Volume XXI 2018
ISSUE no.1
MBNA Publishing House Constanta 2018

Scientific Bulletin of Naval Academy

SBNA PAPER • OPEN ACCESS

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To cite this article: O N Volintiru, I C Scurtu, E Dragomir and T M Stefanescu, Scientific Bulletin of Naval Academy, Vol. XXI 2018, pg. 375-380.

Available online at www.anmb.ro

ISSN: 2392-8956; ISSN-L: 1454-864X

doi: 10.21279/1454-864X-18-I1-057

Contributions to the study of functional parameters in the exploitation of chilled water system for particular ships

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Abstract. Under normal operating conditions, the chilled water system controls and distributes cooled water, usually produced by two chilled water plants, to coolers in air treatment units, coolers for machinery spaces and coolers of various electronic components. The main purpose of the chilled water plant is to cool the water from the main return ring at a temperature of 7 [°C] and then to distribute it to consumers through the distribution ring. Under special operating conditions, depending on the cooling requirements, the other chilled water plants may also be switched on. For example, if only three of the five chilled water plants are available and the ship is under special operating conditions, can be ensured cooling conditions for all ship compartments except machinery spaces.

Keywords: chilled water plant, air, ventilation, heat, air conditioning plant

1. Introduction

For marine chilled water systems, the calculation and exploitation parameters are provided in the standards. In preliminary and design calculations, other norms will be considered, such as increased comfort conditions for passenger ships, operating conditions for machines, aggregates and appliances and so on. The efficiency of the operation of chilled water plants depends on the processes taking place in the compartments served as well as on the weather conditions of the outside environment.

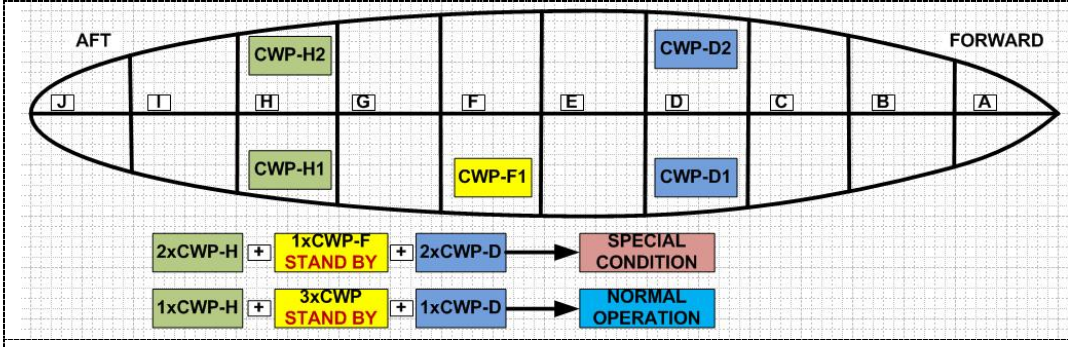

Figure 1. Chilled water plant location onboard ship and type of operation

2. General characteristics of the chilled water system for particular ships

For a frigate of 5000 tonnes, the chilled water system consists of a flow system designed to operate with a maximum of four chilled water plants running and another one in standby. The system comprises five section, each with a flow requirement from flow capacity of a single chilled water plant. A frigate of 5000 tonnes has five chilled water plant with a power of 300 kW or 1.000.000 BTU each.

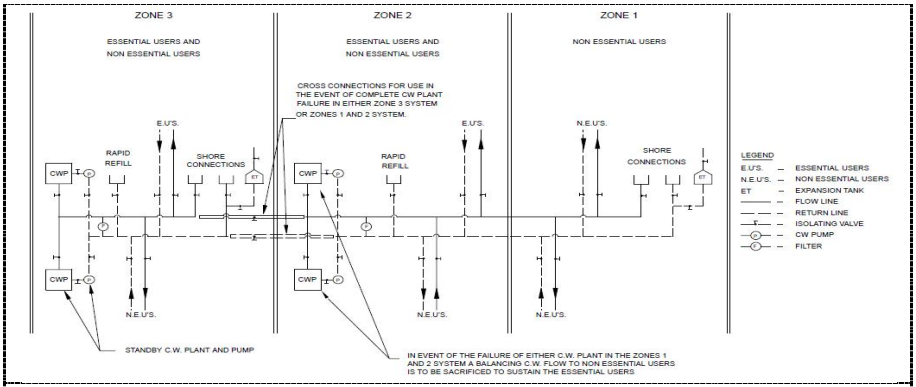

Figure 2. Chilled water system [4]

2.1. Chilled water plant main characteristics

For a frigate of 5000 tones, chilled water plant has main operational characteristics:

- chilled water plant capacity: 300 kW or 1000000 BTUs;
- chilled water system flow: 38 $[\frac{m^3}{h}]$;
- chilled water supply temperature: 7 [°C];
- chilled water return temperature: 13 [°C];
- sea water temperature: from – 2 [°C] to 35 [°C];
- machinery spaces temperature: from 4[°C] to 55 [°C];
- machinery spaces relative humidity: from 30 % to 80 %;
- refrigerant: R134A, 200 Kg;
- operational for ship pitch ± 20 º;
- operational for ship roll ± 20 º cyclic period higher than 10 seconds;
- compressor type: screw;
- pumps type (sea water, chilled water): centrifugal;

Figure 3. Chilled water plant with a capacity of 300 kW

2.2. Operation of the chilled water plant

The chilled water plant has a screw type compressor which compresses refrigerant gas and discharges it to an oil separator. Gas passes from the top of the oil separator to a condenser where it is cooled by sea water. The gas condenses and liquid refrigerant flows to a sub-cooler. The liquid then passes through a thermostatic regulating valve and then into a chiller or evaporator where heat is transferred from the chilled water to the liquid refrigerant. As the refrigerant absorbs heat it changes back to a gas and is returned to the suction side of the compressor.

The sea water pump takes suction directly from the sea and discharges through the condenser to a thermostatic valve. This valve regulates the flow of seawater to the overboard discharge, recirculating some water to the suction side of the pump to maintain a temperature of 28…32 [°C].

The chilled water pump discharges water through the chiller where it is cooled before passing up to the chilled water supply main.

Oil and refrigerant gas are discharged from the compressor and are separated in an oil separator. The oil collects in the bottom of the separator and is pumped via a cooler, a filter and an oil distribution manifold to the compressor.

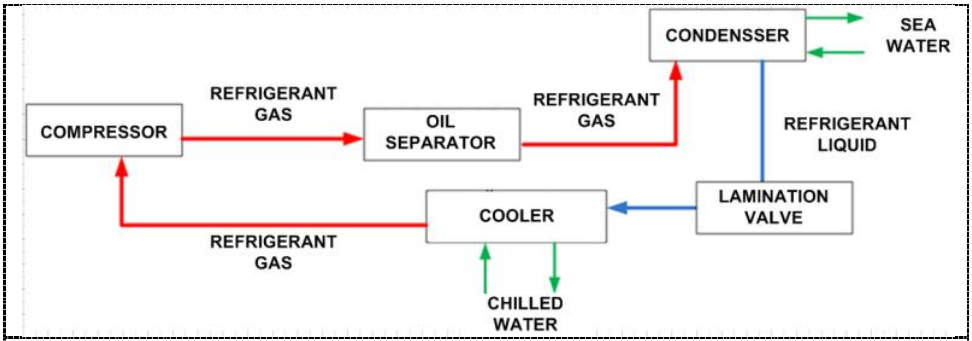

Figure 4. Chilled water plant cycle

2.3. Chilled water plant parameters

The chilled water plant parameters are collected by local control panels. The chilled water control panels are sited as close as possible to the equipment served. Control and indication of the chilled water plant are made by control and protective panels. The panels include the indication, alarm and automatic plant shutdown. Control of the chilled water pumps, seawater pumps and refrigerant compressors is also made from the control and protection panels.

Figure 5. Control and protective panel

Table 1. Chilled water plant with a capacity of 300 kW theoretical parameters operation limit

Parameter	Value		
	min	**normal**	**max**
Chilled water inlet [ºC]	0	13	30
Chilled water outlet [ºC]	0	7	30
Compressor suction [ºC]	-10	2/10	30
Compressor discharge pressure [bar]	0/4	8	12
Refrigerant outlet [ºC]	15	36	50
Compressor discharge temperature [ºC]	15	55	80

Table 2. Chilled water plant with a capacity of 300 kW real exploitation parameters depending on load

Parameter	Value				
	Load 0%	**Load 20%**	**Load 40%**	**Load 60%**	**Load 90%**
Chilled water inlet [ºC]	17.5	13.8	9.3	9.2	12.4
Chilled water output [ºC]	21.6	10.3	6.4	6.2	7.8
Compressor suction [bar]	3.2	2.8	2.4	2.4	2.3
Compressor suction [ºC]	17.7	8	9.1	9.1	14.3
Compressor discharge pressure [bar]	5.9	5.6	7.7	7.8	8.9
Condenser refrigerant outlet [ºC]	23.7	21.7	35	35.3	39
Compressor discharge temperature [ºC]	44.2	44.9	59.6	59.6	59

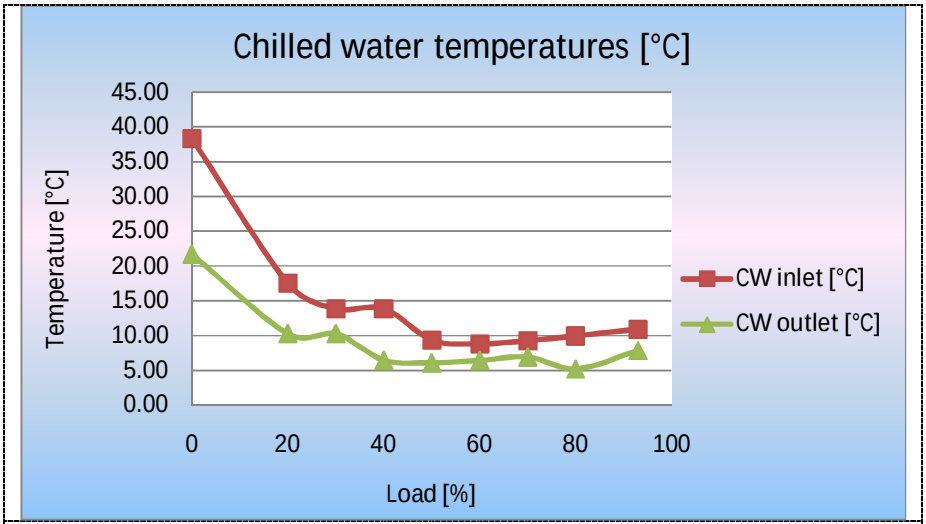

Figure 6. Chilled water temperatures

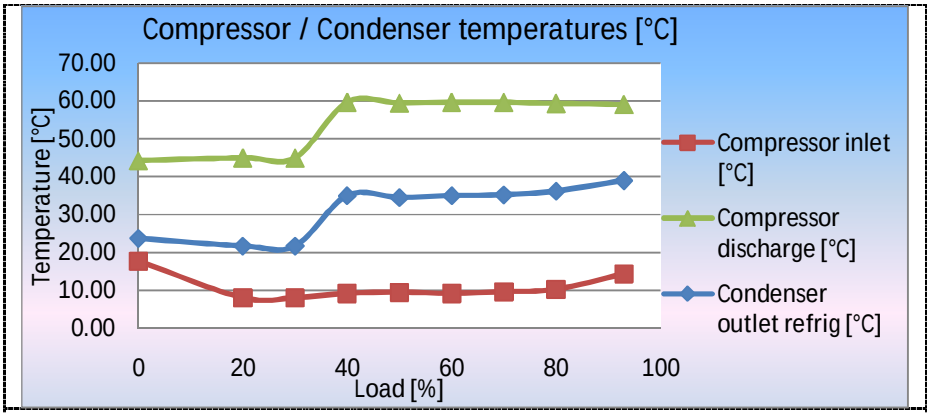

Figure 7. Compressor / Condenser temperatures

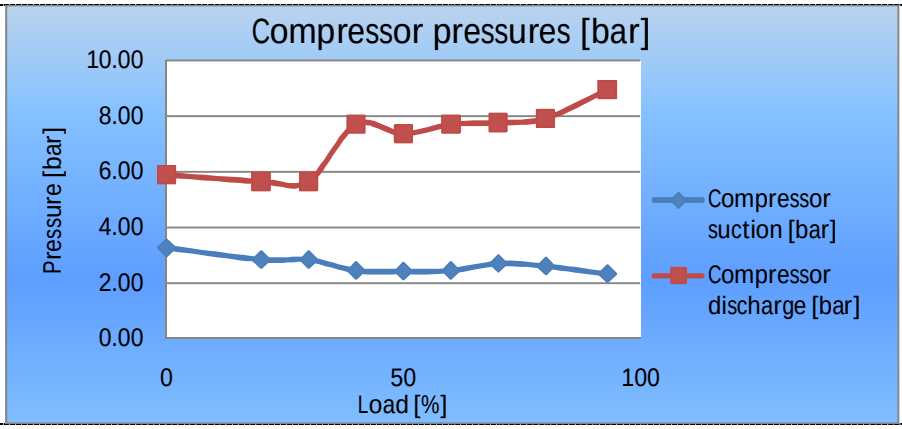

Figure 8. Compressor pressures

3. Simulation of cooling demand for cooler

CoolPack is a collection of simulation models for refrigeration systems. The models each have a specific purpose: cycle analysis, dimensioning of main components, energy analysis and -optimization. The simulation was made for 100 [%] load for cooling demand. Main input values were:

- cooling load: 300 [kW];
- inlet temperature: 13 [°C];
- outlet temperature: 7 [°C];

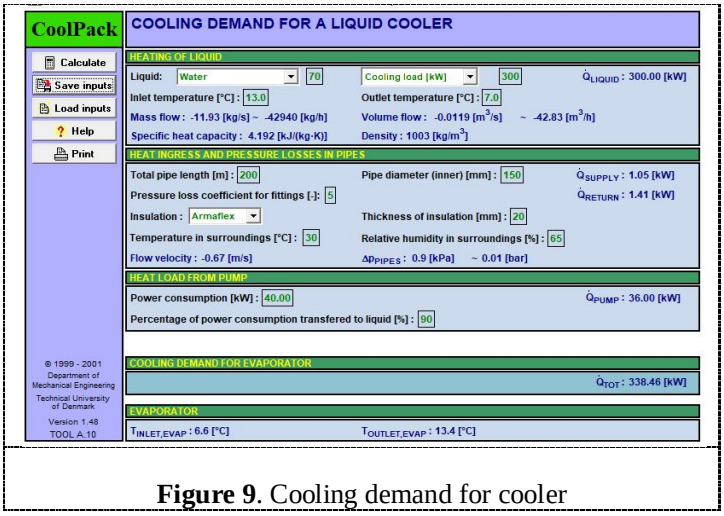

Figure 9. Cooling demand for cooler

4. Conclusions

The system design is to be based on a constant volume of water being in circulation under all cooling conditions. The design water inlet and outlet temperature at the chilled water plant are to be 13.5 [°C] and 6.5 [°C] respectively at the full cooling load conditions, the system and chilled water plant evaporators are to be designed for a water temperature drop of 7 [K] at full load. Essential systems and non-essential systems may be supplied from the same chilled water plant provided that arrangements are made for the essential system users to take precedence over the non-essential system users during periods of routine maintenance or chilled water plant failure.

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