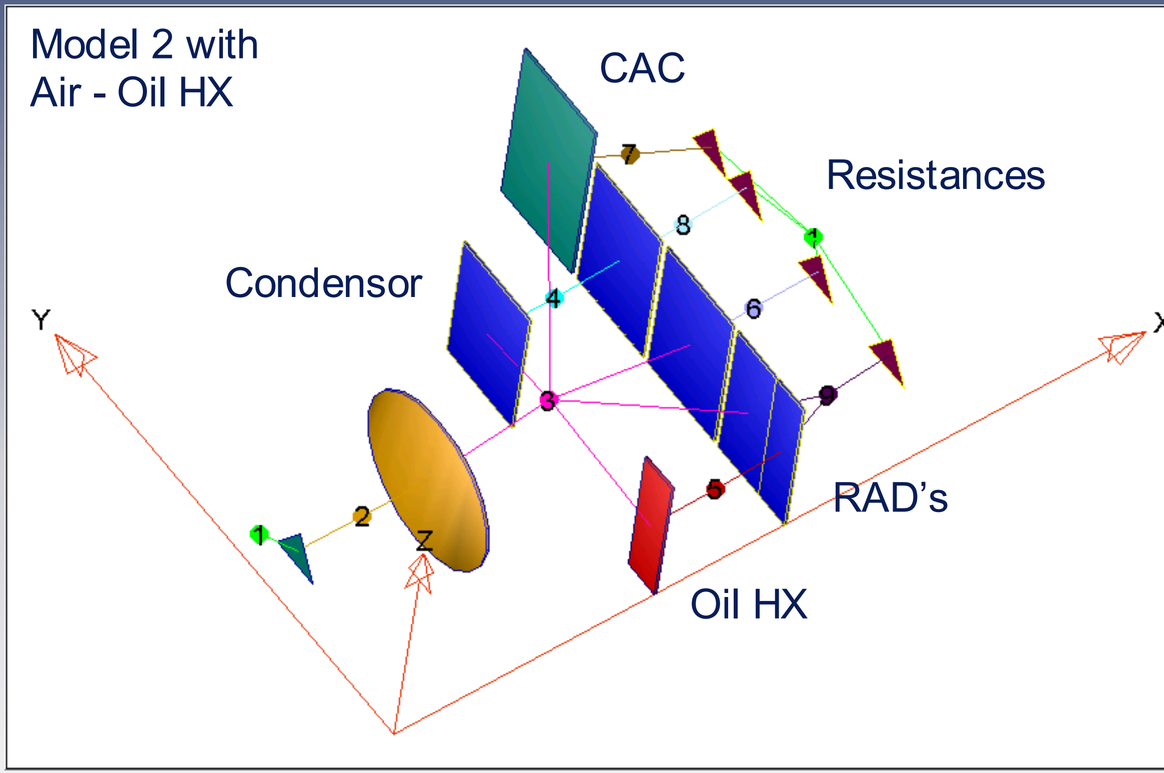




External Flow Model



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 devided 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 inhomoginous flow distribution over the core areas are not taken into account

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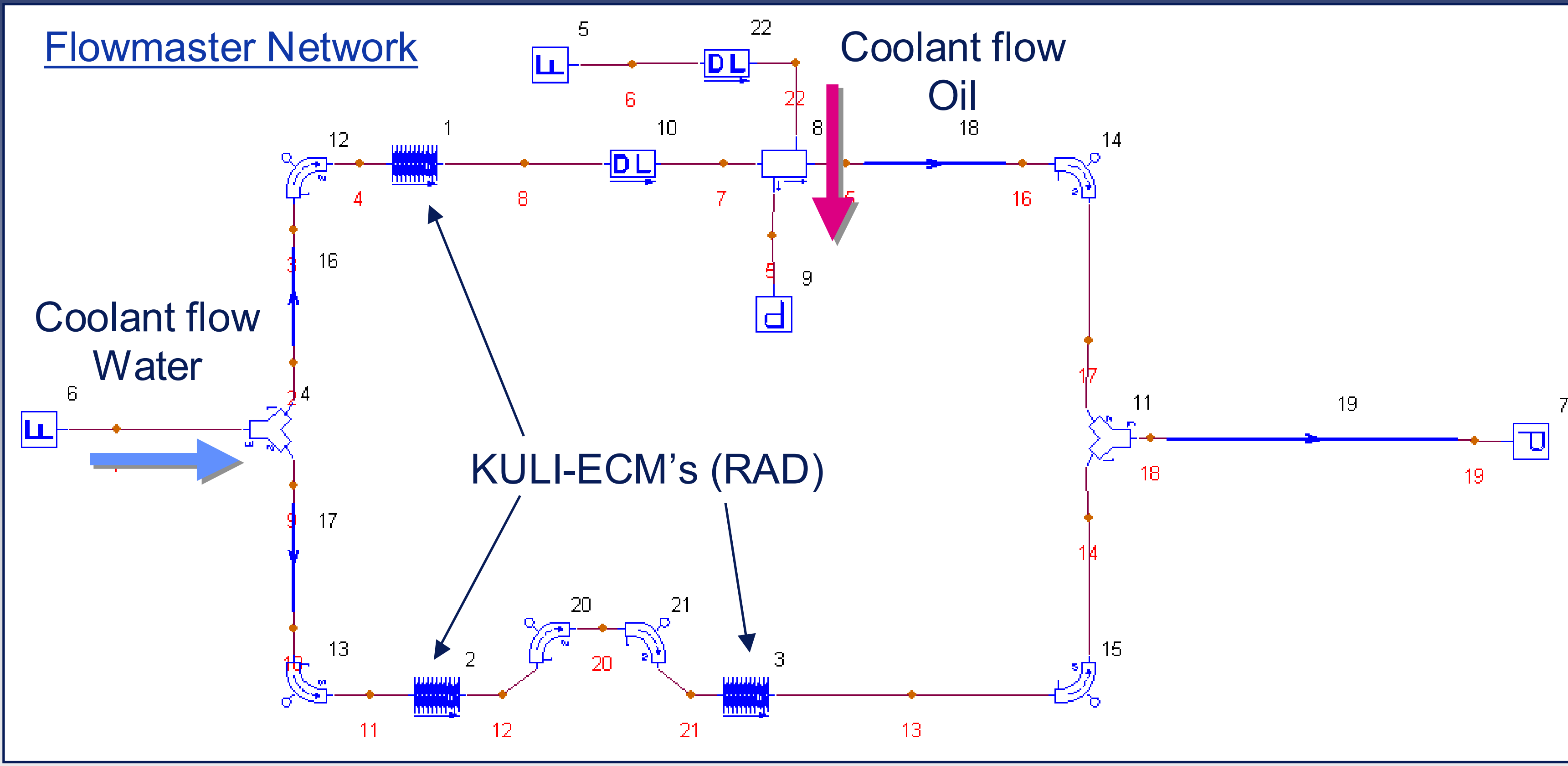
Internal Flow Model

- 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

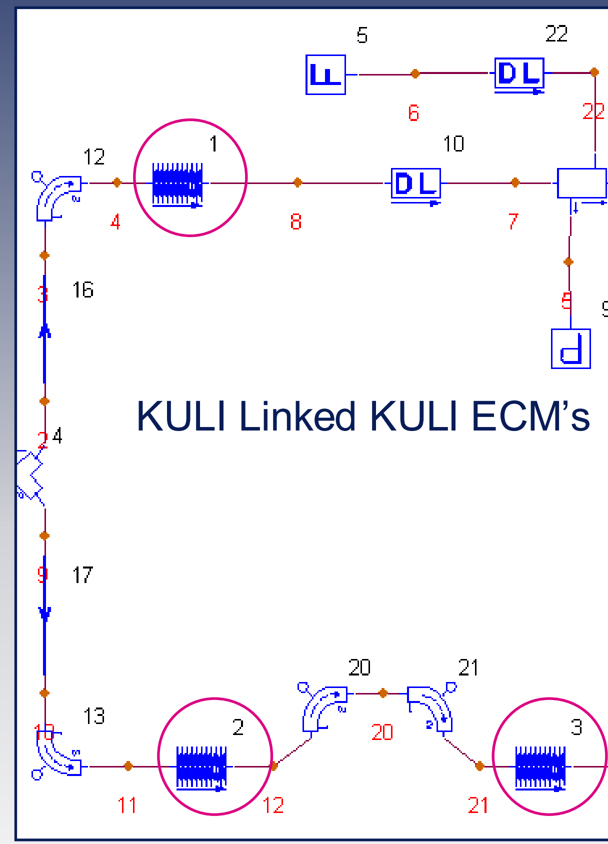


Internal Flow Model

Isystems

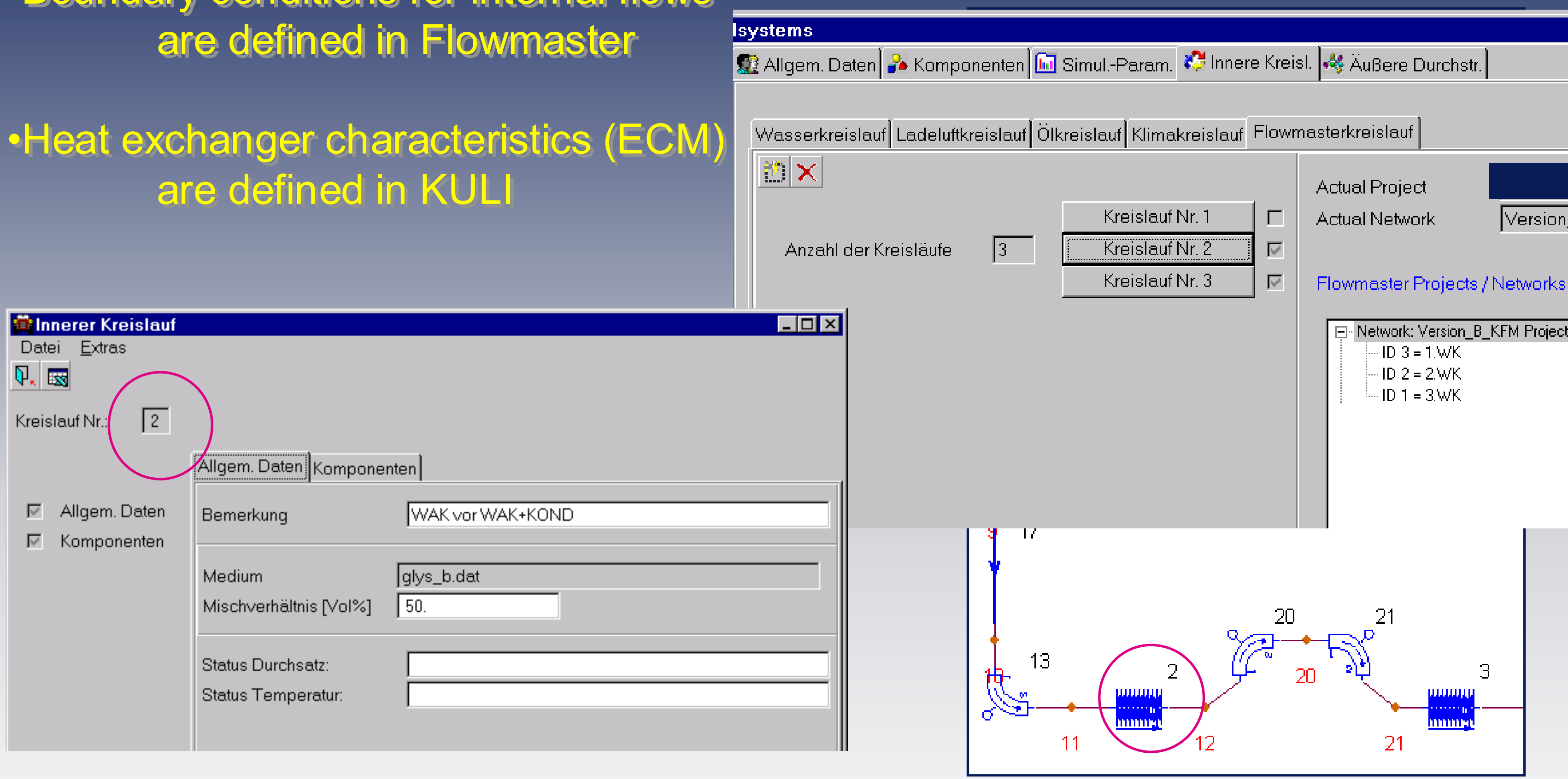
Allgem. Daten | Komponenten | Simul.-Param. | Innere Kreisl.

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
2.WK	355	675	86	500	400	0	3
3.WK	355	675	86	500	800	0	2
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	



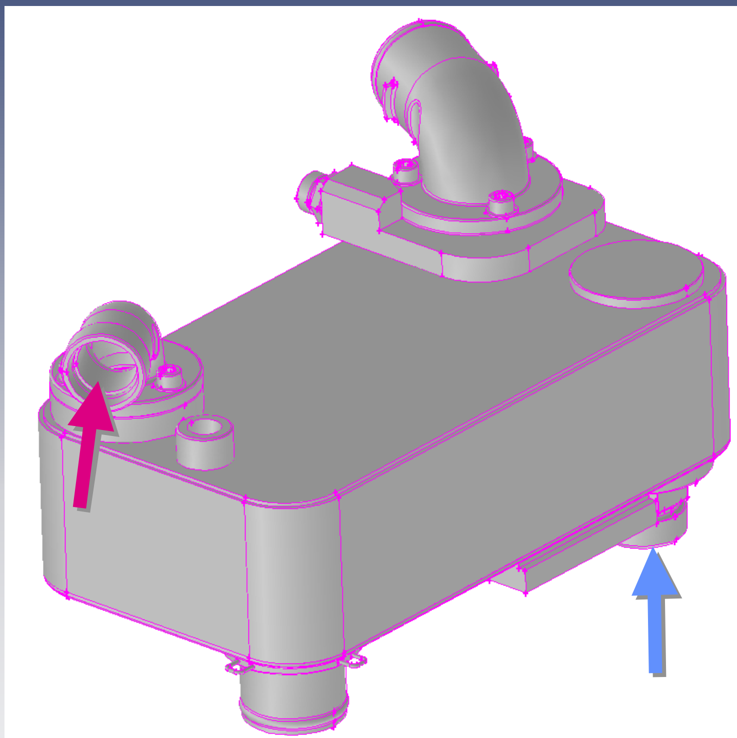
Internal Flow Model

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

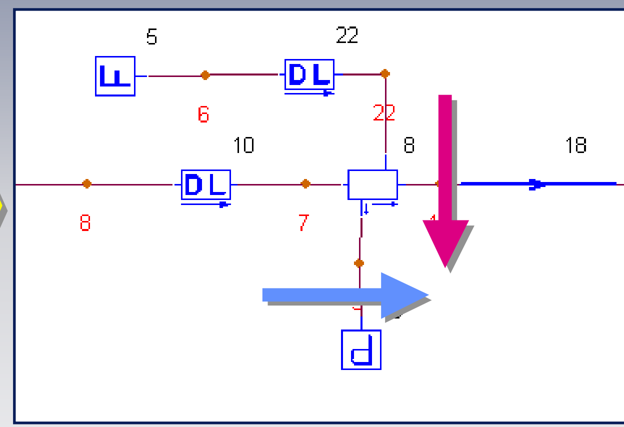


Internal Flow Model

- Water - Oil HX Model in Flowmaster



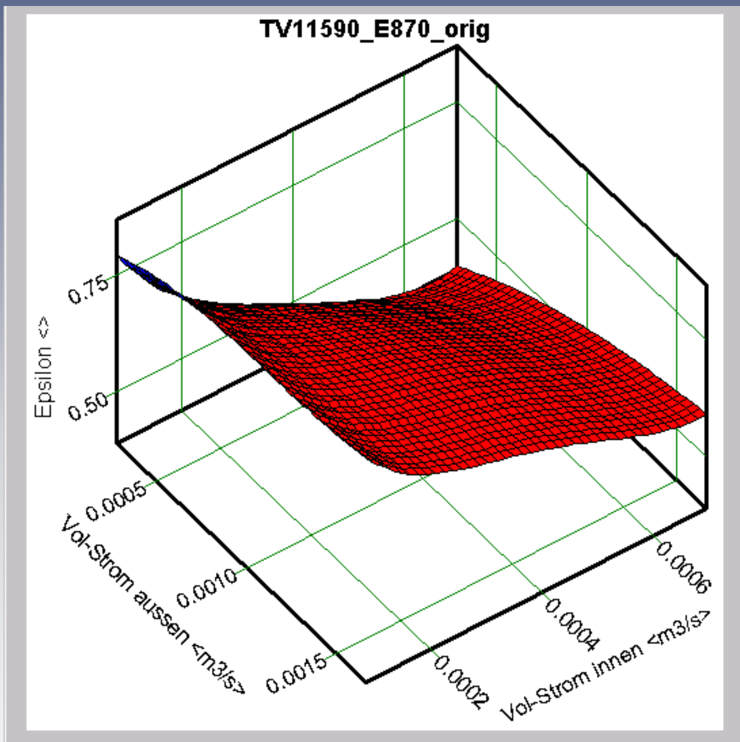
Input:
- Curves: Pressure loss vs. volumetric flow (i/o)
- Surface: Effectiveness vs. volumetric flows



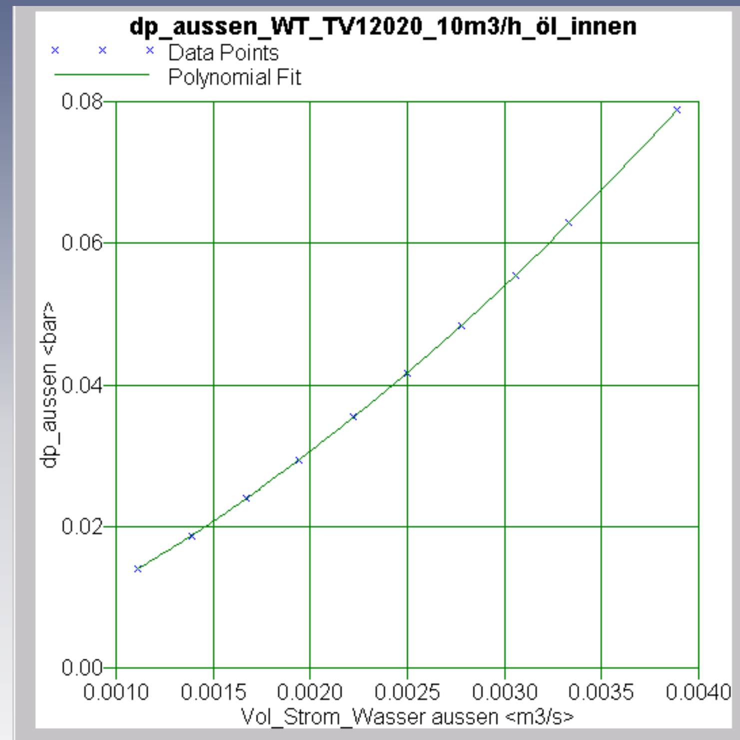
Internal Flow Model

- Water - Oil HX Model in Flowmaster

Effectiveness vs. volumetric flows

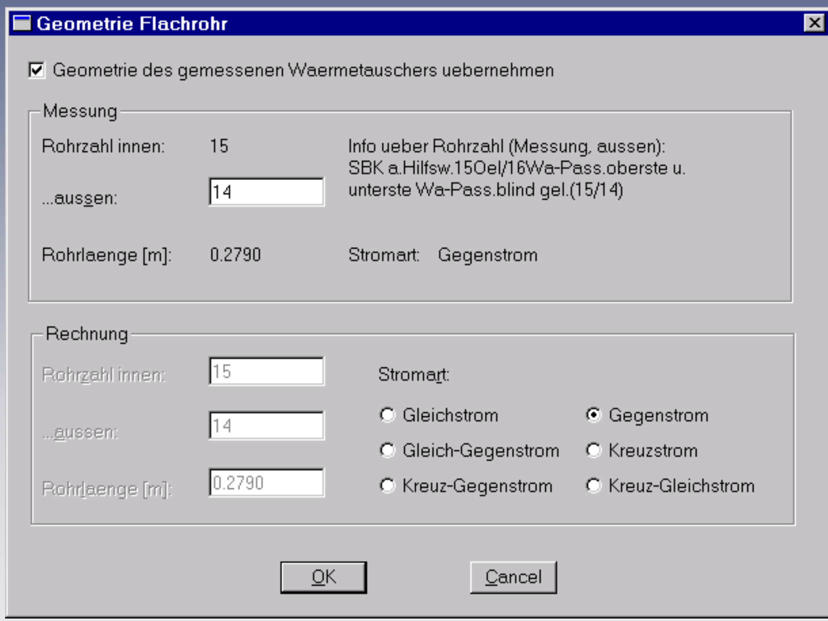


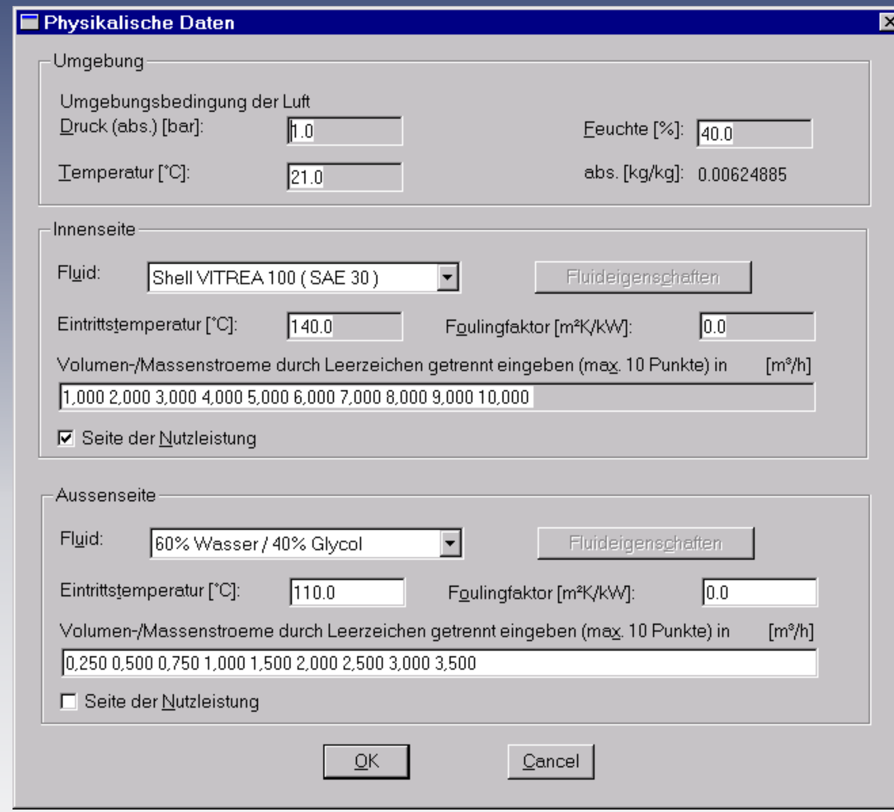
Pressure loss vs. Volumetric flow (i/o)



Internal Flow Model

- Water - Oil HX Data from Modine Component Calculation Program





Internal Flow Model

- Water - Oil HX Data from Modine Component Calculation Program

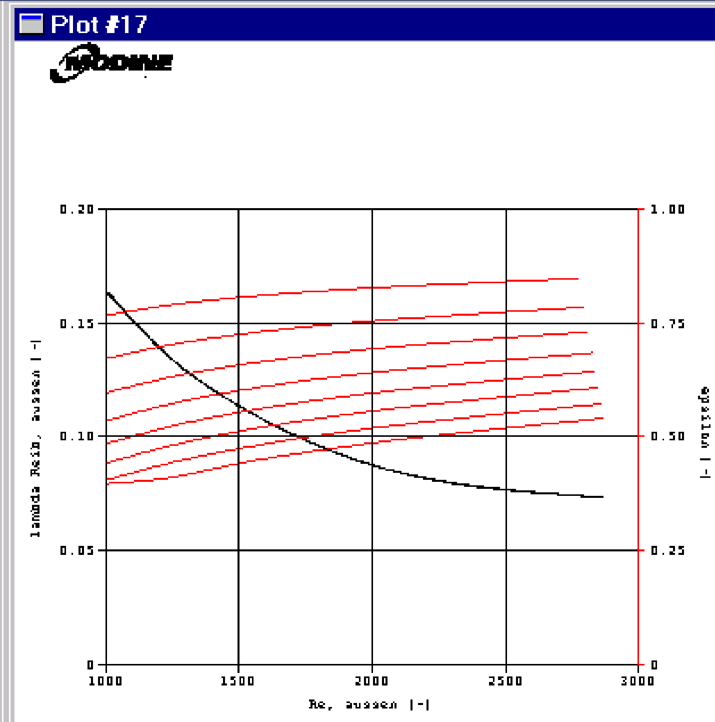
Wärmeaustauscher - [tv12020 #3]

File Edit Input Calculate Graphic Window Help

```
Benutzerbemerkung:  DataSet for Flowmaster Input
Datensatz:          TV12020    KKZ:                    E947
Versuchsbericht:    VB10963    Zeichnungsnummer: 1521962.15
Datensatzinfo:      SBK a.Hilfsw.15Oel/16Wa-Pass.oberste u. unterste Wa-Pass.blind gel.(
```

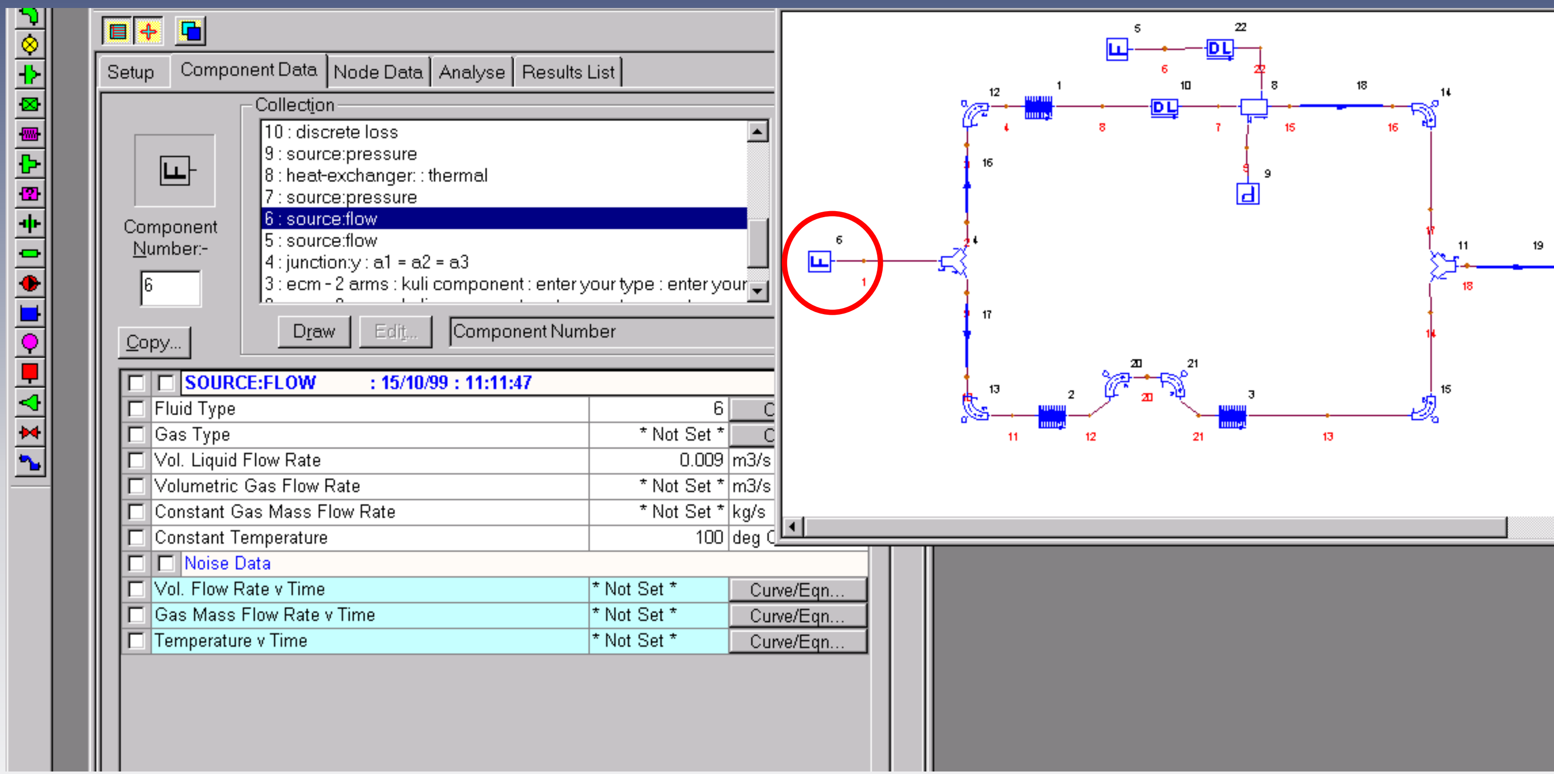
1.00m³/h | 2.00m³/h | 3.00m³/h | 4.00m³/h | 5.00m³/h | 6.00m³/h | 7.00m³/h | 8.00m³/h | 9.00m³/h | 10.00m³/h | i/a

	wm i[m/s]	Re i	alpha i[kW/m²K	etaR i	a*e*A i[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	0.17	7.1198e+002	2.35
63	0.23	6.0570e+001	2.051	0.8176	6.3488	9.0464	0.20	8.2297e+002	2.61
64	0.27	7.5818e+001	2.306	0.8003	7.0745	8.8124	0.01	6.7170e+001	0.42
65	0.27	7.4915e+001	2.294	0.8011	7.0411	8.8248	0.03	1.3137e+002	0.68



Internal Flow Model

- Boundary condition input for the coolant flows



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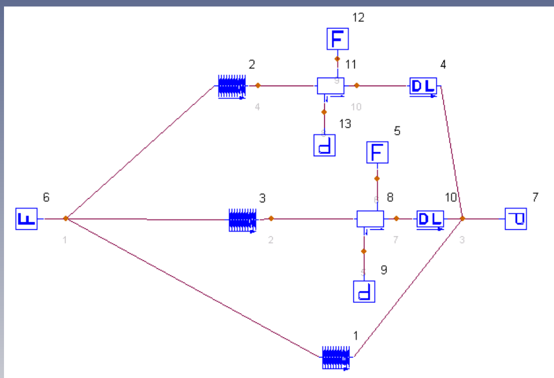
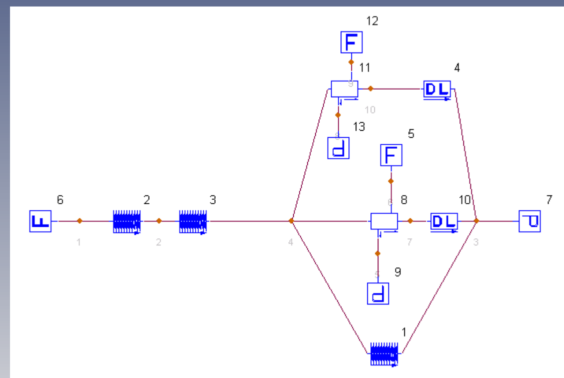
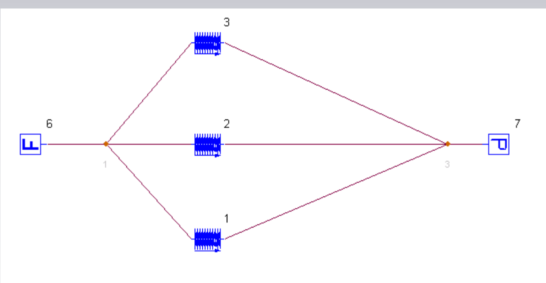
Results

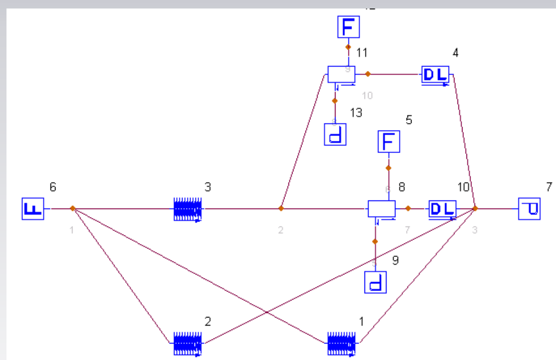
Several simplified concepts for inner flow design were simulated and a best configuration for the given operating points was identified







And more...

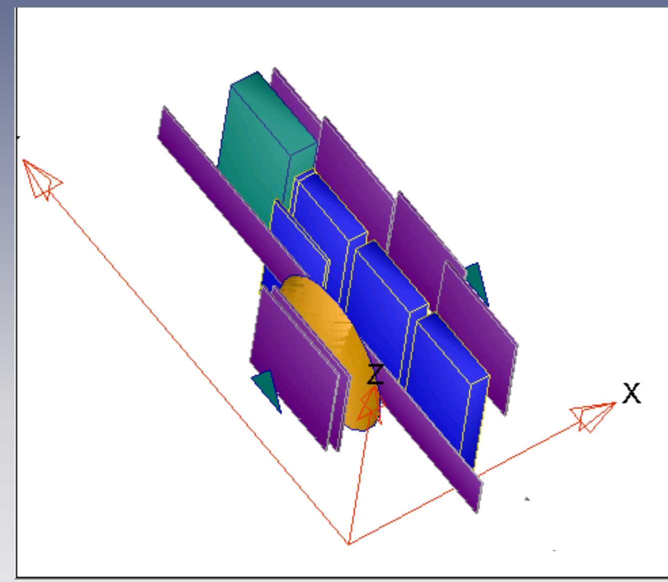


Parameters to vary:
- serial / parallel
- No. of Oil HX
- Location of Oil HX
- Single/Multi flow to adjust flow distribution

Results

external flow configuration modeled in KULI can be varied by:

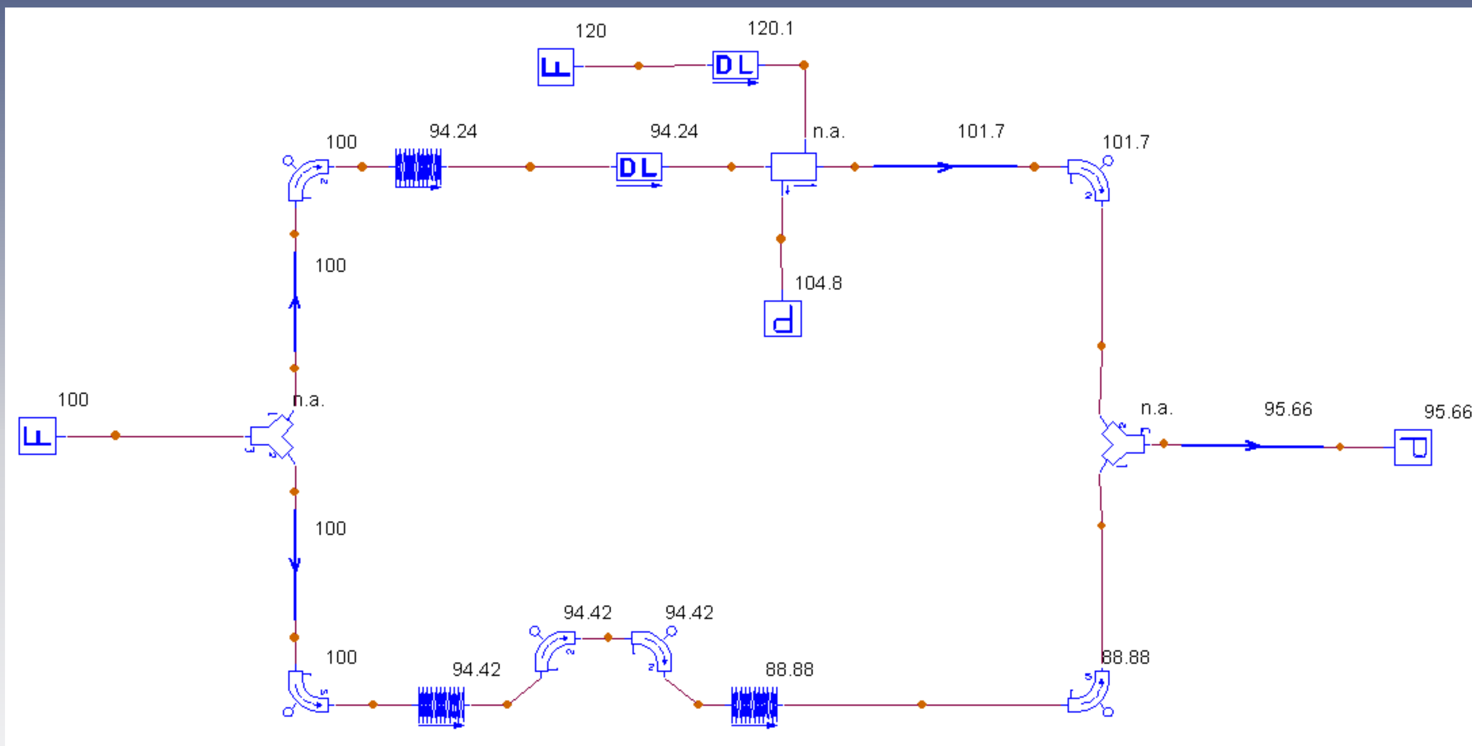
- location of the condensor/oil HX
- air fin density to balance mass flow
- definitions of the resistances
- fan rpm's
- (core and fan size)



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

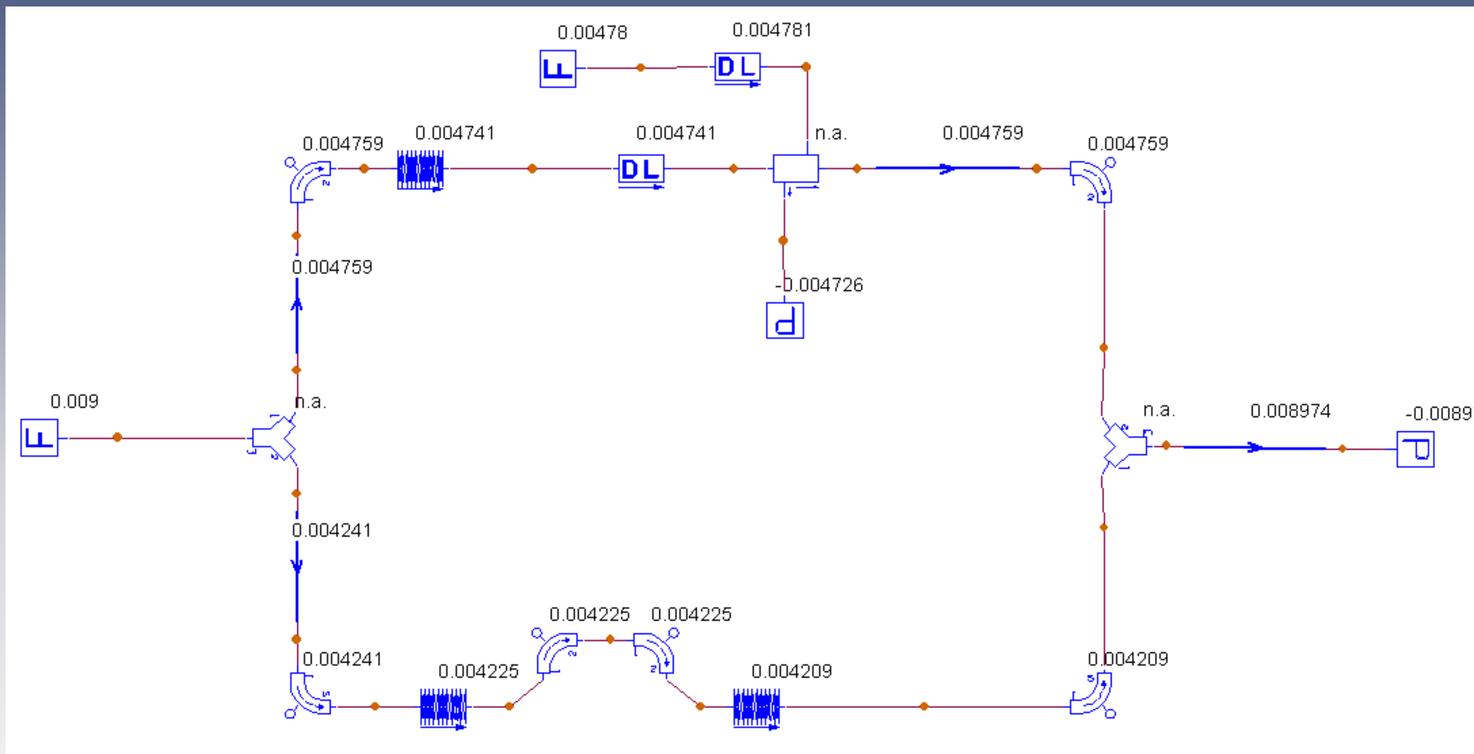
Results

Internal flow results in Flowmaster: Temperature in C



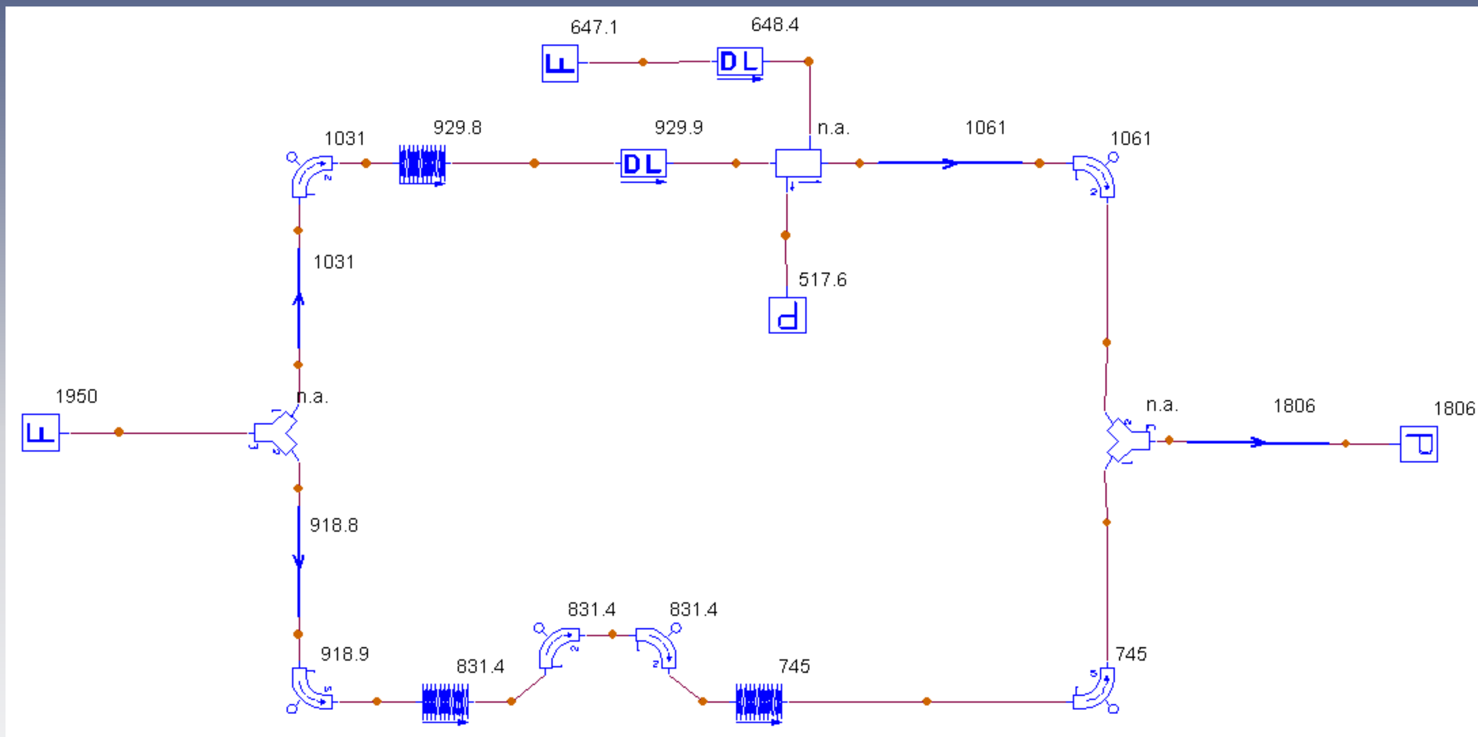
Results

Internal flow results in Flowmaster: Volumetric flow in m^3/h



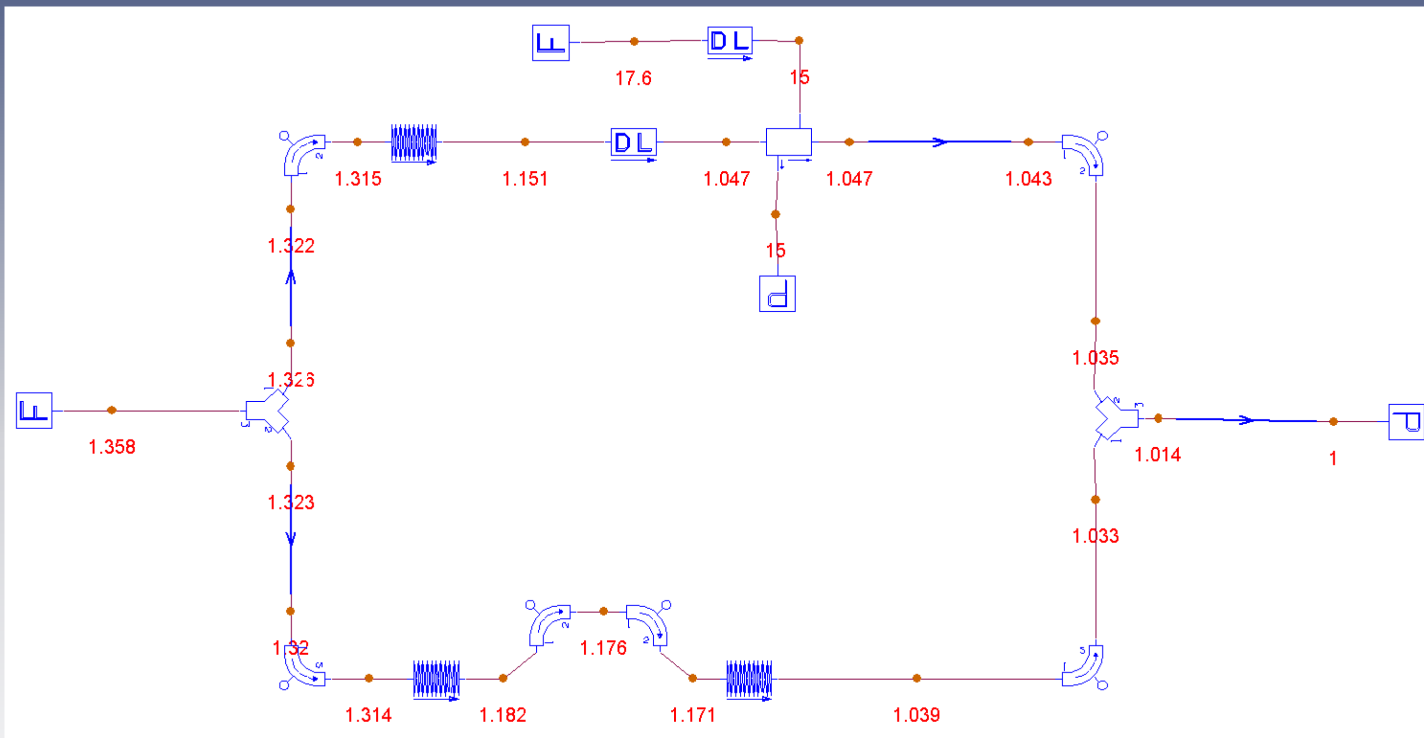
Results

Internal flow results in Flowmaster: Total heat flow in kW



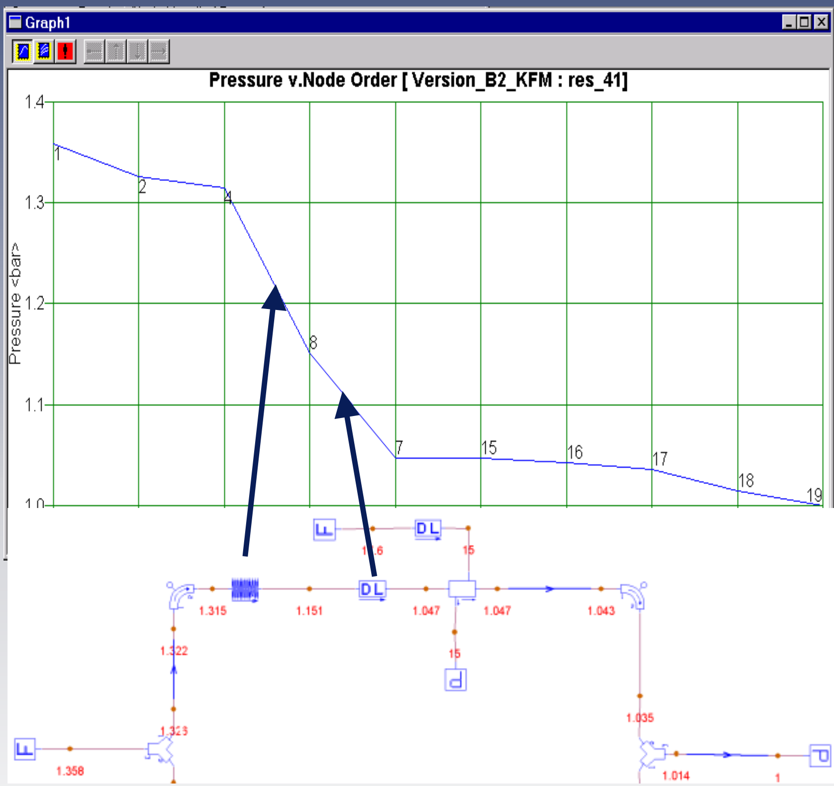
Results

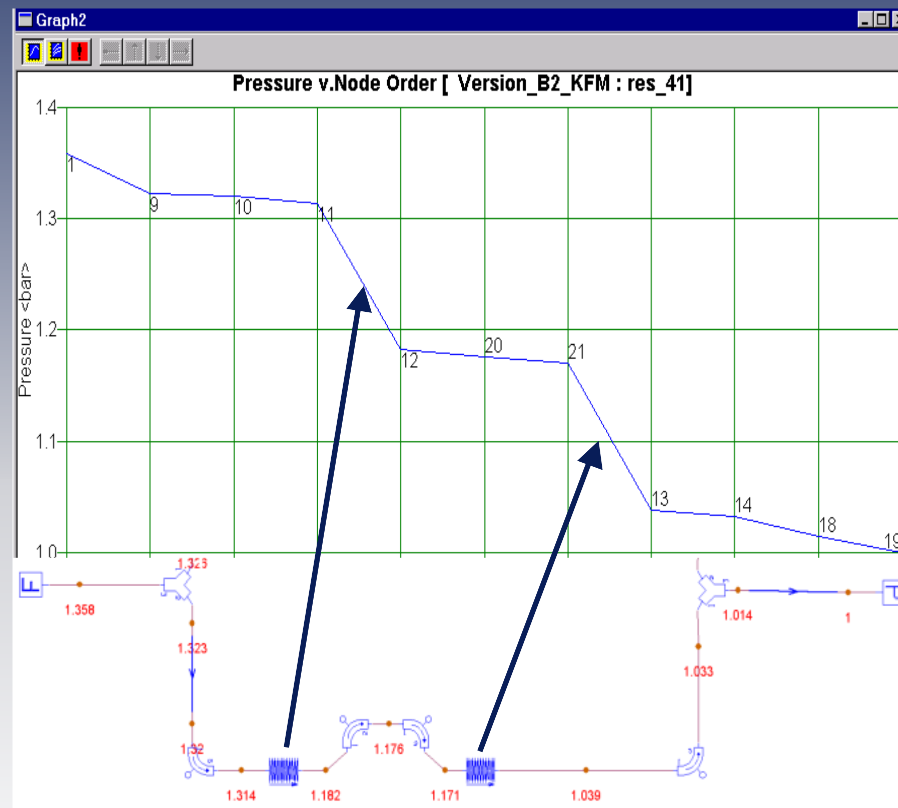
Internal flow results in Flowmaster: Pressure node values in bar



Results

Internal flow results in Flowmaster: Node values





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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 constrains (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

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