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Trenitalia Cooling System Design Document

Prepared by:	Checked by:	Approved by:
Aritz Arrizabalaga	Itxaso Segues	Itxaso Segues

1. ISSUE CONTROL AND DISTRIBUTION

ISSUE CONTROL

ISSUE	REASON	DATE
00_00	First version	29.02.2016

DISTRIBUTION

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DESIGN REPORT - COOLING SYSTEM CAF P&A (TRENITALIA PROJECT)

Rev	Date	Author	Description
-	23.02.2016	AAOL	Initial release
A	29.02.2016	AAOL	Point 3.1; 4.1 and 5.1 modified.
B			
C			
D			

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1 INTRODUCTION

CAF P&A sets a Purchase Order Nº 4114/029059 to HINE S.A. for the design and manufacturing of two cooling systems for the electric converter of a locomotive.

This project is named as Trenitalia project and final destination is Italia,

HINE's job number for the referred project is OF-154080.

2 OBJECTIVE

Present report is a design report that will cover all relevant engineering information concerning the project.

3 INITIAL DATA

As some spare elements from the cooling system are purchased by CAF P&A, data is already given by CAF P&A.

3.1 Basic given data

Parameter	**Value**
Cooling capacity required	25kW per cooling system / 100 kW per locomotive
Fluid:	60% Water and 40% Glycol. For example, Antifrogen N 40% or similar.
Flow:	Q ≥ 75l/min
T water in (to cabinet)	56 ºC (max)
T air in (to cooler fan)	45 ºC
Pressure drop (estimated)	2 bar

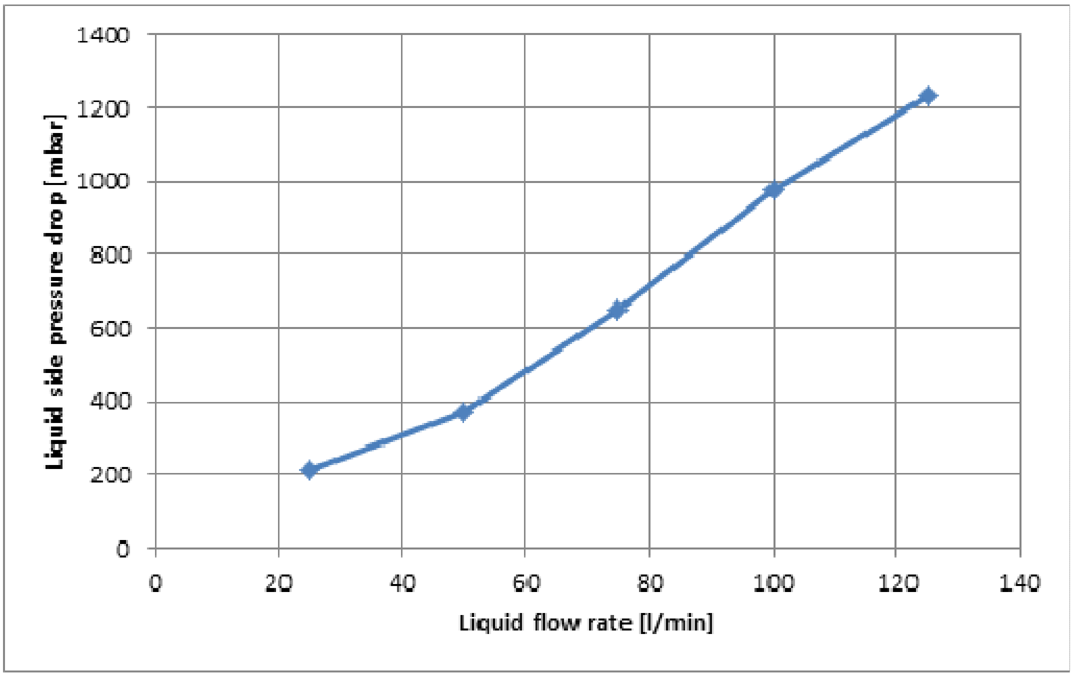
3.2 Cooler

The cooler is **Customer supply**. The information regarding the cooler is partial:

Existing data of cooler efficiency with oil as a cooling fluid:

Description	**Value**
Heat dissipation Power	25W
T_air_inlet	45ºC
T_air_outlet	51.2ºC
T_oil_inlet	60ºC
T_oil_outlet	54.5ºC
Oil flow	75 l/min
Pressure drop (oil)	0.65bar
Ambient humidity	60%
Air flow	3.6m^3/s

Pressure drop calculations with water-glycol fluid (according to following graph):



NOTE: Pressure losses curve including connector in/out Staubli RME 20.1155/JS3 + RME 20.7155/JS3

4 BASIC CALCULATIONS

4.1 Water-glycol temperature rise calculation

Water glycol flow is Q ≥ 75l/min. And heat power is 25kW.

Calculations are done at limit condition (most critical) with maximum allowable water glycol inlet temperature (56ºC). At 56 ºC fluid density and specific heat are the following:

Density (40% mix @ 56 ºC) = 1,055 Kg/l

Specific heat (40% mix @ 56 ºC) = 3,55 kJ/Kg*K

Therefore, temperature rise can be calculated:

25kW = 75 [l/min] *1,055 [Kg/l]*1/60 [min/s]*3,55 [kJ/Kg*K]*(X-56)[K]

T water IN = 56 ºC

T water OUT = 61,34 ºC aproximately

ΔT water = 5,34 ºC

4.2 Cooler air temperature rise calculation

Data corresponding to the cooler is very limited. But the air flow is known and therefore the air temperature rise can be calculated approximately:

Based in the air mass flow data given (3,6 m^3/s), we can do same calculation:

For T air IN = 45ºC

Mass flow = 3,6 m^3/s

Specific Heat of air at 45ºC = 1,008 KJ/Kg*K (aprox)

25kW * 1000 [W/kW] = 3,6 [m^3/s] * 1000 [l/m^3] *1,008 [kJ/Kg*K]*(X-45)[K]

T air IN = 45 ºC

T air OUT = 51,9 ºC approximately

ΔT air = 6,9 ºC

5 COOLER SIZING

5.1 With the existing data

In this project, the cooler is customer supplied but the data corresponding to the cooling capacity for the refereed fluid and flow is known.

Specific cooling capacity of the cooler is measured as the amount of kW the cooler can dissipate at a certain flow for every ºC difference between hot fluid entering temperature and cool air entering temperature.

ΔT = T water OUT – T air IN = 61,34 ºC– 45 ºC = 16,34 ºC

Heat power = 25 kW

Specific cooling capacity required = 25 / 16,34 = **1,53 kW/ºC**

That specific cooling capacity for water glycol can be achieved by the cooler proposed by the customer:

Performance

Water cooler

Ambient temperature: 45°C.
Ambient pressure: 101325 Pa (0 m).

Parameters	Request	TESIO CS Proposal
Heat Rejection dirty [kW]	25	25
Cooling capacity [kW/K]	-	1.7
Fouling	10%	10%
Coolant Type	Water 60% + glycol 40%	
Coolant Flow [l/min]	75	75
Coolant Inlet Temperature [°C]	63	60
Coolant Outlet Temperature [°C]	56	54.5
Coolant pressure drop [mbar]	-	450
Air Flow [m³/s]	3.6	3.6
Air Inlet Temperature [°C]	45	45
Air Outlet Temperature [°C]	-	51.2
Air Side Pressure Drop [Pa]	-	560

So, with the known values of the cooler selected by the customer, we wil get the water outlet temperature:

T water IN [ºC] – 45 ºC = (25kW / 1.7 [kW/K])

T water IN = 59,71 ºC

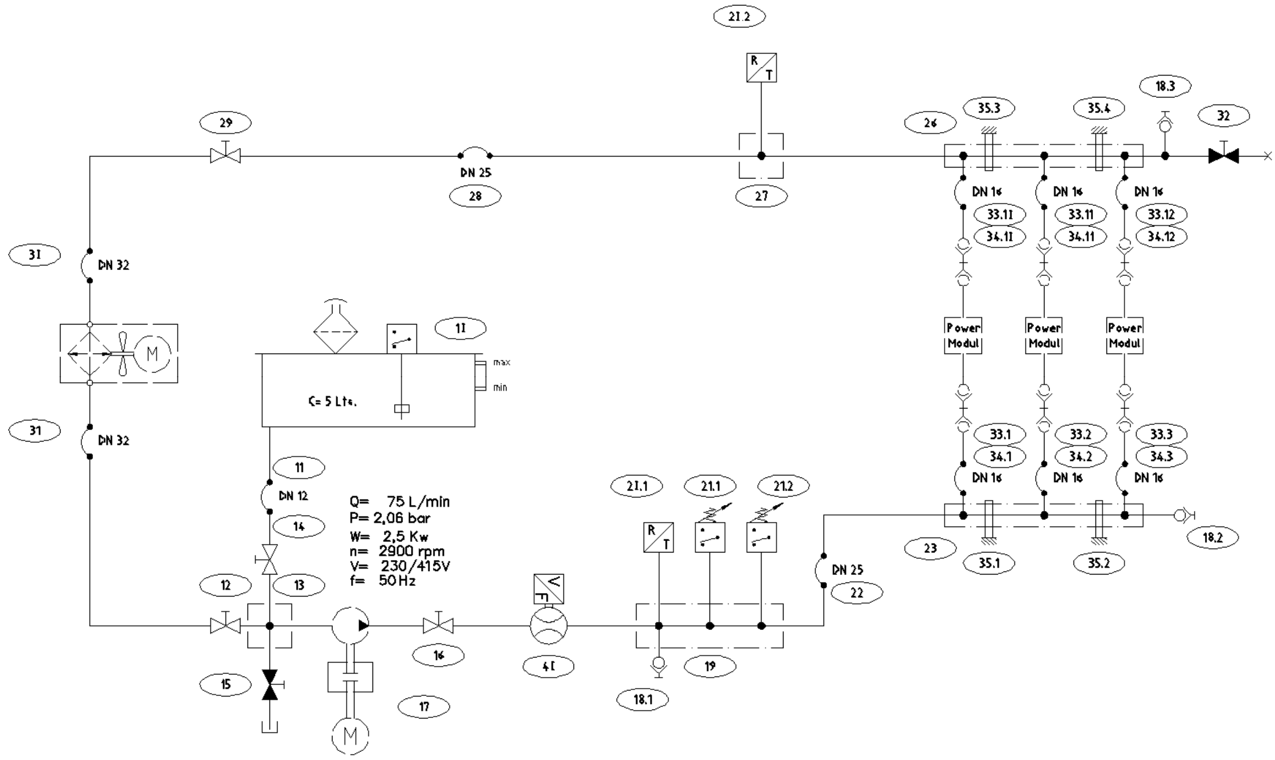
ΔT water = 5,34 ºC

T water OUT = 54,37 ºC

Cooler calculation is not our responsibility but the data given can be used in comparison with the existing cooler.

6 PRESSURE DROP CALCULATIONS

6.1 Flow diagram



6.2 Configuration – Pressure drop calculations

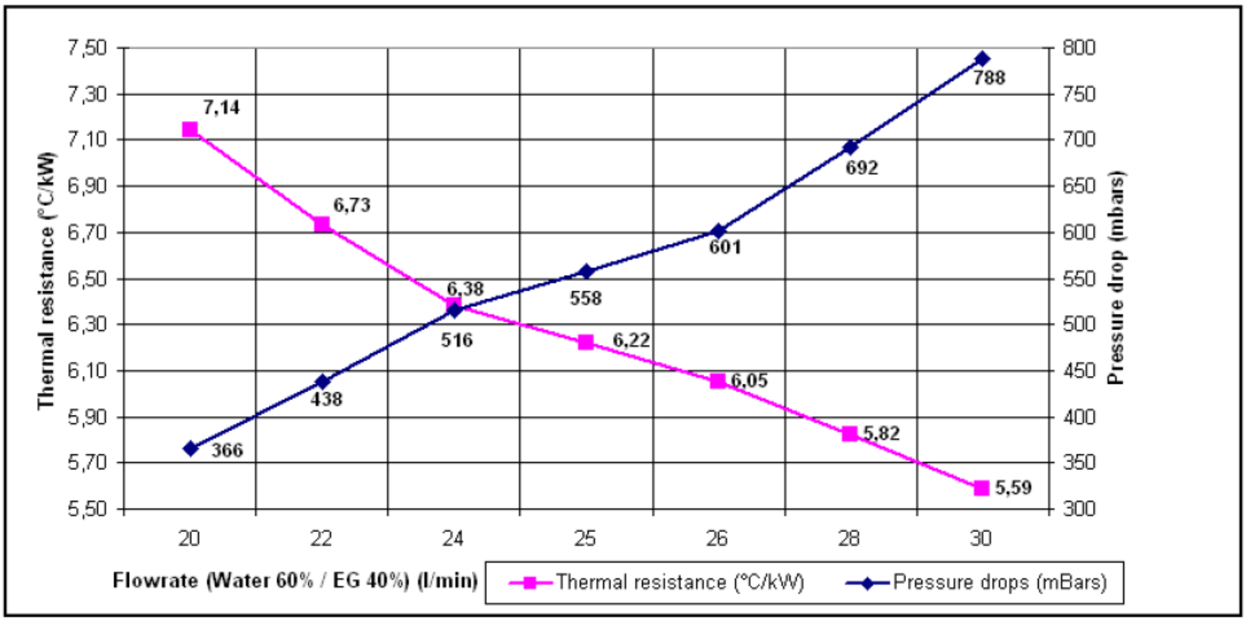
The flow of water glycol in all the circuit is 75 l/min, except in the 3 power modules, which are in parallel connection and share equally the flow (75/3= 25 l/min). The pressure drop through every power module is equal.

The total pressure drop of the circuit will be calculated by the sum of:

1. the pressure drop through power modules (“cold plates”) + quick couplings + fittings and hoses (DN16) at 25 l/min flow.
2. the pressure drop through the cooler + main lines at 75 l/min flow.

Pressure drop at 25l/min

Data supplied by CAF P&A:



NOTE: the pressure drop includes the pressure drop related to the connectors (quick couplings) mounted on the coldplate.

For 25 l/min, pressure drop of the cold plates (including 2 x quick coupling connectors SPT12) is **0,558 bar.**

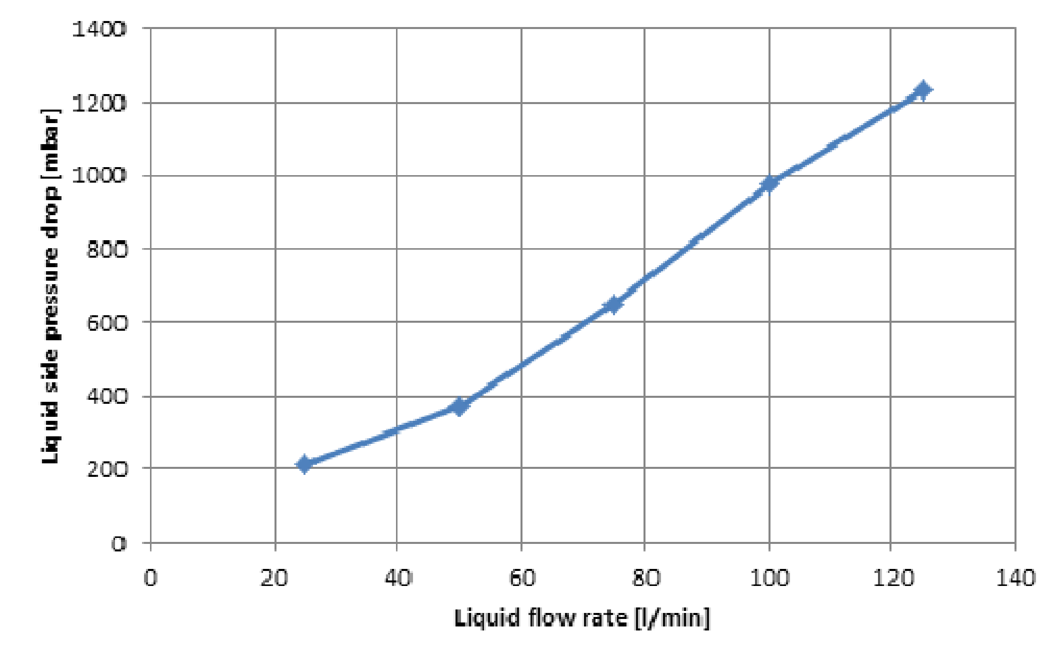
The pressure drop through the fittings (2xGE18LR, D_{int}=15) and the hoses (internal diameter of 16 mm) can be obtained from the 3D design of the cooling system, measuring length of hoses, length of rigid tubes and fitting configuration.

From the design we get 2 meters of 16mm hose + 2 meters of 16mm rigid tube + 4 elbows. Fluid conditions at 63ºC are 2 cSt or less. Calculated pressure drop for such conditions are **0,27 bar**.

Total pressure drop in 25 l/min branch is = <u>**0,828 bar**</u>

Pressure drop at 75 l/min

Pressure drop of the cooler → given data:



NOTE: Pressure losses curve including connector in/out Staubli RME 20.1155/JS3 + RME 20.7155/JS3

For actual flow of 75 l/min, pressure drop is **0,625 bar**.

For the pressure drop of the fittings and hoses for the rest of the circuit, calculations will be based also on the 3D design. Piping/hoses internal to the motorpump-structure will be 1" (internal diameter of 25mm) and hoses external to this structure are preferred to be 1 ¼" (internal diameter of 32mm), due to larger hose length. Note that the end connection to the cooling tower needs to be reduced to 1" using quick couplings, due to the connection ports.

As before, we get 4 meters of 1" hose internal to the motorpump-structure, with 4 x 90º elbow fittings, for a 2 cSt fluid and 75 l/min, the pressure drop is: **0,29 bar**.

Hoses external to this motorpump-structure are going to be 8 meters of 1 ¼" hoses with 4 x 90º elbows: **0,32 bar**

Total pressure drop in 75 l/min branch is = **1,235 bar**

Total Pressure drop:

Total pressure drop will be the sum of both branches: 0,828 bar + 1,235 = 2,063 bar.

At 63 ºC fluid viscosity is close to 1 cSt, so calculated pressure drops in pipes and hoses are rather conservative. However, as other local pressure drops have not been calculated and as safety margin a **2,5 bar** pressure drop is a good estimation.

7 PUMP SELECTION

Pump flow = 75 l/min (4,5 m^3/h)

Pressure = 2,2 bar

We will oversize the pump slightly to account for 4,5 m^3/h and 2,5 bar.

8 EXPANSION TANK CALCULATION

The expansion tank will account for liquid level variations due to liquid temperature variations. At the same time, it will act as liquid reservoir store a fluid quantity enough to avoid frequent refilling.

Temperature variation in the fluid can be as big as follows:

Minimum ambient temperature = -25 ºC

Maximum ambient or fluid temperature = 55 ºC

ΔT = 80 ºC

Fluid volume in the circuit is largely dependent on the amount of fluid the cooler can hold inside (unknown data) + fluid in the pipes and hoses. The total amount of fluid in the circuit is estimated to be 35 litres.

The thermal expansion coefficient for the fluid is β = 0,0007 [K^{-1}].

So the volume variation can be calculated as = 0,0007 [K^{-1}] * 35 [Ltr] * 80 [ºC] = 1,96 litres

The capacity of the expansion tank is decided to be between 5 and 10 litres, depending on space available in detailed design (confirmed capacity of 6 litres at design stage).

Olaberria, 23th February 2016