Optimisation of pump- and cooling water systems

A report made by Grontmij Carl Bro, APV and DESMI

2008

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INTRODUCTION:

The co-operation between DESMI, APV and Grontmij Carl Bro was established more than a year ago due to the increased demands for reduction of the CO_2 emission to the environment.

The co-operation between the pump supplier, the heat exchange supplier, and the system designer was initiated with a view to trying to optimise auxiliary service systems on board ships by combining the designer's knowledge and the practical experience of the two suppliers. The optimisations were centred on reducing the needed power for the pump and in that way reducing the CO_2 emission to the environment.

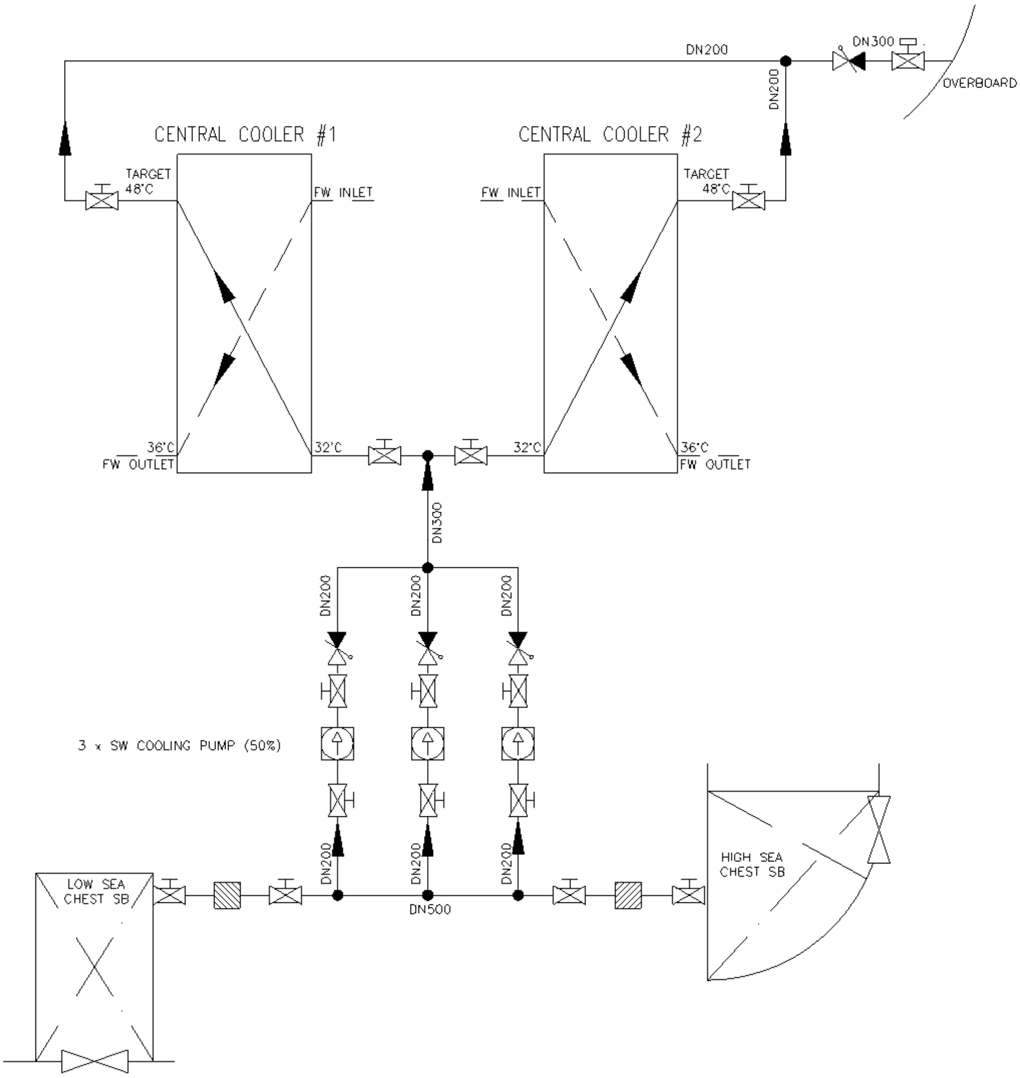
The cooperation partners first focused on the seawater (SW) cooling system, being one of the parts in an ordinary central cooling water system. The chosen vessel type is a bulk carrier, which is very familiar to almost all, and in that way the conclusion of the studies in this report can easily be adopted to optimising projects at existing vessels and of course to optimising all new-building projects.

DESCRIPTION OF THE SYSTEM USED IN ALL CALCULATION CASES

The pipe system showed on the simplified drawing 611-01 is a typical seawater (SW) cooling system for a handy size bulk carrier.

The two of the three SW pumps (two pumps rated at 50% of the specified flow – one pump rated at 50% as standby pump) draw SW from a common manifold pipe, which is connected to a low sea chest and a high sea chest. The SW is discharged from the SW pumps through the two parallel-connected coolers and overboard to the sea again.

The system with three 50% pumps has been used because this is the most common way to design the system and because it ensures a flexible and reliable operation of the system.



System drawing: 611-01

CASE STUDIES

SPECIFICATION OF SW COMPONENTS:

The case studies have been divided in different steps to illustrate the progress in the project. These steps have been named as follows:

- CASE STUDY NO. 1: Calculation of the existing final design including the existing pumps and coolers.
- CASE STUDY NO. 2: Same as case study No. 1 but with a new optimised pump.
- CASE STUDY NO. 3: Calculation with a new cooler based on 2x50% instead of 2x65% cooling capacity, please see explanation later. New optimised pump, corresponding to the new coolers, has been used.
- CASE STUDY NO. 4: Calculations with optimised coolers in respect of low-pressure drop. New optimised pumps, corresponding to the new coolers, have been used.

SPECIFICATION OF OPERATING CONDITIONS:

All of the evaluated case studies have been based on the same operating conditions e.g. same SW temperatures, same pipe diameters, same location of equipment etc.

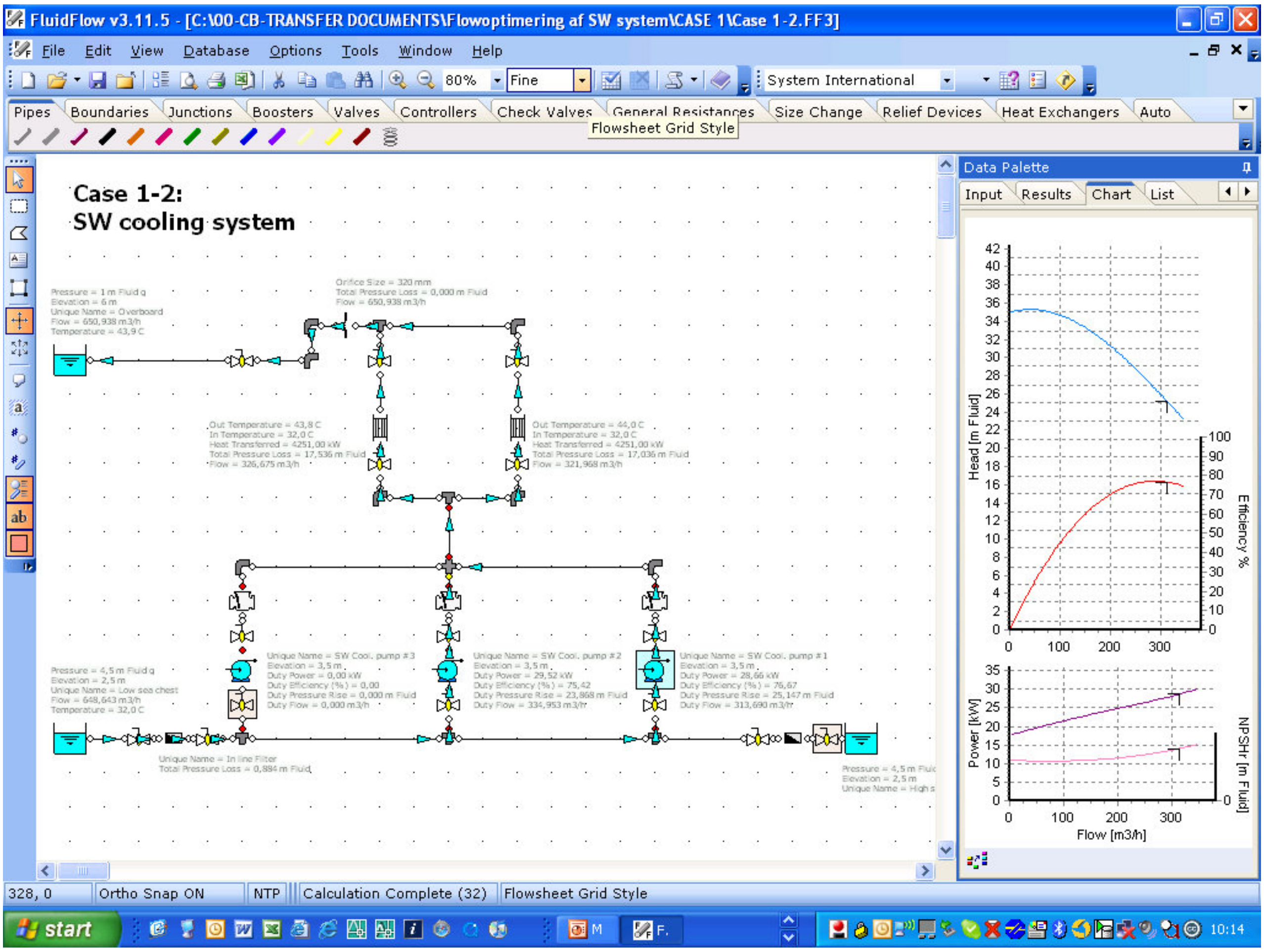
Filter:	Inline SW filter at suction side. High sea chest is closed.
Running time for pumps:	365 days per year
Pipes:	Normal steel pipe. DIN sizes
Calculation:	Operating conditions used in the FluidFlow calculation:

Ambient SW temperature:	32 deg.C
FW temperature out:	36 deg.C
Inlet location:	2.5 m above base line
Outlet location:	6.0 m above base line
Location of pumps:	3.5 m above base line
Location of coolers:	9.5 m above base line
Vessel draft aft:	7.0 m

SPECIFICATION OF CALCULATION TOOL:

The case studies have been calculated and evaluated in a fluid calculation program named FluidFlow, which is a powerful design and simulation tool for pipe systems. The FluidFlow designing tool facilitates quick and effective evaluations such as:

- Pressure loss calculations for fluid, gas and slurry systems
- Selection of optimal pumps / ventilators
- Cavitation control of pumps
- Calculation of air pipes connected to tanks for pressurized system



FluidFlow screen dump of present SW cooling system.
Each case study has been calculated in FluidFlow. See Appendix 1 page 5-14

CASE STUDY NO. 1:

The SW cooling water system was originally designed with a pump capacity / pressure from a preliminary specification stated in the building specification for the vessel, with no specific knowledge of flow resistance for coolers, filters and elevation location of each equipment.

The system was not optimised in the detailed production design by the yard when the other system-related equipment and the hydrostatic pressure heights were known. Furthermore the pump was bought as a standard stock pump in a low efficiency design.

The practice of using the “first, qualified guess” as the final specification for purchasing the pump has unfortunately been seen especially at the yards in the “young” shipbuilding nations, where the yards have less technical experience.

The coolers were selected with a cooling water heat transfer capacity each of 2x65% of the total heat transfer requirement, calculated according to a cooling water balance where the different cooling consumers, mainly the main engine and the auxiliary engines, were added and multiplied by an estimated load factor.

SPECIFICATION OF SW COMPONENTS:

Pumps: 3 x 230 m^3/h at 3.0 barg.

Pump data appear from the component appendix.

Coolers:

- 2 X 4251 kW heat exchangers (cooling capacity based on cooling consumer load balance, Tropical – see Appendix 1 page 3)
- SW flow based on the preliminarily chosen pump capacity.
- Flow resistance for cooler is stated as 0,87 bar at 230 m3/h

Cooler data appear from the component appendix.

CONCLUSION: CASE STUDY NO. 1:

We have focused on two scenarios when the 2 pumps are in operation. The first one is specified in case 1-1 and the second one is specified in case 1-2

1-1 The operator tries to keep each of the pumps at the 230 m^3/h operation point. To ensure this it is necessary to throttle the discharge valves or insert an orifice due to the fact that the system pressure is lower than the specified operation point at 3.0 barg.

In this scenario the mechanical power in the duty point of each of the running pumps is **25.85 kW** which corresponds to the below per year / pump:

Fuel consumption (ts/year/pump):	**51.30**
CO_2 emission (ts/year):	**159.6**
Running cost (USD/year):	**32,807.0**

ref. calculation in appendix 1 page 2

1-2 The operator lets each of the pumps run at the system pressure. The pump is very close “to run out” of its curve and delivers approx. 321 m^3/h SW at 2,4bar.

In this scenario the pump’s mechanical power in the duty point is **29.09 kW** which corresponds to the below per year / pump:

Fuel consumption (ts/year/pump):	**57.70**
CO_2 emission (ts/year):	**179,6**
Running cost (USD/year):	**36,919.0**

ref. calculation in appendix 1 page 2

We have used 1-2 as reference condition.

CASE STUDY NO. 2:

In this scenario we have kept the cooler as specified in order to evaluate the reduction of the power consumption when changing the pump head and optimising the pump efficiency to the system pressure.

SPECIFICATION OF SW COMPONENTS:

Pumps: 3 x 230 m3/h at 1.2 barg.

Pump data appear from the component appendix.

Coolers:

- 2 x 4251 kW heat exchangers (cooling capacity based on cooling consumer load balance, Tropical – see Appendix 1 page 3)
- SW flow based on the preliminary pump capacity chosen.
- Flow resistance for cooler is stated as 0.87 bar at 230 m3/h

Cooler data appear from the component appendix.

CONCLUSION: CASE STUDY NO. 2:

The pump is now running at the specified system pressure, and it is not necessary to throttle valves or insert an orifice to keep the pump at the specified operation point.

The necessary mechanical power for running each pump is **9.89 kW** which corresponds to the below per year / pump:

Fuel consumption (ts/year/pump):	**19.60**
CO_2 emission (ts/year):	**61.0**
Running cost (USD/year):	**12,545.0**

ref. calculation in appendix 1 page 2

The savings compared with:

Case study No. 1-2:	**66%**

CASE STUDY NO. 3:

The total cooling capacity has now been reduced from a total duty of 2 x 65% into 2 x 50%. After reducing the total duty to 2 x 50% each cooler still has a built in Heat Transfer Coefficient (HTC) margin of 15%. We wish to emphasize that the 15% reduction of the HTC margin equals a 15% reduction of the K-value.

Unfortunately the way that designers, shipyards and ship owners specify coolers has resulted in a double safety factor for the cooler. This study tries to describe the consequence of this common mistake.

SPECIFICATION OF SW COMPONENTS:

Pumps: 3 x 205 m3/h at 0.9 barg.

Pump data appear from the component appendix.

Coolers:

- 2 X 3270 kW heat exchangers (cooling capacity based on cooling consumer load balance, Tropical – see Appendix 1 page 4)
- Flow resistance and SW flow for cooler is stated as 0.69 bar at 205 m3/h

Cooler data appear from the component appendix.

CONCLUSION: CASE STUDY NO. 3:

By using the built in safety HTC margin in the cooler, allows the cooler to operate at a lower flow / lower pressure drop which dramatically affects the fuel consumption / CO_2 emission.

The necessary mechanical power for running each pump is **6.80 kW** which corresponds to the below per year / pump:

Fuel consumption (ts/year/pump):	**13.48**
CO_2 emission (ts/year):	**42.0**
Running cost (USD/year):	**8,630.0**

ref. calculation in appendix 1 page 2

The savings compared with:

Case study No. 1-2:	**77%**
Case study No. 2:	**31%**

CASE STUDY NO. 4:

As a result of the big savings in case study 2 and 3 compared to case study 1, the task was to optimise the coolers due to the pressure drop and compare the yearly costs / CO_2 emission to the environment with the purchasing costs of the entire system. The purpose of this case study 4 was to determine the optimum between initial installation costs and operational costs.

SPECIFICATION OF SW COMPONENTS:

The study required that the following 6 scenarios/steps were considered:
The pump and cooler data is mentioned in the component appendix.

Case 4-1: Pumps: Coolers:	 3 x 180 m3/h at 0.4 barg. • 2 X 3270 kW heat exchangers • SW flow 180 m^3/h • Pressure drop 0.2 bar
Case 4-2 Pumps: Coolers:	 3 x 180 m3/h at 0.5 barg. • 2 X 3270 kW heat exchangers • SW flow 180 m^3/h • Pressure drop 0.3 bar
Case 4-3 Pumps: Coolers:	 3 x 180 m3/h at 0.6 barg. • 2 X 3270 kW heat exchangers • SW flow 180 m^3/h • Pressure drop 0.4 bar
Case 4-4 Pumps: Coolers:	 3 x 180 m3/h at 0.7 barg. • 2 X 3270 kW heat exchangers • SW flow 180 m^3/h • Pressure drop 0.5 bar
Case 4-5 Pumps: Coolers:	 3 x 180 m3/h at 0.8 barg. • 2 X 3270 kW heat exchangers • SW flow 180 m^3/h • Pressure drop 0.6 bar
Case 4-6 Pumps: Coolers:	 3 x 180 m3/h at 0.9 barg. • 2 X 3270 kW heat exchangers • SW flow 180 m^3/h • Pressure drop 0.7 bar

CONCLUSION: CASE STUDY NO. 4

It is very clear that a cooler with at pressure drop of 0.2 bar (Case study 4-1) is the most optimised SW cooling water system with regard to low yearly running costs and a very low CO_2 emission to the environment. The necessary mechanical power for running each pump in each case study is:

4-1:	2.69 kW
4-2:	3.46 kW
4-3:	4.11 kW
4-4:	4.66 kW
4-5:	5.21 kW
4-6:	5.84 kW

The necessary power for case study 4-1 corresponds to the below per year / pump:

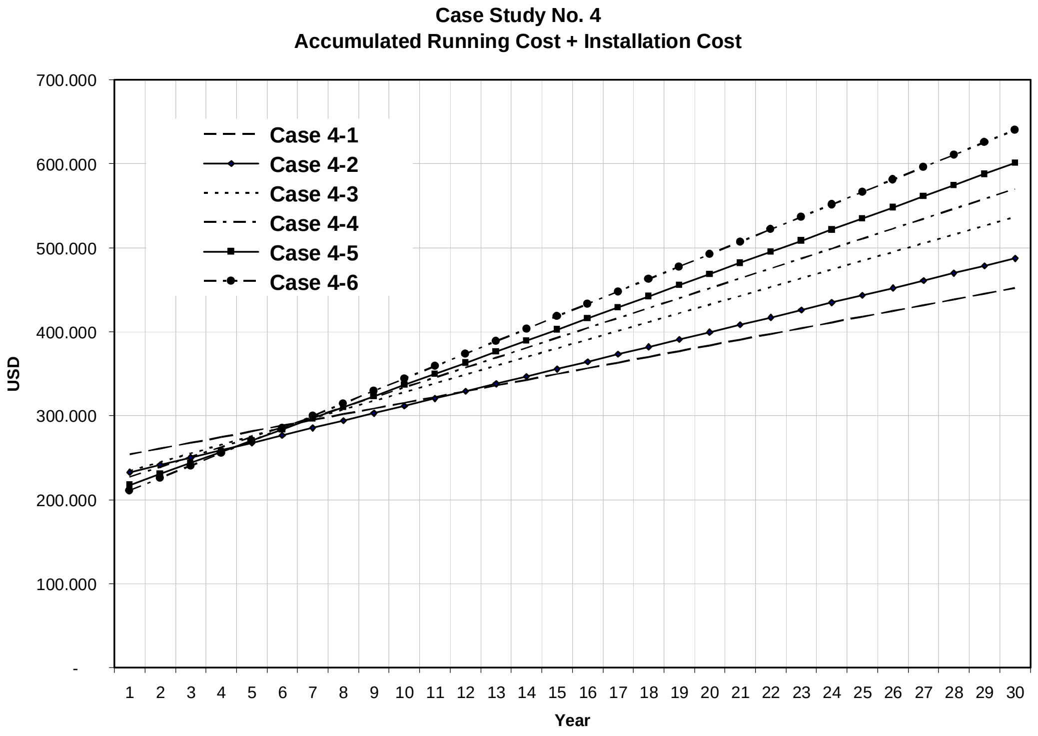
Fuel consumption (ts/year/pump):	**5.33**
CO_2 emission (ts/year):	**16.1**
Running cost (USD/year):	**3,414**

ref. calculation in appendix 1 page 2

The savings case study 4-1 compared with:

Case study No. 1-2:	**91%**
Case study No. 2:	**73%**
Case study No. 3:	**60%**

It has to be mentioned that a cooler with a very low pressure drop is a larger cooler and of course in that way a more expensive cooler. The increased initial installation costs will afterwards be compared to the operational costs.

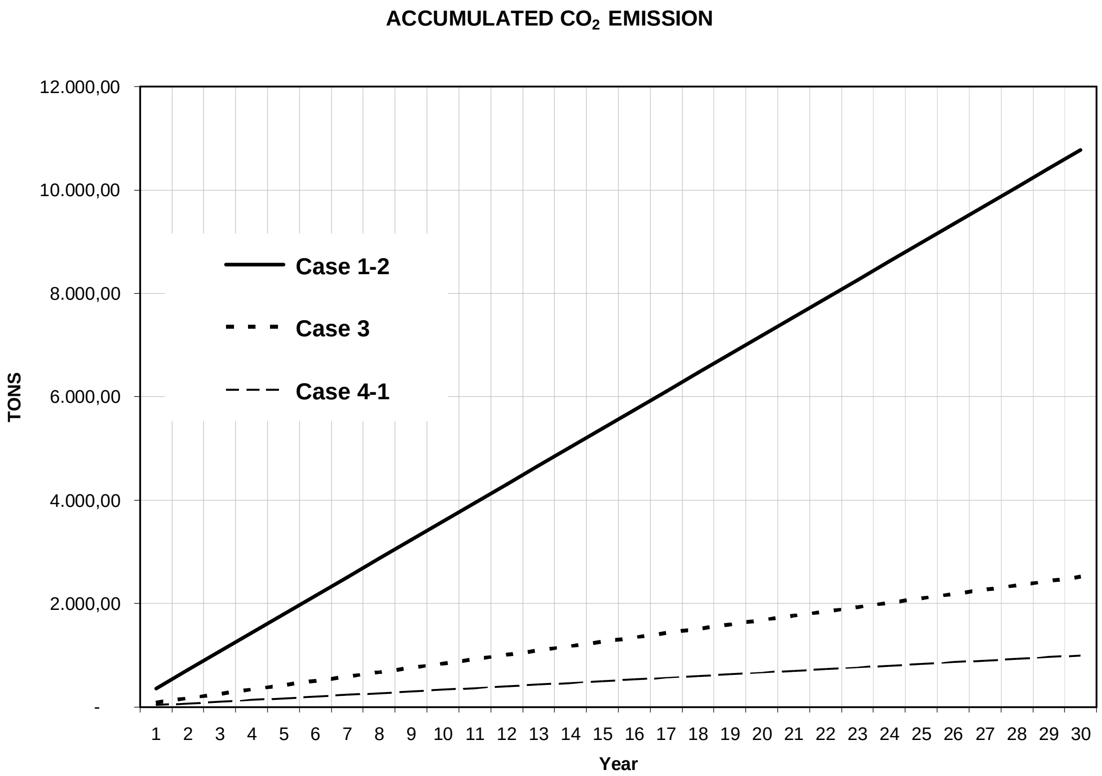


OVERALL CONCLUSION:

- The pressure drop of the cooler is essential. The cooler is the component in the sea water system causing the highest resistance, and consequently it has a significant impact on the overall system pressure and in that way facilitates the installation of smaller pumps. Therefore the chosen cooler pressure drop should be specified very clearly, when purchasing departments are purchasing the coolers.

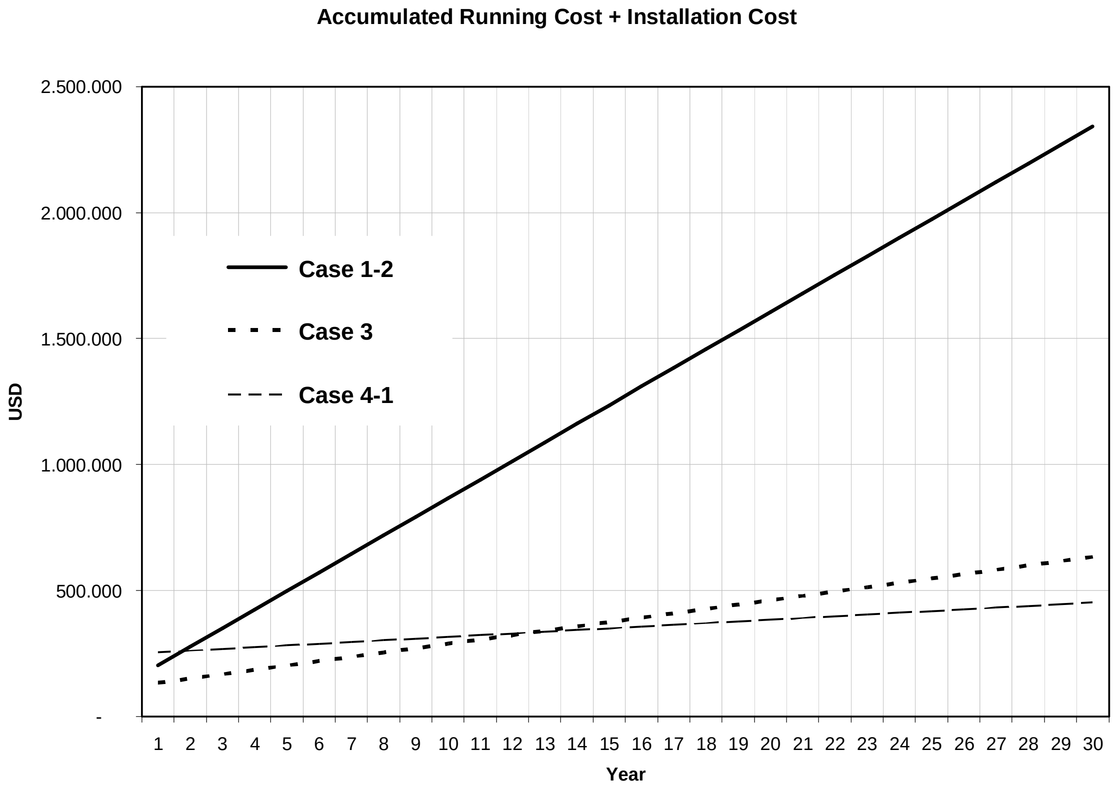
Figures for one pump:

Fuel cons./ CO_2 emission Case Study 1-2 (ts/year):	**57.70 / 179.6**
Fuel cons./ CO_2 emission Case Study 3 (ts/year):	**13.48 / 42.0**
Fuel cons./ CO_2 emission Case Study 4-1(ts/year):	**5.33 / 16.6**



Accumulated CO_2 emission for two pumps running

- The overall costs, purchasing + running costs, indicate that the installation of coolers with a very low pressure drop is a good investment both for low overall costs, but also for the environment. Installation of 3 pumps + 2 coolers (only 2 pumps running).



Accumulated Cost

- An additional benefit of a very low pressure drop on the SW cooler side is that the Fresh Water (FW) side also decreases dramatically and in that way also generates smaller FW pumps. These pumps have not been included in this report but will result in shorter investment payback time.

- It is important that the pumps chosen are "high efficiency pumps".

- Let the pump specification be open until the pipe system has been designed in detail, so that all components are well known, e.g. location of equipment, pipe length, quantity of bends etc. In that way the pump can be optimised to exactly fit the system pressure.

- Low pressure gives the benefit of less stress on all components.

FUTURE INVESTIGATION POSSIBILITIES

- Fixed back flushing arrangement shall be installed together with a cleaning in place (CIP) arrangement to keep the pressure drop across the coolers as low as possible and the efficiency of the coolers as high as possible. Smaller cooler pressure drop – more sensitive coolers.
- SW pumps as 2x100% or 3x50% or another division of pump sizes.
- Using a harbour cooling pump as a supplement to above.
- 2-speed pump, in order to adjust the pump capacity based on actual need.
- Frequency controlled SW pumps regulated by temperature transmitter on the discharge side of the coolers. The result will be even better than the above speed regulation and the capacity of the pump can be adjusted very close to the actual need.
- LT cooling water system optimisation bringing down the pump sizes, which results in further overall power reduction.
- More Partners e.g. dialog with manufactures of FW cooling consumers, and dialog with ship owner regarding operation facts.

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Appendix 1
Calculation Documents

1. Consumption & CO_2 calculation.. Page 2

2. Cooling water balance 2 x 65% (Case 1 + 2)....................................... Page 3

3. Cooling water balance 2 x 50% (Case 3 + 4)....................................... Page 4

4. Fluid Flow calculations for each case story................................... Page 5 - 14

	CASE STUDY 1-1	CASE STUDY 1-2	CASE STUDY 2	CASE STUDY 3	CASE STUDY 4-1	CASE STUDY 4-2	CASE STUDY 4-3	CASE STUDY 4-4	CASE STUDY 4-5	CASE STUDY 4-6
	BASE PUMP	BASE PUMP	NEW PUMP	NEW PUMP	NEW PUMP	NEW PUMP	NEW PUMP	NEW PUMP	NEW PUMP	NEW PUMP
	2x65% COOLER	2x65% COOLER	2x65% COOLER	2x50% COOLER	2x50% COOLER 0.2 dP	2x50% COOLER 0.3 dP	2x50% COOLER 0.4 dP	2x50% COOLER 0.5 dP	2x50% COOLER 0.6 dP	2x50% COOLER 0.7 dP
Average required pump power [kW]	25,85	29,09	9,89	6,80	2,69	3,46	4,11	4,66	5,21	5,84
Yearly consumption [ts/year/pump]	51,26	57,69	19,60	13,48	5,33	6,86	8,15	9,24	10,33	11,57
Yearly CO_2 emission [ts/year]	159,63	179,63	61,04	41,99	16,61	21,37	25,38	28,78	32,17	36,03
Fuel consumption [USD/pump]	32.807	36.919	12.545	8.630	3.414	4.391	5.216	5.914	6.612	7.405

CO_2 emission for HFO [kg/kg fuel]	3,114
Efficiency factor electrical motor	93%
Efficiency factor aux. diesel / generator	95%
Running days / year [days]	365
Aux diesel specific consumption [g/kWh]	200
Bunker price [USD/ts]	640

615-00-1

CONDITION: AT SEA - 100% (SMCR) MAIN ENGINE LOAD - TROPICAL CONDITION

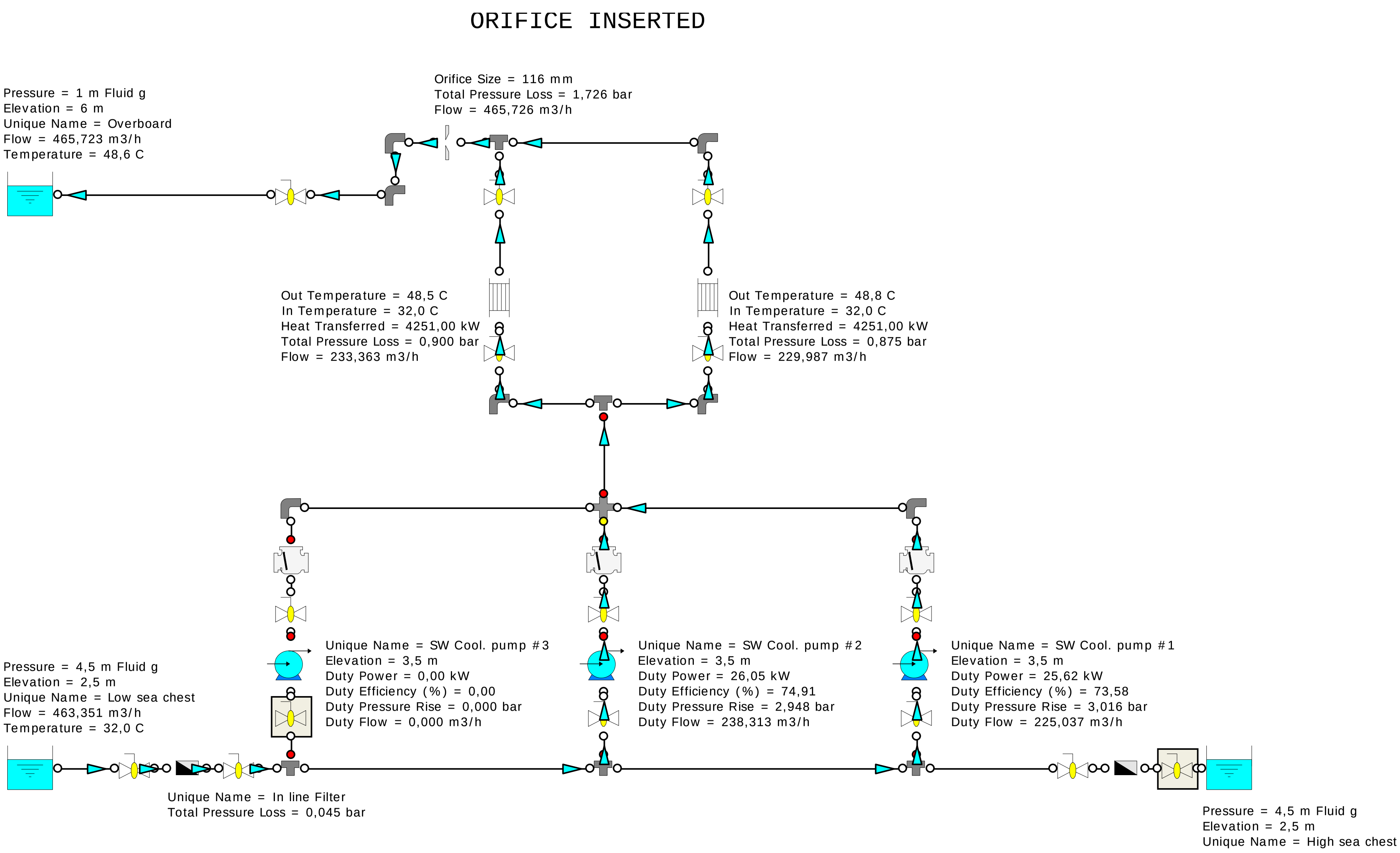
ITEM NO. :	DESCRIPTION:	LOAD	HEAT DISS.	HEAT DISS. AT LOAD	TOL.	SPEC. COOL.	COOL. WATER FLOW	INLET TEMP.	OUTLET TEMP. AT MAX. LOAD	COOLING WATER FLOW	Delta P	REMARK
		[%]	[kW]	[kW]	[+%]	[m^3/H]	[m^3/H]	[deg. C]	[deg. C]	[m^3/H]	[kPa]	
563.01	M/E LO COOLER +	100%	700	700,0	10%	95	104,5	36,0	42,4	104,50	20,00	
562.03	JACKET WATER COOLER	100%	1240	1240,0	10%	95	104,5	42,4	53,7		20,00	
411.01	M/E SCAVENGER AIR COOLER	100%	3000	3000,0	0%	137	137	36,0	55,0	137,00	50,00	
431.01	A/E 1 TOTAL (LO, JACK. W. AND SCAV. AIR COOLER)	90%	420	378,0	0%	28,7	28,7	36,0	47,4	28,70	39,20	
431.02	A/E 2 TOTAL (LO, JACK. W. AND SCAV. AIR COOLER)	90%	420	378,0	0%	28,7	28,7	36,0	47,4	28,70	39,20	
431.03	A/E 3 TOTAL (LO, JACK. W. AND SCAV. AIR COOLER)	0%	420	0,0	0%	28,7	28,7	36,0	36,0	0,00	39,20	
312.01	REFR. COMPRESSOR UNIT FOR A/C PLANT	75%	196	147,0	0%	40	40	36,0	39,2	40,00	39,20	
312.02	REFR. COMPRESSOR UNIT FOR A/C PLANT	75%	196	147,0	0%	40	40	36,0	39,2	40,00	39,20	
355.01	PROVISON COOLING COMPRESSOR	75%	9,5	7,1	0%	4,2	4,2	36,0	37,5	4,20	15,70	
355.02	PROVISON COOLING COMPRESSOR	75%	9,5	7,1	0%	4,2	4,2	36,0	37,5	4,20	15,70	
314.03	REFR. COMP. FOR A/S UNIT GALLEY	75%	17,8	13,4	0%	5,22	5,22	36,0	38,2	5,22	50,00	
314.02	REFR. COMP. FOR A/S UNIT ENG. CONTR. ROOM	75%	17,2	12,9	0%	5,22	5,22	36,0	38,1	5,22	50,00	
682.01	STEAM DUMP COOLER	50%	998	499,0	0%	36	36	36,0	48,0	36,00		
562.07	SAMPLE COOLER	0%	2	0,0	0%	2	2	36,0	36,0	0,00		
423.03	SHAFT BEARING	100%	1,7	1,7	0%	0,15	0,15	36,0	45,8	0,15		
461.01	STARTING AIR COMPRESSOR	50%	16,7	8,4	0%	3,24	3,24	36,0	38,2	3,24		
461.02	STARTING AIR COMPRESSOR	0%	16,7	0,0	0%	3,24	3,24	36,0	36,0	0,00		
TOTAL REQUIREMENT:				**6540**	[kW]							
TOTAL LT FLOW:				**437**	[m^3/h]							
TOTAL SW FLOW:				**460**	[m^3/h]							
FW TEMP OUTLET OF COOLERS:				**36,0**	[deg. C]							
FW TEMP INLET TO COOLERS:				**49,0**	[deg. C]							
SW TEMP INLET TO COOLERS:				**32,0**	[deg. C]							
SW TEMP OUTLET OF COOLERS:				**48,0**	[deg. C]	TARGET						
COOL. REQ. FOR EACH COOLER:			65%	**4251**	[kW]							
LT FLOW FOR EACH COOLER:				**437**	[m^3/h]							
SW FLOW FOR EACH COOLER:				**460**	[m^3/h]	To be provided by 2 x 50% SW pumps running in parallel operation						

615-00-2

CONDITION: AT SEA - 100% (SMCR) MAIN ENGINE LOAD - TROPICAL CONDITION

ITEM NO. :	DESCRIPTION:	LOAD	HEAT DISS.	HEAT DISS. AT LOAD	TOL.	SPEC. COOL.	COOL. WATER FLOW	INLET TEMP.	OUTLET TEMP. AT MAX. LOAD	COOLING WATER FLOW	Delta P	REMARK
		[%]	[kW]	[kW]	[+%]	[m^3/H]	[m^3/H]	[deg. C]	[deg. C]	[m^3/H]	[kPa]	
563.01	M/E LO COOLER +	100%	700	700,0	10%	95	104,5	36,0	42,4	104,50	20,00	
562.03	JACKET WATER COOLER	100%	1240	1240,0	10%	95	104,5	42,4	53,7		20,00	
411.01	M/E SCAVENGER AIR COOLER	100%	3000	3000,0	0%	137	137	36,0	55,0	137,00	50,00	
431.01	A/E 1 TOTAL (LO, JACK. W. AND SCAV. AIR COOLER)	90%	420	378,0	0%	28,7	28,7	36,0	47,4	28,70	39,20	
431.02	A/E 2 TOTAL (LO, JACK. W. AND SCAV. AIR COOLER)	90%	420	378,0	0%	28,7	28,7	36,0	47,4	28,70	39,20	
431.03	A/E 3 TOTAL (LO, JACK. W. AND SCAV. AIR COOLER)	0%	420	0,0	0%	28,7	28,7	36,0	36,0	0,00	39,20	
312.01	REFR. COMPRESSOR UNIT FOR A/C PLANT	75%	196	147,0	0%	40	40	36,0	39,2	40,00	39,20	
312.02	REFR. COMPRESSOR UNIT FOR A/C PLANT	75%	196	147,0	0%	40	40	36,0	39,2	40,00	39,20	
355.01	PROVISON COOLING COMPRESSOR	75%	9,5	7,1	0%	4,2	4,2	36,0	37,5	4,20	15,70	
355.02	PROVISON COOLING COMPRESSOR	75%	9,5	7,1	0%	4,2	4,2	36,0	37,5	4,20	15,70	
314.03	REFR. COMP. FOR A/S UNIT GALLEY	75%	17,8	13,4	0%	5,22	5,22	36,0	38,2	5,22	50,00	
314.02	REFR. COMP. FOR A/S UNIT ENG. CONTR. ROOM	75%	17,2	12,9	0%	5,22	5,22	36,0	38,1	5,22	50,00	
682.01	STEAM DUMP COOLER	50%	998	499,0	0%	36	36	36,0	48,0	36,00		
562.07	SAMPLE COOLER	0%	2	0,0	0%	2	2	36,0	36,0	0,00		
423.03	SHAFT BEARING	100%	1,7	1,7	0%	0,15	0,15	36,0	45,8	0,15		
461.01	STARTING AIR COMPRESSOR	50%	16,7	8,4	0%	3,24	3,24	36,0	38,2	3,24		
461.02	STARTING AIR COMPRESSOR	0%	16,7	0,0	0%	3,24	3,24	36,0	36,0	0,00		
TOTAL REQUIREMENT:				**6540**	[kW]							
TOTAL LT FLOW:				**437**	[m^3/h]							
TOTAL SW FLOW:				**460**	[m^3/h]							
FW TEMP OUTLET OF COOLERS:				**36,0**	[deg. C]							
FW TEMP INLET TO COOLERS:				**49,0**	[deg. C]							
SW TEMP INLET TO COOLERS:				**32,0**	[deg. C]							
SW TEMP OUTLET OF COOLERS:				**48,0**	[deg. C]	TARGET						
COOL. REQ. FOR EACH COOLER:			50%	**3270**	[kW]							
LT FLOW FOR EACH COOLER:				**437**	[m^3/h]							
SW FLOW FOR EACH COOLER:				**460**	[m^3/h]	To be provided by 2 x 50% SW pumps running in parallel operation						

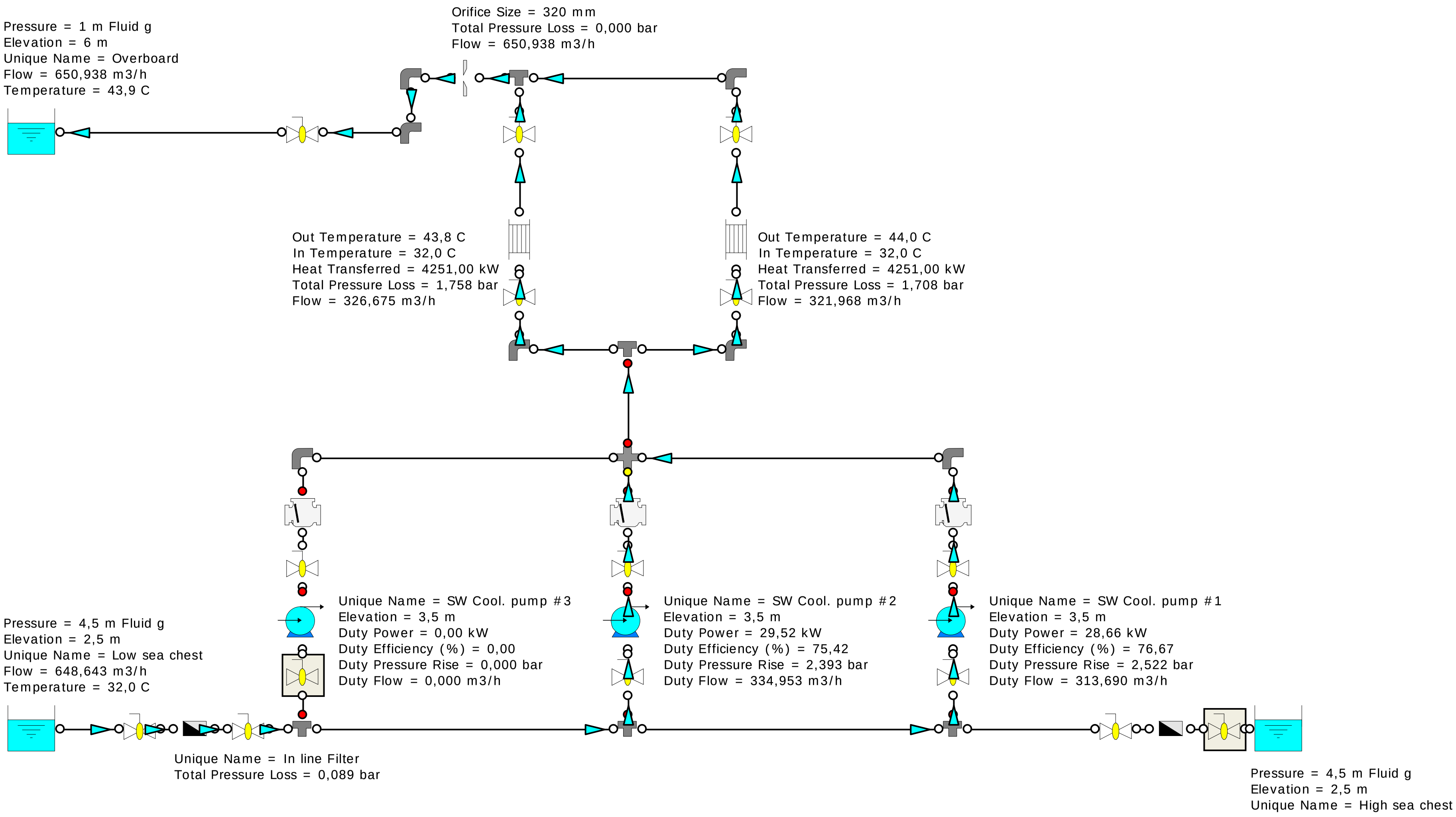
Case 1-1:
SW cooling system



Average Duty Power = 25,85 kW

Average Duty Efficiency (%) = 74,3

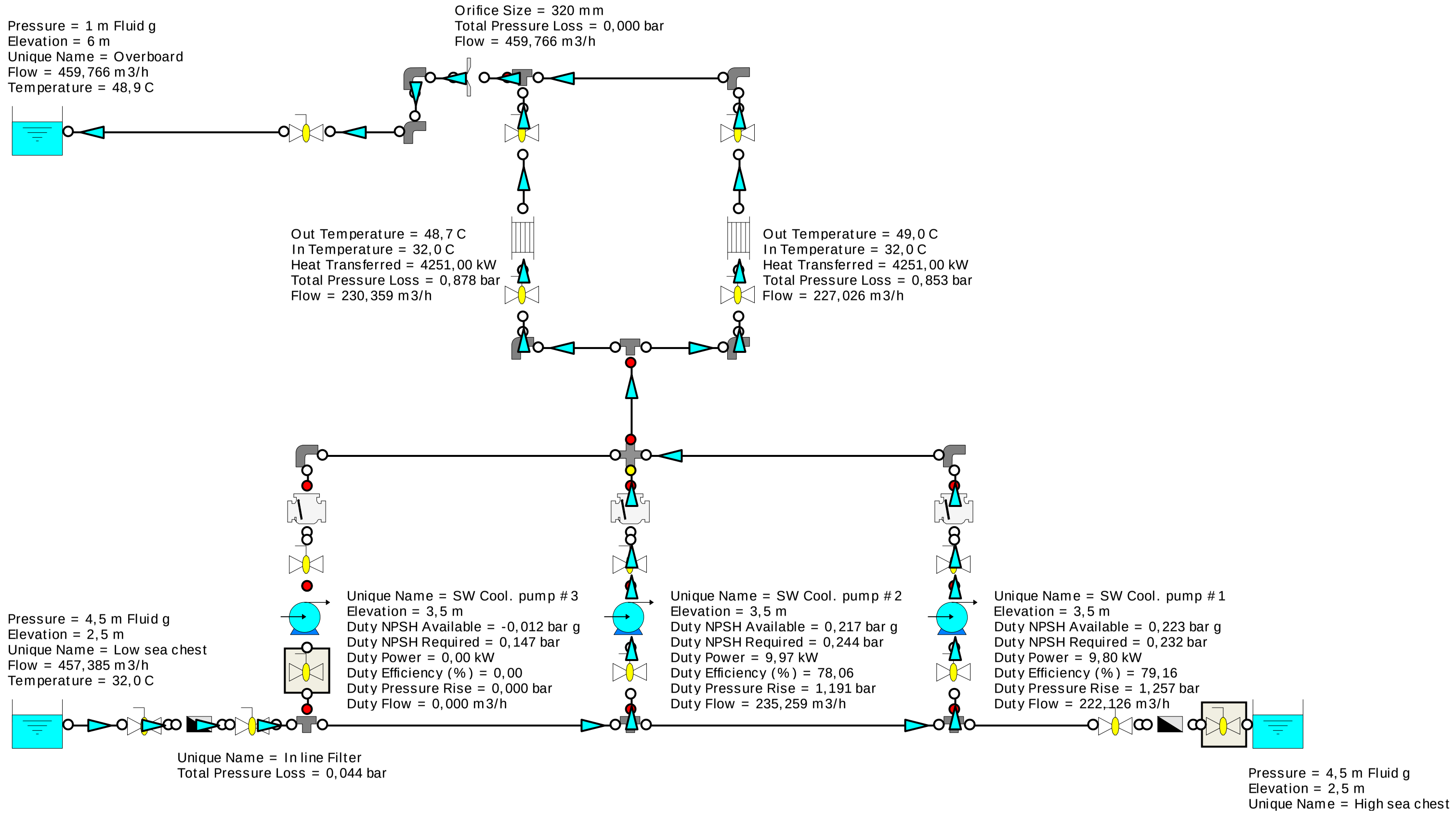
Case 1-2:
SW cooling system



Average Duty Power = 29,09 kW

Average Duty Efficiency (%) = 76,0

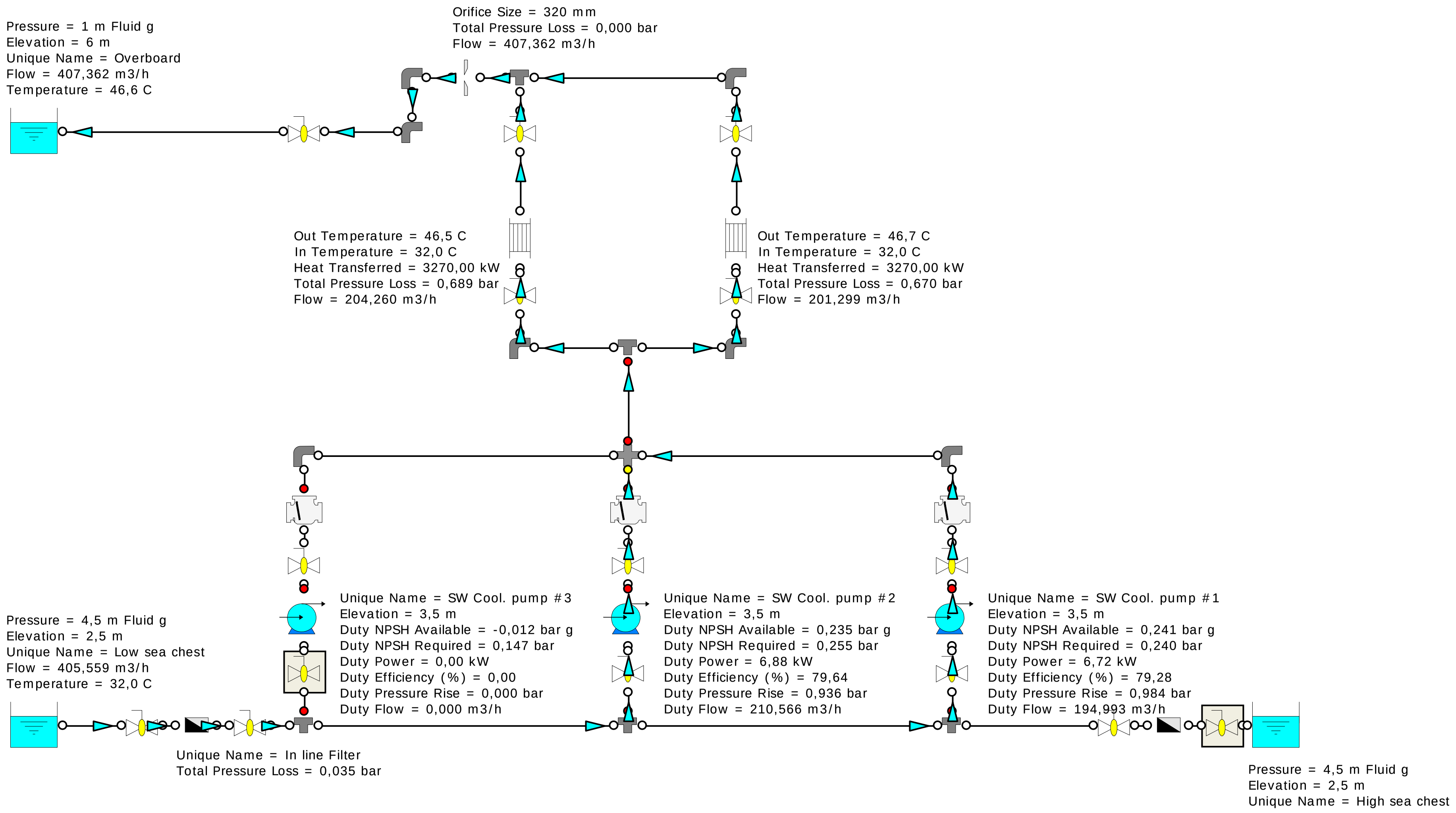
Case 2:
SW cooling system



Duty Power = 9,87 kW

Duty Efficiency (%) = 78,88

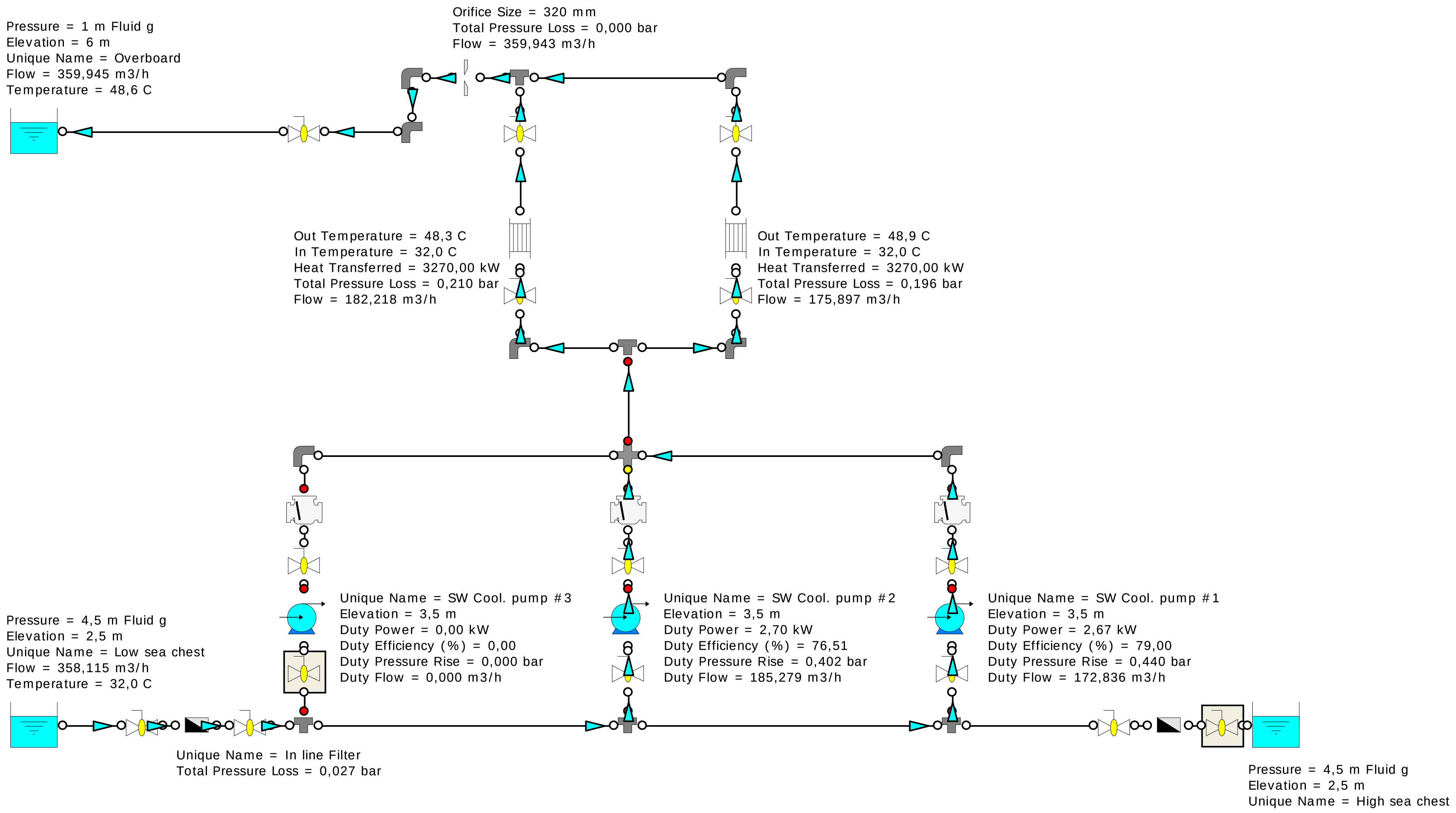
Case 3:
SW cooling system



Average Duty Power = 6,80 kW

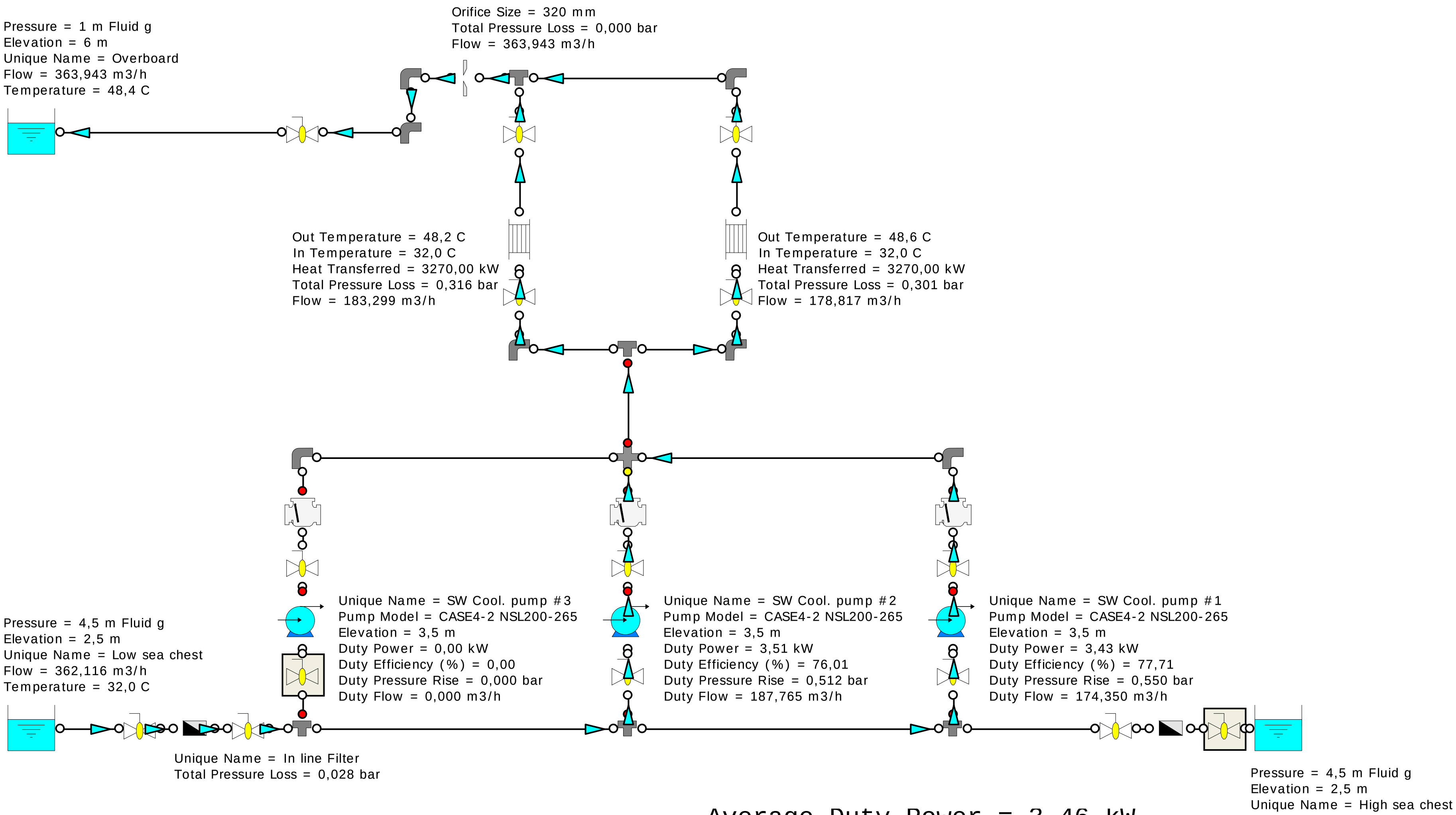
Average Duty Efficiency (%) = 79,5

Case 4-1:
SW cooling system



Average Duty Power = 2,69 kW
Average Duty Efficiency (%) = 77,8

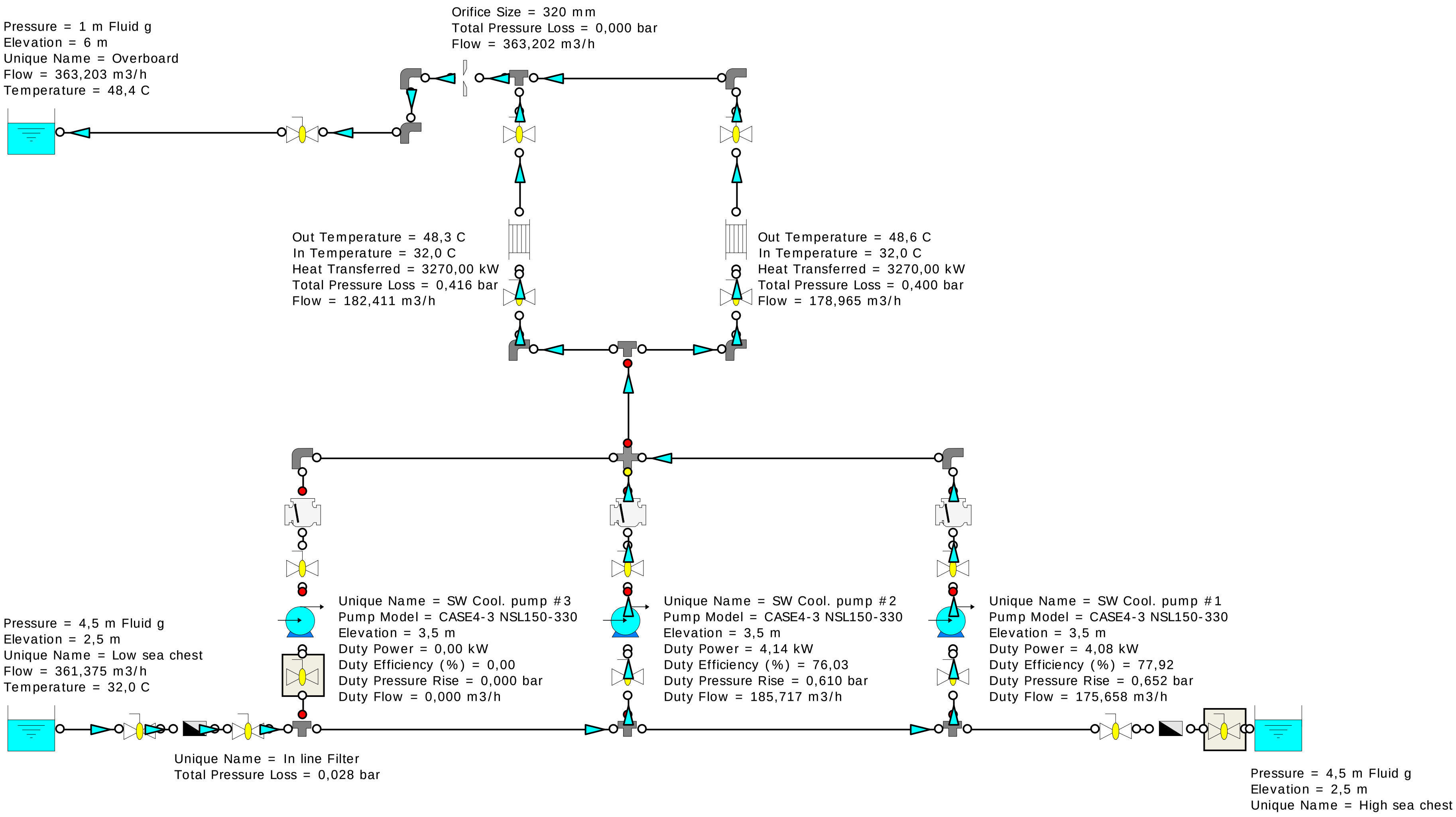
Case 4-2:
SW cooling system



Average Duty Power = 3,46 kW

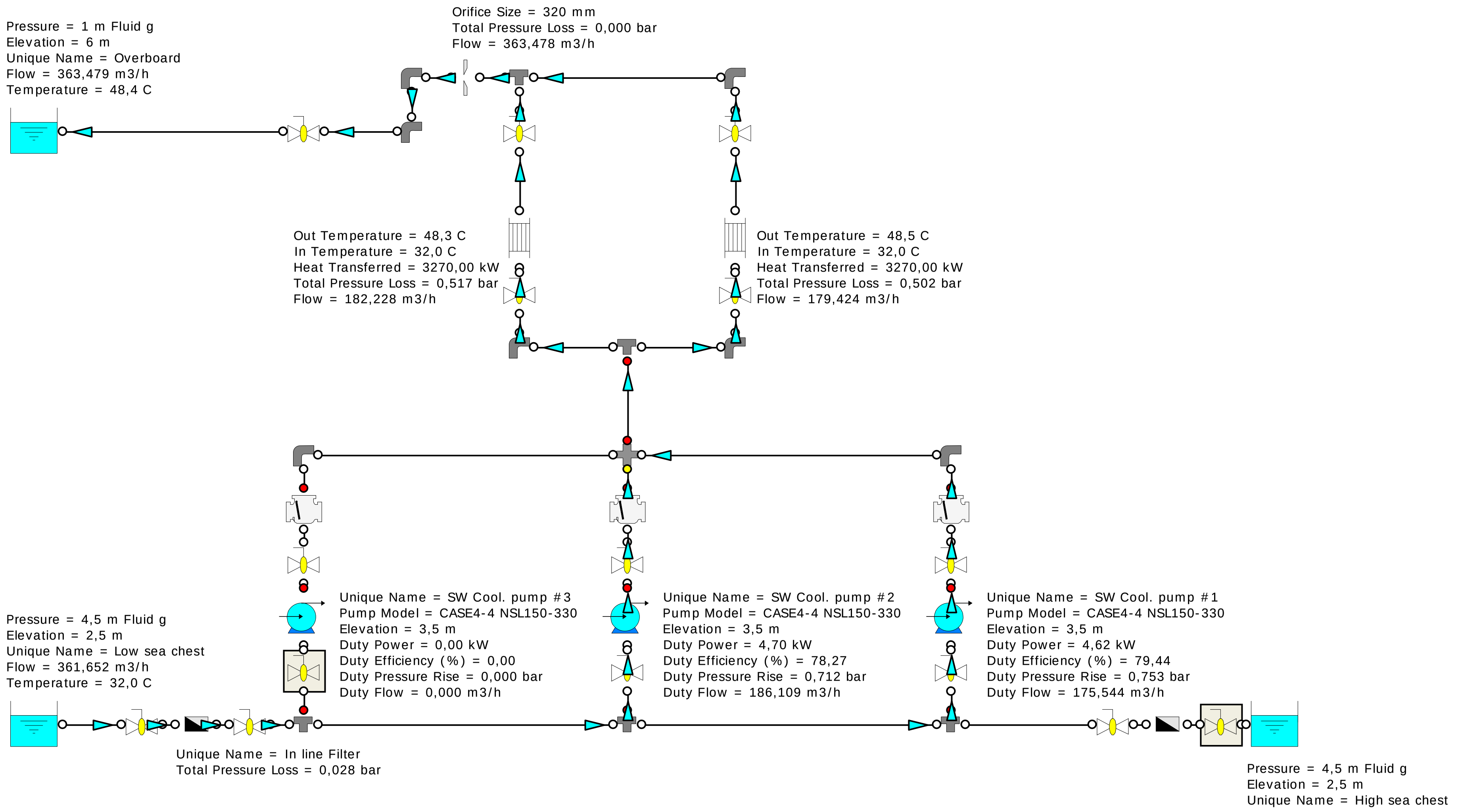
Average Duty Efficiency (%) = 76,9

Case 4-3:
SW cooling system



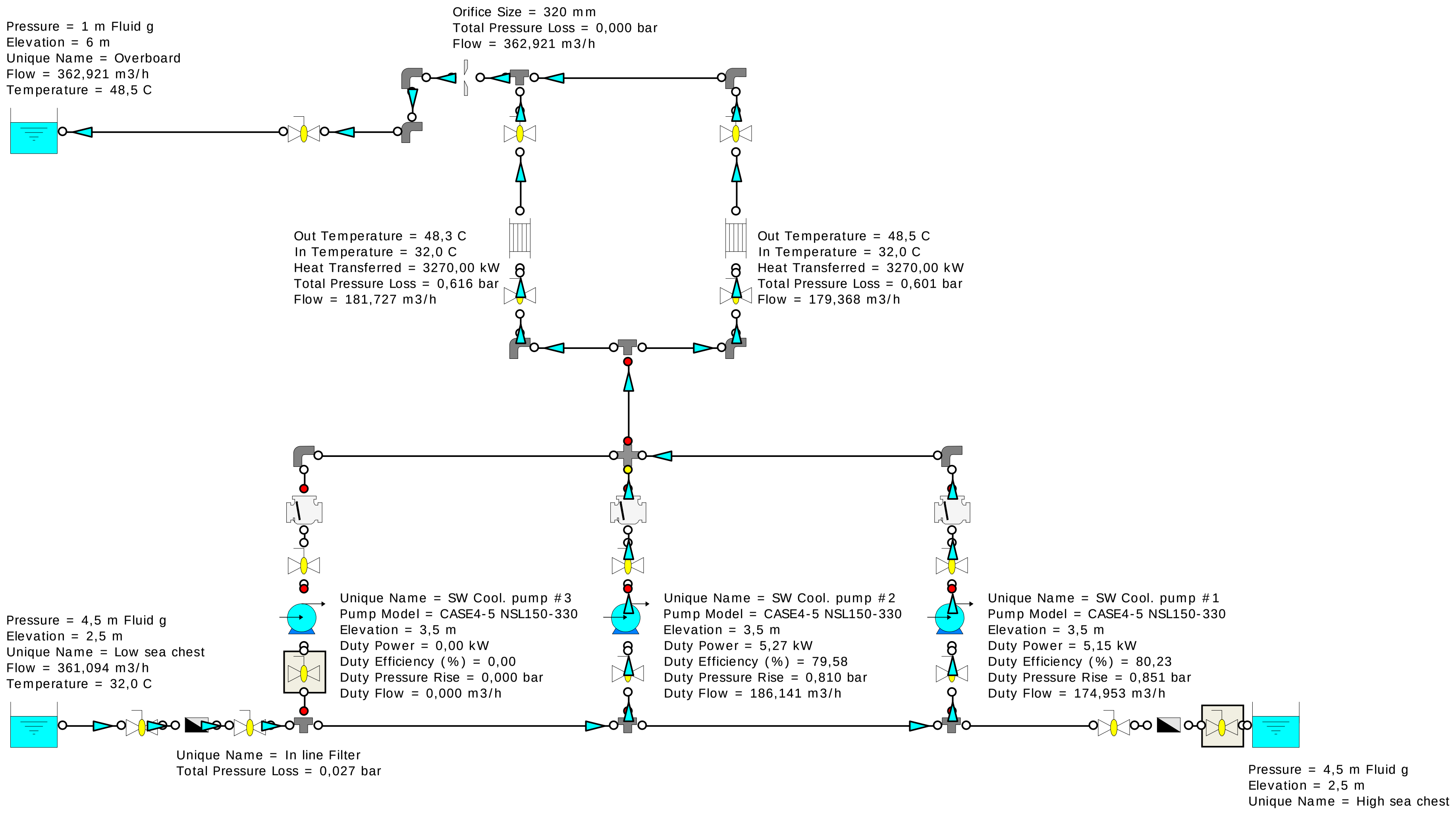
Average Duty Power = 4,11 kW
Average Duty Efficiency (%) = 77,0

Case 4-4:
SW cooling system



Average Duty Power = 4,66 kW
Average Duty Efficiency (%) = 78,9

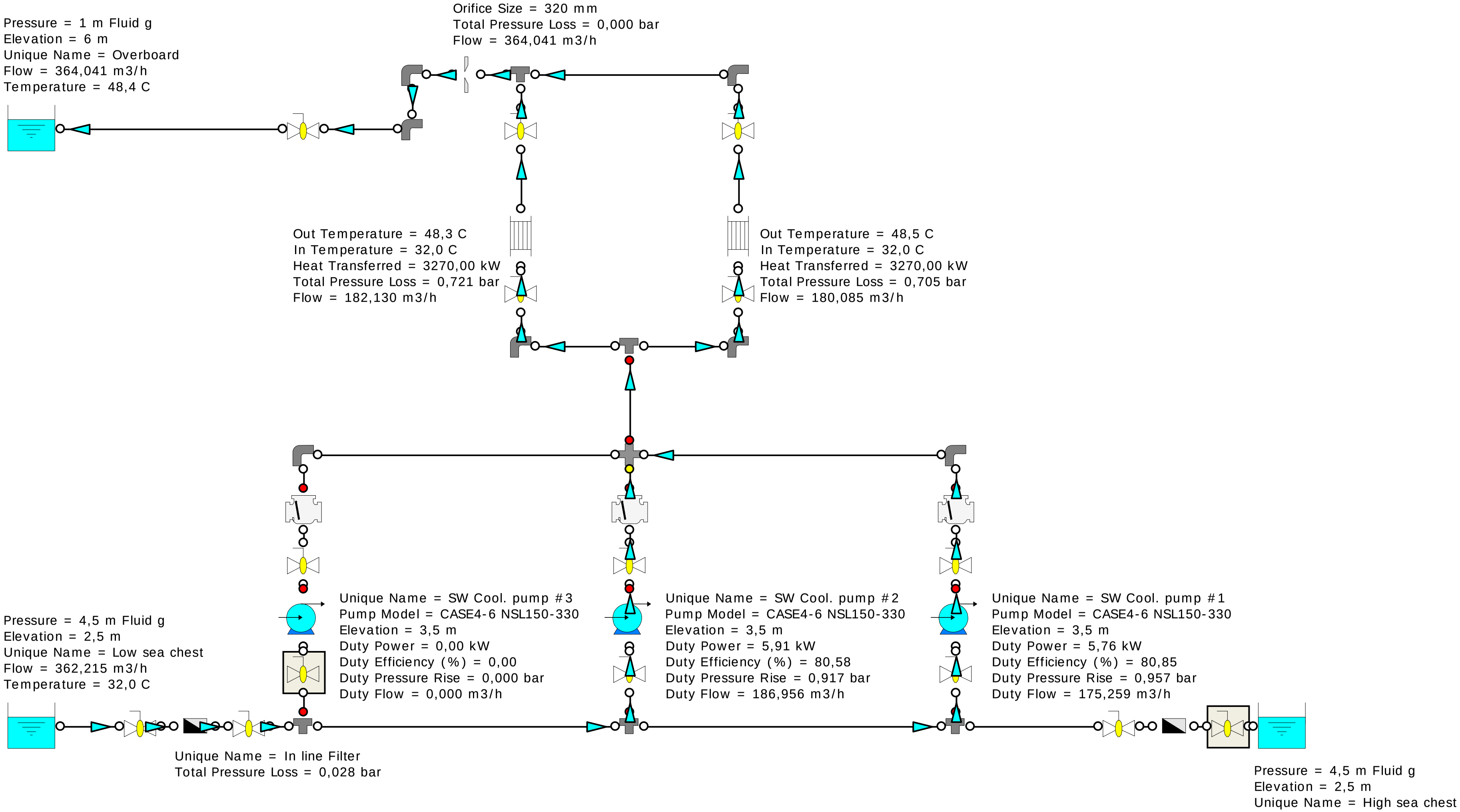
Case 4-5:
SW cooling system



Average Duty Power = 5,21 kW

Average Duty Efficiency (%) = 79,9

Case 4-6:
SW cooling system



Average Duty Power = 5,84 kW

Average Duty Efficiency (%) = 80,7

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