

Analysis on Anti-freezing Technology of Polar Cruise Ship's Liquid Tank

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Abstract

With the development of polar tourism, polar cruises are in great demand, but the polar environment is so bad that it poses a great challenge to the antifreeze ability of polar cruises. Based on the anti-freezing range of the liquid tank of polar cruise ship, the anti-freezing schemes for ballast tank, seawater tank and fuel tank are put forward according to the theory and empirical formula, the results show that the design scheme is reasonable and effective for polar cruise tank anti-freezing experience.

Keywords

Polar Cruises; Ballast Tanks; Seawater Tanks; Fuel Tanks.

1. Introduction

The development of polar tourism has driven the demand for polar cruises. However, the polar environment is harsh, and high requirements are placed on ship design, construction, operation, environmental protection and other aspects, which are embodied in ice resistance, ice navigation safety, cold and coating resistance, perfect emergency escape and rescue capabilities, and environment Protection requirements, relevant international conventions on polar ships, etc. The small polar cruise ships currently in operation are all built by the United States, Italy, Russia and other countries. China's performance in this field is still blank.

Among them, for the cold and eastward resistance of extremely low wheels, the design environment temperature of the polar wheel sailing on ice reached 100C, and the ship was partially exposed to the ice above the waterline of the ice this week and was affected by low humidity, resulting in low humidity in the thin warehouse. The mobility of the medium becomes even worse. Condensation of ballast water is unlikely to cause damage to the structure. At the same time, it may also cause the adjustment of ballast water to be blocked, affecting the normal operation of the cruise ship. The fuel level of tank A will increase or even freeze, which may cause the equipment to fail to operate normally; For this reason, the "International Polar Waters A" requires sea tanks and E-carrying tanks to avoid ice accumulation in anti-east aspects. A, including downloads, should consider the damage caused by low-temperature water diversion. All oil tanks must Insulation is achieved by the required temperature range and so on. The research in this article will also accumulate valuable design experience for the construction of the pole wheel in the future.

2. Antifreeze range and objects of tank

The antifreeze range of small polar cruise ships is generally divided into two types, namely, the cabins that directly contact the external water environment, such as ballast tanks and seawater tanks; the other is the cabins that need to maintain the energy supply of the entire ship and the life of the crew, such as fresh water. Tanks and fuel tanks, etc. According to similar ship types and actual application results of this ship, some general anti-freezing objects and corresponding

anti-freezing measures for ships sailing in ice areas are sorted out as shown in Figure 1 for anti-freezing objects in ballast and corresponding measures.

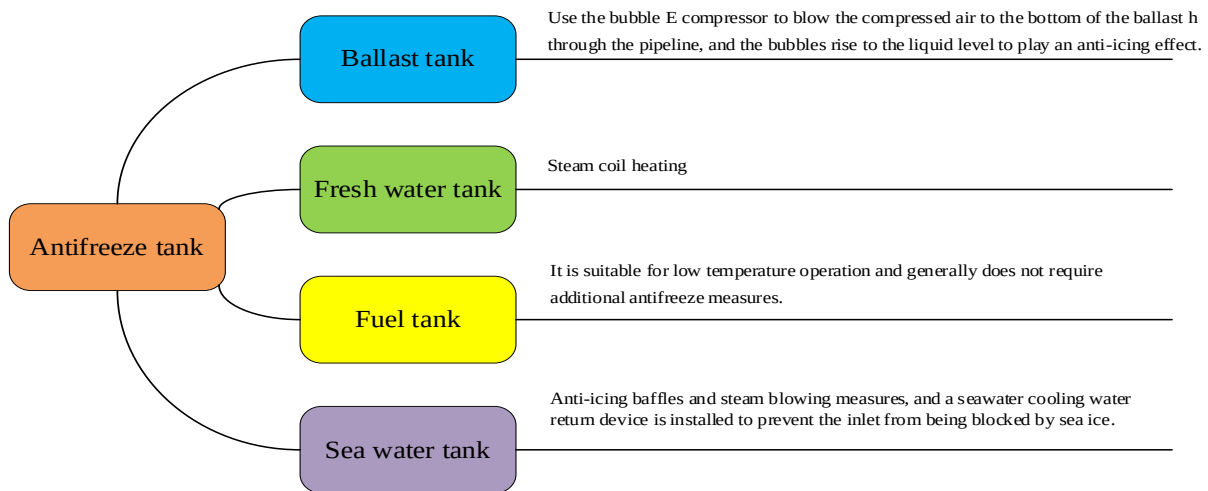


Figure 1. Objects of antifreeze ballast and corresponding measures

3. Ballast tanks

3.1. Specification requirements

Internationally, the WINTERIZATION BASIC class symbol puts forward the following requirements for anti-freezing of ballast tanks:

- 1) Functional requirements. Under the design environmental conditions, it is ensured that the safe ballast water of the ship can be loaded, discharged and leased, and the water surface of the ballast tanks is prevented from freezing.
- 2) Antifreeze measures for ballast tanks. For ships with the Winterized Basic classification symbol, when the cabin part is above LIWL, an air blowing system or a vertical steam heating coil can be used to maintain a large enough opening on the ice surface. According to the above analysis, the first choice is the air-blown antifreeze system for the antifreeze of the ballast tank.

3.2. Design principle of blowing system

The compressed air blowing system of Polar Cruises includes 1 blowing air compressor, 1 blowing dryer, 1 blowing air bottle, several sets of pressure valve sets, safety valves and various branch pipelines. The technical parameters of each component are shown in Table 1.

Table 1. Technical indicators of small polar cruise ships

Product name	Technical index
Bubble air compressor	Displacement is 45 m ³ /h; working pressure is 0.4 MPa, start when the pressure is 0.25 MPa, and stop when the pressure is 0.45 MPa
Blow dryer	
Blowing air bottle	The volume is 0.5 m ³
Pressure valve group	The inlet working pressure is 0.4 MPa, the outlet working pressure is 0.1 MPa Take-off pressure 0.1 MPa DN15, working pressure ≤0.1 MPa
Safety valve	
Pipeline	

The bubbling system and pipeline design of a ballast tank is shown in Figure 2. It can be observed that air is blown to the perforated pipeline at the bottom of the ballast tank through the air pipeline. The pipeline has a total of 10 air outlets and diameters. It is 6mm.

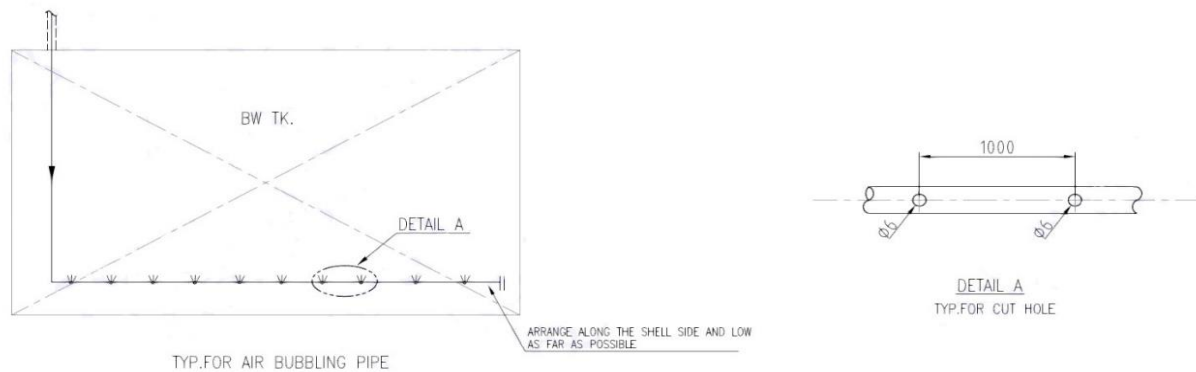


Figure 2 Schematic diagram of the blowing system and its pipeline design

3.3. Theoretical calculation of air compressor parameters

3.3.1. Calculation of air compressor displacement

Generally speaking, the unit dissipated air volume for ship anti-icing is $V_s = 5L / (m^2 \cdot \min)$.

According to the empirical formula, the air consumption required for the anti-freezing of the entire ship is:

$$V_{sum} = 60V_s(1 + a) \sum_{i=1}^n A_n \quad (1)$$

Among them, a is the air consumption margin, generally 0.1-0.2; A_n is the waterline area of each ballast tank on the ship, the unit is m^2 .

According to the cabin layout of a small polar cruise ship, as shown in Figure 3, the waterline area of each ballast tank can be calculated. And calculate the compressed air consumption required by each cabin according to formula (1), and then determine the displacement of the bubble blowing system, so as to determine the displacement of the air compressor.

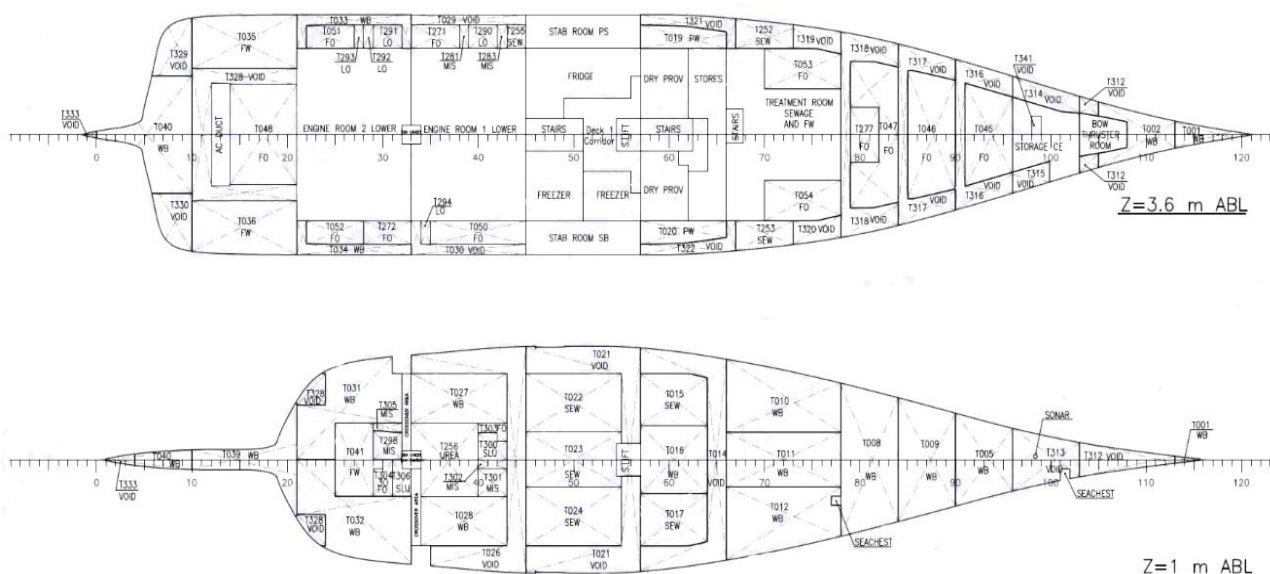


Table 2. Calculation table of cavitation system of ballast tank

Serial number	Ballast tank number	Waterline areaA/m ²	Air consumption rate(L/h)	Number of blowing pipes n	Actual pipe diameter DN (mm)
1	T001	9.854	0.591	2	15
2	T002	36.445	2.187	2	15
3	T005	33.216	1.993	2	15
4	T009	45.365	2.722	2	15
5	T008	54.854	3.291	2	15
6	T010	72.621	4.357	2	15
7	T011	60.632	3.638	2	15
8	T012	72.412	4.345	2	15
9	T016	49.364	2.962	2	15
10	T027	50.752	3.045	2	15
11	T028	50.165	3.010	2	15
12	T031	55.626	3.338	2	15
13	T032	55.187	3.311	2	15
14	T039	28.260	1.696	2	15
15	T040	15.799	0.948	2	15
The amount of air required for the whole ship's bubble blowing system			41.433	/	/

According to the calculation data in the above table, the total air consumption rate of a total of 15 ballast water tanks is 41.433L/h. Considering a certain design margin, The throughput of the air blowing system of the ballast tank can be set at about 50L/h.

3.3.2. Calculation of air pipe size

According to the turbine design manual, the air velocity in the steel pipe is 20m/s.

The calculation of the inner diameter of the compressed air pipeline can generally be obtained by the following formula:

$$d = 0.0188 \sqrt{\frac{q}{V}} \quad (2)$$

Among them, d is the inner diameter of the air pipe, m; q is the air flow through the section of the pipe per unit time, m³/h; V is the air velocity, m/h.

Substituting the air velocity and the volume flow of air into the above formula can determine that the diameter of the air pipeline of the small polar cruise ship's ballast tank blowing system is DN15.

3.4. Blowing test procedure

3.4.1. Test location

The blowing test is generally carried out on the anchorage or wharf before or after the sea trial. During the test, the manhole cover on the top of the ballast tank needs to be opened, and the operation is dangerous.

3.4.2. Ballast conditions

- i) Because it is necessary to observe the effect of the blowing system from the manhole on the roof of the cabin, the test water level in the cabin should be greater than the position where the human eye can directly observe;
- ii) The test should try to simulate the worst ballast conditions when sailing in polar waters to observe the effect of bubbling;
- iii) Considering the ship's stability and safe return to port requirements, during the test, ensure that the bow and stern tilt are moderate to avoid bottoming damage of the propeller.

3.4.3. Test procedure

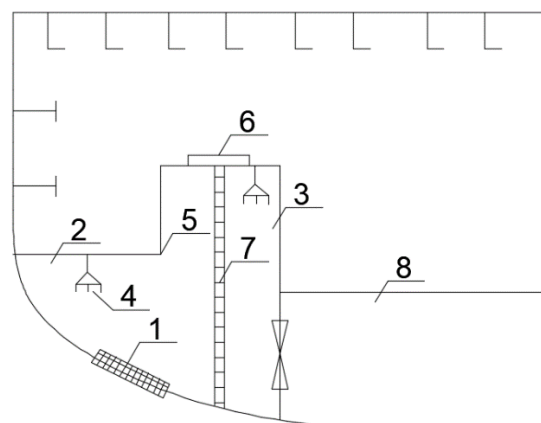
- i) Preparations before the test: Open the manholes of each ballast tank equipped with a blowing system, and confirm the water level position of each tank according to the ballast situation required for sailing in polar waters, and calculate the aperture size of each throttle plate ;

- ii) Open the whole ship's main pipe and release the shut-off valve, and start to inject water into the cabin;
- iii) Start the air compressor;
- iv) Observe the bubble blowing effect in the cabin through the roof manhole. If the effect is not good and no obvious bubbles are generated, replace the throttle plate with different apertures until a better bubble blowing effect is observed;
- v) Determine the best throttle plate aperture and complete the test.

4. Sea water tank

When a polar cruise ship sails in ice waters, the broken ice and ice slag in the seawater will be sucked into the seawater tank along with the seawater, causing systemic failures such as blockage, cooling, and ballasting. If only the heating tube is used to melt the crushed ice in the cabin, on the one hand, the efficiency of deicing will not be guaranteed, on the other hand, it may increase the steam volume of the boiler, resulting in non-compliance with the energy-saving and environmental protection regulations for sailing in ice areas. Therefore, it is necessary to design a set of anti-icing measures in the seawater tank that is direct and convenient, and does not increase energy consumption.

The addition of anti-icing partitions in seawater tanks is often used to "filter" the broken ice in the seawater. The principle is to add a barrier compartment at the inlet of the seawater tank, usually called an ice water tank, which can remove the broken ice. The melting or blocking is outside the inlet pipe of the sea water tank, which plays a role in protecting the sea water tank. As shown in Figure 4, according to the structural characteristics of the polar cruise sea tank, it is designed to prevent interference with other stiffeners, and the overall design is embossed. The interior of the ice-water tank is divided into two parts by the anti-icing partition. The part near the side is called the coarse ice area, and the part near the ship is called the fine ice area. There are many small holes on the anti-icing partition, the diameter of which is 20mm. Therefore, the seawater on the left side contains unfiltered large particles of crushed ice, while the right side contains small particles of crushed ice. To ensure that the crushed ice can be further melted, ice melting nozzles are installed on both sides to use steam to crush large particles of ice. Melt into small particles of crushed ice, and further melt the crushed ice in the fine ice particle area, so that the ice content of the sea water before entering the sea tank and the sea water main is greatly reduced.



1—Sea water tank inlet grille; 2—Coarse ice particle area; 3—Fine ice particle area; 4—Melting sprinklers; 5—Ice water tank frame; 6—Ice water tank top cover; 7—Ice-proof baffle; 8—Sea water tank

Figure 4. Layout of the ice water tank

5. Fuel tank

Fuel tanks are liquid tanks used to store fuel used by main and auxiliary engines. They are generally arranged in double bottoms, and some large ships also use deep tanks as fuel tanks. The fuel tanks of small polar cruise ships are distributed on the bow, stern and stern side. The cold protection measures of fuel tanks are generally divided into active heating and passive insulation methods. The following content respectively analyzes the two types of anti-freezing methods, and analyzes the feasibility of various options in combination with the structural characteristics of polar cruise fuel tanks.

5.1. Steam coil heating

The steam coil heating method of oil tanks is the most commonly used method in the field of marine engineering to prevent cold and ensure oil products, and the calculation methods for technical indicators such as heating area, gas consumption, and coil length have been in the national standard "A very detailed introduction is given in the calculation method of oil tank steam heating system (CB/T 3373-2013).

5.1.1. Thermal insulation steam

When the tank is in the insulation state, the calculation formula of the insulation steam consumption q_m is:

$$q_m = 3600 \frac{K_w A_w (\theta_t - \theta_w) + K_a A_a (\theta_t - \theta_a) + K_h A_h (\theta_t - \theta_h)}{\Delta i} \quad (3)$$

When the tank is heated, the calculation formula for the required steam volume is:

$$q_{h1} = q_m = 3600 \frac{(K_w A_w + K_a A_a + K_h A_h) (\theta_t - \theta_o)}{(e^{a_1 t_r} - 1) \Delta i} \quad (4)$$

among them,

$$q_{h1} = q_m = 3600 \frac{(K_w A_w + K_a A_a + K_h A_h) (\theta_t - \theta_o)}{(e^{a_1 t_r} - 1) \Delta i} \quad (5)$$

$$a_1 = 3600 \frac{(K_w A_w + K_a A_a + K_h A_h)}{\rho V C_o}$$

q_m —The amount of steam required when the tank is in an insulated state, kg/h;

K_w —Heat transfer coefficient when the tank wall is in contact with seawater, W/(m²•°C);

A_w —The wet surface area of the tank wall when in contact with seawater, m²;

θ_t —Steam temperature at the inlet of the steam coil, °C;

θ_w —Temporary sea water temperature, °C;

K_a —Heat transfer coefficient when the tank wall is in contact with the atmosphere, W/(m²•°C);

A_a —The surface area of the tank wall when in contact with the atmosphere, m²;

θ_a —Atmospheric temperature, °C;

Δi —Specific Enthalpy of Steam, J/kg;

K_h —Heat transfer coefficient of adjacent bulkhead adjacent to the calculated tank bulkhead, W/(m²•°C);

A_h —Heat transfer area of adjacent bulkhead, m²;

θ_h —Internal temperature of adjacent compartments, °C;

t_r —Required heating time, h;

ρ —Oil density, kg/m³;

V —Fuel volume, m³;

C_o —Specific heat capacity of fuel, J/(kg•°C).

5.1.2. Heating steam

When the heating area is constant, the calculation formula of air consumption q_{h2} is:

$$q_{h2} = 3600 \frac{K_s A_s}{\Delta i} \left[(\theta_s - \theta_{m1}) + \frac{\theta_1 - \theta_o}{e^{a_2 t}} \right] \quad (6)$$

among them,

$$a_2 = 3600 \frac{(K_w A_w + K_a A_a + K_h A_h)}{\rho V C_o} \quad (7)$$

$$\theta_1 = \frac{K_s A_s \theta_s + K_w A_w \theta_w + K_s A_s \theta_s + K_h A_h \theta_h}{K_s A_s + K_w A_w + K_s A_s + K_h A_h} \quad (8)$$

q_{h2} —Steam consumption when the heating area of the tank is at a fixed value, kg/h; θ_s —Average heating temperature of steam in the coil, °C.

5.1.3. Heating area

When the amount of steam required by the tank is determined, the calculation formula for the heating area A_s is:

$$A_s = \frac{q_{h1} \Delta i}{K_s (\theta_s - \theta_t)} \quad (9)$$

A_s —Heating area, m².

5.1.4. Length of heating coil

The calculation formula for the total length of the tank heating coil is:

$$L = A / (\pi \cdot D) \quad (10)$$

L —The total length of the heating coil, m;

D —Outer diameter of steam coil, m.

5.1.5. Heating time

When the required air consumption is a certain value, the calculation formula for the corresponding heating time is:

$$t_{r1} = \frac{\rho V C_o}{3600 (K_w A_w + K_a A_a + K_h A_h)} \ln \left(\frac{\theta_{m2} - \theta_o}{\theta_{m2} - \theta_t} \right) \quad (11)$$

among them,

$$\theta_{m2} = \frac{q_{h1} \cdot \Delta i + K_w A_w \theta_w + K_a A_a \theta_a + K_h A_h \theta_h}{3600 (K_w A_w + K_a A_a + K_h A_h)} \quad (12)$$

When the heating area is determined, the corresponding heating time is:

$$t_{r2} = \frac{\rho V C_o}{3600 (K_s A_s + K_w A_w + K_a A_a + K_h A_h)} \ln \left(\frac{\theta_{m1} - \theta_o}{\theta_{m1} - \theta_t} \right) \quad (13)$$

5.2. Circulating fuel heating of the fuel supply unit

The circulating fuel oil heating system of the fuel supply unit is proposed for the purpose of energy saving and emission reduction based on the shortcomings of traditional steam coil heating. The basic design idea is to install the heater installed in the fuel oil sedimentation tank or the daily-use tank, and the fuel heated by the special heater, pass through the suction pipe on the suction side of the fuel transfer pump, and reject it to the suction set in the fuel storage tank. At the mouth, use this part of the rejected hot oil to mix an appropriate amount of cold oil in the tank, so as to achieve the purpose of heating the necessary amount of fuel. Therefore, the use of fuel transfer heating system can heat the fuel in the tank without installing steam heating coils in the fuel storage tank and transport it to the settling tank. This heating method only heats the part of the fuel oil that will be transported in the storage tank, instead of the traditional steam heating coil heating the entire fuel tank, so as to prevent the fuel in the storage tank from passing through the surface of the tank to the surrounding environment Dissipate heat in the process, so as to achieve the purpose of minimizing energy consumption.

The two main processes of the fuel cell cycle fuel heating system are heating and transportation. When working in heating mode, the fuel transfer pump stops running, and the fuel transfer pump draws out the hot oil in the precipitation tank or daily-use tank. After it is heated to a suitable temperature by the fuel heater, it is delivered to the fuel through the suction pipe of the fuel transfer pump. The suction port in the storage compartment is mixed with the cold oil there to achieve the purpose of heating the fuel. When the system is working in the "delivery" mode, the fuel transfer pump stops running, and the fuel delivery pump delivers the heated fuel from the fuel storage tank to the sedimentation tank through the suction port.

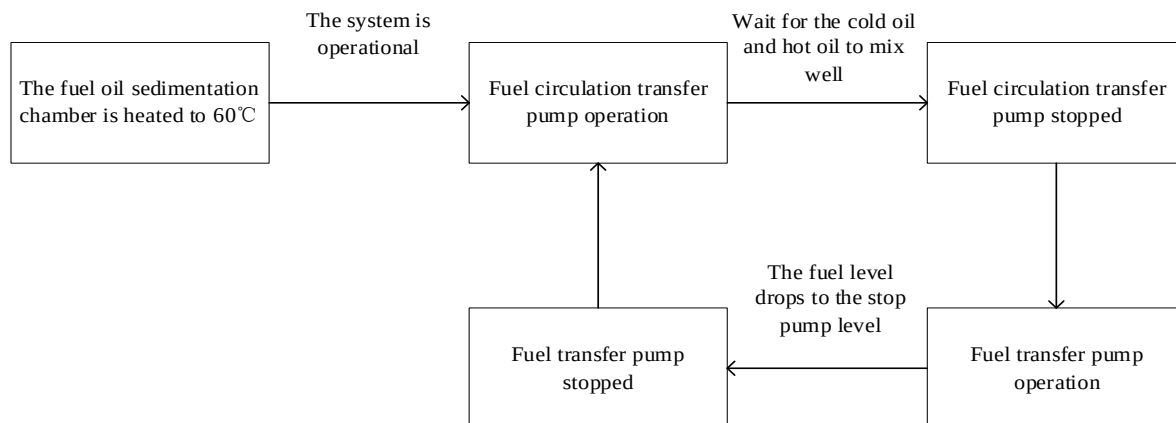


Figure 5. The operation process of the circulating fuel heating system of the fuel supply unit

6. Conclusion

Based on the ship type and working environment characteristics of small polar cruise ships, this article discusses the antifreeze measures of key tanks, and the following conclusions and experiences are formed:

- (1) The anti-freezing measures of ballast tanks need to adopt a compressed air blowing system. Before design, the selection of blowing system is determined according to the size parameters of each tank. At the same time, this article describes the general steps and points of attention of the terminal blowing test;
- (2) The sea water tank is directly in contact with low-temperature sea water and broken ice. In this paper, based on previous studies, an ice water tank constructed in the sea water tank is used to filter the sea water and floating ice before flowing to the sea water pipeline. Certain practicality;
- (3) The fuel oil tank is the fuel storage compartment for the entire ship. The application method of the steam coil system and the calculation method of the parameters in the system selection process are emphatically introduced.

According to the research on the main antifreeze technology of polar cruise ships in this article, it can provide reference and experience for the subsequent antifreeze and optimization of polar cruise ships.

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