# Analysis of the Role of Selenoid Valve on Foodstuff Cooling Machine on MV Ship. Double In

Agus Salim[1], Andi Wahyu Romly Saputra[2], and Syamsu Alam[3]

[1] Makassar Polytechnic of Seafaring Science Technika Study Program, Jln. Tentara Pelajar No. 173 Makassar, Postal Code. 90172
visionsalim@gmail.com

**Abstract.** This research was conducted during PRALA (Sea Practice) on the MV. Double In, managed by CHH Shipping Management Co. Ltd., over a period of 12 months and 2 days. Data was gathered through on-site observations, ship documents, and photographic records, and analyzed using SPSS. The results revealed a buildup of dirt on the solenoid valve due to a contaminated air dryer, leading to freon circulation issues. Consequently, cleaning and replacement of solenoid valve components and air dryers were carried out, followed by regular maintenance to ensure optimal function.

**Keywords:** Selenoid valve, Freon circulation, Contamination

## 1 Introduction

Scheduled and meticulous maintenance is essential for the smooth operation of the vessel on long-distance voyages. This includes maintenance of the main engines and auxiliary equipment, as well as ensuring the safety, comfort, and availability of food supplies for the crew. One of the critical components in this maintenance is the refrigeration system that is tasked with keeping the temperature of the food storage room at an optimal level, preventing damage or rapid spoilage from occurring. According to research, the refrigerant commonly used in ship refrigeration systems is CFC or R22 because it has good physical and thermal properties, is stable, non-flammable, non-toxic, and is compatible with refrigeration system component materials.

Frequent issues arise with food refrigeration systems on ships, including low lubricating oil in the crankcase, suboptimal temperatures in the meat storage room, compressor shutdowns due to poor vacuum, and spark accumulation on evaporator coil pipes. These issues can lead to spoilage of perishable items like vegetables due to insufficiently controlled temperatures. Additionally, poorly sealed solenoid valves are a major cause of refrigeration failures. On August 25, 2023, a temperature alarm indicated an abnormal temperature in the food storage room. Inspection revealed dirt buildup on the solenoid valve caused by a contaminated filter dryer in the refrigeration system.

This research aims to identify the factors that cause the solenoid valve to not function properly in the food refrigeration system on the ship. Knowing and improving how to


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maintain the refrigeration machine system, it is hoped that this research can provide theoretical and practical insights. Theoretically, this research is expected to increase knowledge about the refrigeration system and its maintenance. Practically, this research can provide an overview to the author as a prospective officer (machinist) and provide important information for fellow cadets who will undergo sea practice.

## 2 Overview

### 2.1 Refrigerator

A refrigerator is a series of machines or auxiliary aircraft on a ship that can work to produce cold temperatures or temperatures (low temperatures) [2].

### 2.2 Cooling Machine Parts and Functions

Some of the equipment that supports the performance of the food refrigeration machine system includes:

**Compressor.** A compressor is a mechanical device and is tasked with sucking refrigerant vapor from the evaporator, then pressing it (compressing), and thus the temperature and pressure of the vapor become higher [8].

**Condenser.** The condenser is part of the system located in the high pressure zone. The condenser plays a role in converting Freon gas into liquid form through a condensation process, where the refrigerant hot gas turns into liquid without a change in pressure [1].

**Evaporator.** A heat exchanger plays a crucial role in the refrigeration cycle by transferring heat between two media. In the evaporator, the refrigerant absorbs heat from the surrounding environment, causing it to change from a liquid phase to a vapor phase. This phase change is essential for cooling the space or medium being refrigerated, as the refrigerant evaporates, absorbing heat and lowering the temperature of the surrounding air or substance [3].

**Expansion Valve.** The liquid from the condenser flows into the receiving tank, and the pressure must be reduced to the same level as the evaporation pressure using a device called an expansion valve. This process reduces the pressure suddenly, resulting in a conditional change that makes the liquid boil and evaporate.

### 2.3 Refrigerator Selenoid Valve

**Fig. 1.** Refrigerator Selenoid Valve (Danfoss BF230)

A solenoid valve is a valve controlled by electric current through a coil or solenoid, widely used in fluid systems such as pneumatic, hydraulic, and automatic machine control. In a cooling machine, the solenoid valve functions to regulate the flow of liquid refrigerant to the evaporator according to the temperature needs of the food storage room, which is controlled by a thermostat. Solenoid valves work by applying electricity to the coil, creating a magnetic field that lifts the valve needle, allowing liquid refrigerant to flow to the expansion valve and evaporator. The thermostat controls the flow of electricity to the solenoid valve coil, connecting it or disconnecting it based on the temperature of the room to maintain the desired temperature [7].

### 2.4 Function and Parts of Refrigerator Selenoid Valve

The solenoid valve in a food refrigeration machine controls the refrigerant flow, ensuring the system maintains the desired temperature. It regulates the flow to key components like the evaporator and condenser, making it essential for the machine's efficiency and proper cooling.

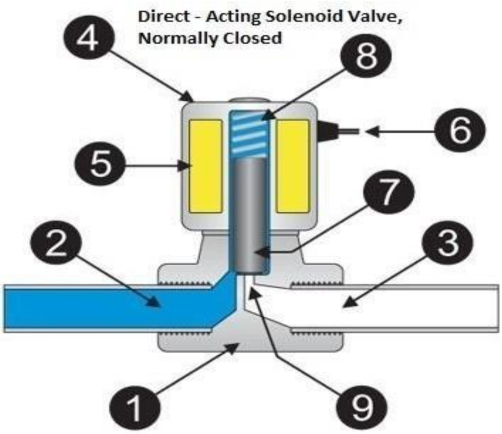


**Fig. 2.** Selenoid Valve Parts

1. Valve Body, which is part of the selenoid valve which functions as the foundation or main support for the seleniod valve body.
2. Inlet Port, which is the part that functions as a pathway for the entry of refrigerant liquid into the selenoid valve
3. Outlet Port, which is the part that functions as a pathway for the exit of refrigerant liquid from the valve
4. Coil, which is the part that functions as a driving medium to obtain additional electrical energy then becomes a magnetic field to move the piston so that the valve opens and the refrigerant liquid can enter.
5. Coil Windings, which is a part that functions almost the same as a coil or coil
6. Voltage Supply Cable, which is the part that functions as an intermediary for the coil to obtain electricity so that the selenoid can function properly.
7. Piston, which is the part that functions to open the valve after the coil or coil gets a source of electric voltage
8. Spring, which is the part that functions to press the piston back to the initial position to close the valve after the coil or coil is no longer powered by an electric source.
9. Orifice, which is a part that serves to reduce the pressure of liquid refrigerant before exiting the selenoid valve and then flowing into the evaporator.

## 3 Research Methods

This research uses two types of descriptive and correlational methods. Descriptive research aims to describe and analyze phenomena in depth, while correlational research looks for relationships between two or more variables. The operational definition of variables is divided into two: dependent and independent variables. The dependent variables in this study include the factors that cause the solenoid valve to work abnormally and the methods of maintenance and repair of these components. Meanwhile, the independent variable is the performance of the solenoid valve in the food refrigeration machine on the ship. The study population includes all solenoid valves and related components, while the sample is the factors that cause abnormal work of solenoid valves.

The data analysis techniques used included both qualitative and quantitative approaches. Qualitative analysis involved the collection and interpretation of descriptive data, while quantitative analysis used descriptive statistics such as central tendency (SPSS). Data collection was done through direct observation and documentation studies. The observation method allowed the researcher to describe and analyze the role of solenoid valves in the ship's food refrigeration machinery, while the documentation study provided a theoretical basis by reading relevant literature. This combination of methods is expected to provide a thorough understanding of the performance and problems associated with solenoid valves in shipboard refrigeration systems.

# 4 Results and Discussion

## 4.1 Research Results

On August 25, 2023, during the voyage of MV. Double In from Sohar, Oman, to Singapore, the foodstuff refrigeration system experienced a temperature increase. The vegetable room's temperature alarm activated during the 16:00-20:00 watch, followed by alarms for the meat and fish rooms during the 00:00-04:00 watch.

After analyzing and then taking action to shut down the cooling system, it was found that the selenoid valve was clogged by a pile of dirt that joined the flow of circulating freon due to the dirty air dryer system.

The following is the cooling machine data starting from the normal state, abnormal then alarm and back to normal after repair, can be seen as follows:

**Table 1.** Research Data on August 24-25, 2023

| Date | Time | Vegetables | Fish | Meat | Ket |
|---|---|---|---|---|---|
| August 24, 2023 | 00.00-04.00 | +6 $C^0$ | -17 $C^0$ | -17 $C^0$ | Normal |
| | 04.00-08.00 | +6 $C^0$ | -17 $C^0$ | -17 $C^0$ | Normal |
| | 08.00-12.00 | +6 $C^0$ | -17 $C^0$ | -17 $C^0$ | Normal |
| | 12.00-16.00 | +6 $C^0$ | -17 $C^0$ | -17 $C^0$ | Normal |
| | 16.00-20.00 | +6 $C^0$ | -17 $C^0$ | -17 $C^0$ | Normal |
| | 20.00-00.00 | +6 $C^0$ | -17 $C^0$ | -17 $C^0$ | Normal |
| August 25, 2023 | 00.00-04.00 | +6 $C^0$ | -17 $C^0$ | -17 $C^0$ | Normal |
| | 04.00-08.00 | +6 $C^0$ | -17 $C^0$ | -17 $C^0$ | Normal |
| | 08.00-12.00 | +6 $C^0$ | -17 $C^0$ | -17 $C^0$ | Normal |
| | 12.00-16.00 | +8 $C^0$ | -15 $C^0$ | -14 $C^0$ | Abnormal |
| | 16.00-20.00 | +13 $C^0$ | -12 $C^0$ | -10 $C^0$ | Alarm |
| | 20.00-00.00 | | | | |
| August 25, 2023 | 00.00-04.00 | Improvements | | | |

| | | | | |
|---|---|---|---|---|
| After Improvement | | | | |
| 04.00-08.00 | +5 $C^0$ | -17 $C^0$ | -18 $C^0$ | Normal |
| 08.00-12.00 | +5 $C^0$ | -18 $C^0$ | -17 $C^0$ | Normal |
| 12.00-16.00 | +5 $C^0$ | -17 $C^0$ | -18 $C^0$ | Normal |
| 16.00-20.00 | +5 $C^0$ | -18 $C^0$ | -17 $C^0$ | Normal |
| 20.00-00.00 | +5 $C^0$ | -17 $C^0$ | -17 $C^0$ | Normal |

The following is data on the condition of the freon cooling machine before damage (Normal), decreasing until it is damaged (Abnormal), can be seen as follows:

**Table 2.** Freon condition data passing through the compressor

| Conditions | Comp RPM | Freon Speed Flow | Freon Pressure In | Out | Freon Temp In | Out |
|---|---|---|---|---|---|---|
| Normal | 1405 | 8,5 | 0,7 | 17,5 | -11 | +75 |
| Abnormal | 1194 | 8,48 | 1,9 | 14 | -8 | +50 |
| Alarm 1 | 1014 | 8,46 | 2,3 | 12,5 | +3 | +45 |
| Alarm 2 | 862 | 8.43 | 2,5 | 12 | +5 | +40 |
| After Improvement | 1433 | 8,55 | 0,75 | 18 | -10 | +75 |

**Table 3.** Condition data of freon passing through the condenser

| Conditions | Comp RPM | Freon Speed Flow | Freon Pressure In | Out | Freon Temp In | Out |
|---|---|---|---|---|---|---|
| Normal | 1405 | 8,57 | 17,30 | 17,25 | +75 | +45 |
| Abnormal | 1194 | 8,54 | 17 | 16,9 | +65 | +40 |
| Alarm 1 | 1014 | 8,49 | 15,8 | 15 | +52 | +33 |
| Alarm 2 | 862 | 8,47 | 12 | 11,5 | +43 | +30 |
| After Improvement | 1433 | 8,62 | 17,10 | 17,3 | +75,5 | +44,5 |

**Table 4.** Freon condition data passing through the evaporator

| Conditions | Comp RPM | Freon Speed Flow | Freon Pressure In | Out | Freon Temp In | Out |
|---|---|---|---|---|---|---|
| Normal | 1405 | 2 | 4,5 | 3,5 | -29 | -13 |
| Abnormal | 1194 | 1,97 | 3 | 2 | -25 | -11 |
| Alarm 1 | 1014 | 1,96 | 1,7 | 1,3 | -17 | -7 |
| Alarm 2 | 862 | 1,94 | 1,5 | 0,9 | -13 | -3 |
| After Improvement | 1433 | 2,06 | 3,56 | 3,56 | -28,4 | -13,2 |

Research using SPSS (Statistical Package for the Social Sciences) involves analyzing the data collected to understand and interpret the research results. In this study, the authors used a paired t-test to evaluate the changes between the conditions before and after the damage to the compressor. The following is an explanation of the results of the analysis using SPSS:

1. Descriptive Statistics Test

The following table shows the descriptive statistics of the measured variables before and after damage and replacement of the selenoid valve:

**Table 5.** Paired Samples Statistics

| Couple | Conditions | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| RPM | Before | 853.27 | 6 | 70,730 | 28,875 |
| | After | 1267.04 | 6 | 234,424 | 95,703 |
| Vol. Freon Flow Reff. | Before | 27473.7 | 6 | 0,0227660 | 0,0092942 |
| | After | 40796.42 | 6 | 0,0755605 | 0,0308474 |
| Pressure IN | Before | 1.6667 | 6 | 0,1472 | 0,0601 |
| | After | .7833 | 6 | 0,2805 | 0,1145 |
| OUT Pressure | Before | 14.5500 | 6 | 0,3266 | 0,1333 |
| | After | 17.0200 | 6 | 1,0838 | 0,4425 |
| INtemperature | Before | -10,500 | 6 | 0,5477 | 0,2236 |
| | After | -7,833 | 6 | 1,4720 | 0,6009 |
| OUT Temperature | Before | -1.83 | 6 | 0,894 | 0,365 |
| | After | -9.50 | 6 | 12,178 | 4,972 |

After the blockage of the cooling system solenoid valve, there was a significant change in the operational parameters. The average RPM decreased drastically from 1267.04 to 853.27, while the refrigerant freon flow volume also experienced a considerable decrease from 40796.42 to 27473.7, accompanied by a very significant increase in variation in all these parameters.

2. Correlation Test

The correlation table displays the relationship between the variables before and after blockage:

**Table 6.** Paired Samples Correlations

| Couple | Correlation | Significance |
|---|---|---|
| RPM | 0.968 | 0,002 |
| Vol. Flow Reff. | 0,968 | 0,002 |
| IN pressure | 0,934 | 0,006 |
| OUT Pressure | 0,987 | 0,000 |
| IN temperature | 0,967 | 0,002 |
| OUT Temperature | 0,886 | 0,019 |

The correlation analysis between the operational parameters before and after the blockage of the cooling system selenoid valve showed consistent findings. The correlation between RPM before and after the malfunction was very high (0.968), signifying a strong and positive relationship between the two. The same was true for refrigerant flow volume (0.968), outpressure (0.987), and outtemperature (0.886), where the very high and significant correlations indicated a strong and positive relationship between the conditions before and after the breakdown. Although the correlation of IN temperature was slightly higher (0.967), it was still significant, indicating a moderately strong and positive relationship between pre- and post-damage conditions. These findings provide a deeper understanding of the impact of damage on the operational performance of refrigeration system compressor valves.

3. Data substantiation with asymptomatic significance with the WiIcoxon Asymp. Signed Test

**Table 7.** Statistics Z Wiicoxon Signed Test

| Parameters | Z Value | Asymp. Sig. (2-tailed) |
|---|---|---|
| RPM | 2.201a | 0.028 |
| Vol. Flow Reff. | 2.201a | 0.028 |
| IN pressure | 2.214a | 0.028 |
| Out Pressure | 2.201a | 0.027 |
| IN temperature | 2.271a | 0.028 |
| Out Temperature | 2.201a | 0.027 |

a. If (sig.) p-vaIue 0.05, it is concluded that there is a statistically significant difference between the data.
b. If (sig.) p-vaIue ≥ 0.05, you do not have enough evidence to conclude a statistically significant difference.

The Asymp. Sig. (asymptomatic significance) value represents the p-value from the adjusted Wilcoxon statistical test. If this value is below the significance threshold (typically 0.05), it indicates a statistically significant difference between the two conditions in the data pairs of compressor RPM, freon flow volume, in-out temperature, in-out pressure, and average pressure.

4. General Conclusions

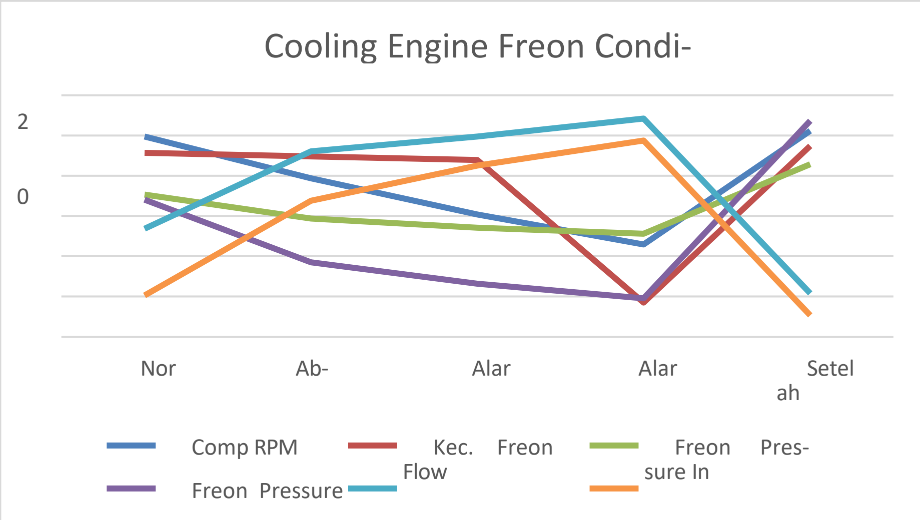


**Fig. 3.** Compressor performance on August 24-25, 2023

The analysis results indicate that the graphs reflect how the operating conditions of the refrigeration machine and freon-related parameters vary under normal, abnormal, alarmed, and repaired conditions. These fluctuations are useful for analyzing the issues and evaluating the effectiveness of repairs. The data can also be further analyzed to assess the performance of the refrigeration system and identify maintenance needs based on patterns observed in the operational data.

The study concludes that damage has a significant effect on the measured operational variables, as indicated by the paired t-test results and high, statistically significant correlations.

## 4.2 Discussion

**Troubleshooting.** The initial steps taken by the author when the cooling machine alarms indicated an increase in the temperature of the food refrigeration rooms on the ship were as follows: The meat room temperature, normally at -17°C, rose to -12°C, and the vegetable room temperature, normally at 7°C, rose to 13°C. Upon receiving the report, KKM checked the logbook, which serves as the primary reference for identifying issues with the cooling machine.

Upon checking the logbook, it was found that there was an abnormal condition in the freon circulation system, indicated by mismatched pressure and temperature readings. This was caused by a blockage of dirt in the solenoid valve, disrupting the normal operation of the cooling machine system.

**Solution.** After KKM identified a blockage in the freon circulation at the solenoid valve due to accumulated dirt from a dirty air dryer, the solution was to turn off the cooling machine system. Corrective actions were then taken, including cleaning and replacing the necessary components to restore normal operation.

**Problem Solving.** Performing maintenance and repair on air dryers and selenoid valves must comply with the procedures set by the company and must also follow the steps set by the maker in the manual book on how to disassemble, maintain, repair, and also install (overhaul) each component.

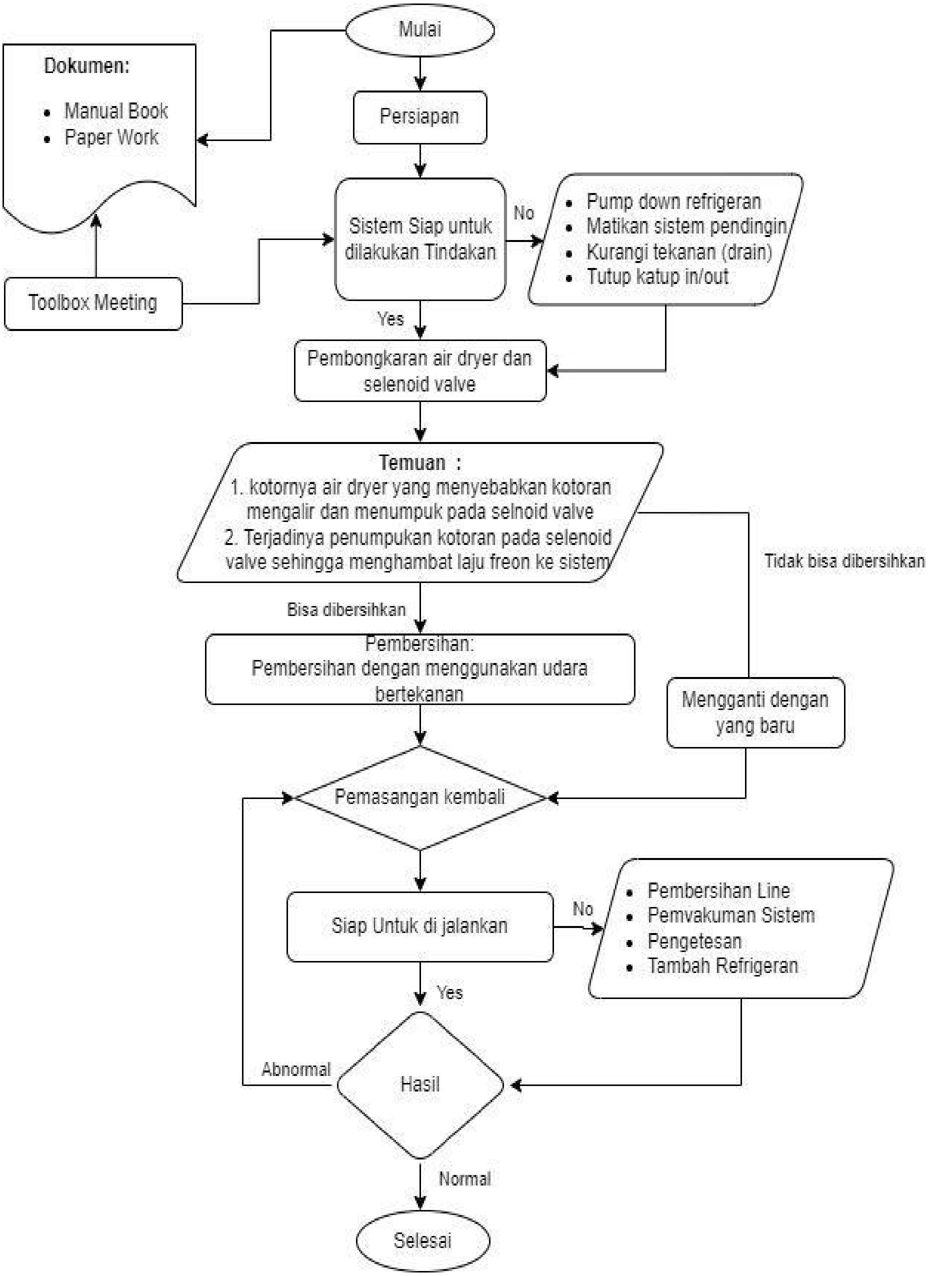


**Fig. 4.**

By following the procedures set by the company and also the steps set by the maker in the manual book, the steps taken do not endanger workers, and work becomes efficient

1. Prepare documents such as manual book, paper work, risk assessment and maintenance report (after completion).
2. Component dismantling
   a. Performed refrigerant pump-down to the condenser.
   b. Shut down the cooling system by following the manual book procedure.
   c. Disassemble the air dryer and selenoid valve.
3. Findings
   During the disassembly of the solenoid valve, it was found that dirt had accumulated, obstructing the freon circulation in the system. This issue occurred because the air dryer filter was dirty, causing the air dryer to malfunction. As a solution, the air dryer and solenoid valve were replaced. Proper maintenance and optimal operating conditions are crucial to prevent similar breakdowns in the future.


**Fig. 5.** Damaged Selenoid Valve

4. Repair on damaged components
   a. Refrigeration engine selenoid valve replacement
      (1) Preparation of a new selenoid valve
      (2) Installation of a new selenoid valve
   b. Replacement of air dryer components
      (1) Preparation of the new air dryer
      (2) Installation of a new air dryer
   c. Line cleaning of the cooling system
      The method used to clean the cooling system from water or dirt is to use nitrogen to blow through.
   d. Cooling system vacuuming
      (1) Connect the vacuum pump hose, turn on the pump and wait 20- 30 minutes.

   (2) Open the vacuum valve to remove air from the system.
   (3) Monitor low pressure on the compressor to ensure the process is running properly.

e. Starting the Cooling System
   (1) Ensure that all system valves are open except compressor suction valve No.1.
   (2) Turn on the power at the compressor starter panel.
   (3) Check the oil level and refill if necessary.
   (4) Start the fresh water cooling system and check the setting of the pressure switch cut-outs on the compressor.
   (5) Open the suction valve of compressor No.1 slowly.
   (6) Perform regular checks on refrigerant pressure and level, and make sure there are no leaks.

f. Filling Refrigerant in the Cooling System
   (1) Use an accurate scale to weigh the refrigerant.
   (2) Connect the manifold gauge set to the low pressure port.
   (3) Turn on the cooling system and set the compressor at the lowest capacity.
   (4) Open the gauge set manifold valve slowly to introduce refrigerant.
   (5) Monitor the amount of refrigerant and close the valve when the required amount is reached.

g. Carry out maintenance to prevent recurrence
   The maintenance steps according to the manual book can be done as follows:
   (1) Daily Maintenance
      i. Is the condition and volume of lubricating oil in the compressor within normal levels
      ii. Is the low pressure and high pressure in accordance with the manual book on the compressor?
      iii. Is there any abnormal sound in the compressor
      iv. Is there abnormal vibration in the compressor
   (2) Periodic maintenance according to the manual book according to the operating hours which is for maintenance on the compressor valve at 10000 working hours or annually from the first day of installation.

## 5 Conclussion

The conclusions from the observations and analysis are as follows:

1. The increase in temperature in the cooling chamber can be caused by the expansion valve opening and closing continuously, which occurs when the solenoid valve malfunctions due to dirt accumulation. This blockage is a result of a dirty air dryer in the system, affecting the normal operation of the refrigeration cycle.
2. Cleaning the system lines to avoid contamination with dirt and other particles is very important. Maintenance and replacement of the air dryer is a way to avoid these problems so that the cooling machine system runs normally.

Suggestions that can be given after analyzing the data are as follows:

### 5.1 To the reader as follows:

1. Routinely check and maintain the cooling system, including taking temperature and pressure, changing the dryer filter, and cleaning the system lines to avoid dirt accumulation and contamination.
2. Applying the SPSS application for data analysis enhances accuracy and efficiency by allowing precise testing of each variable based on its significance level. This statistical tool helps ensure reliable results and supports more effective decision-making.

### 5.2 To future researchers

To analyze the electricity usage for the solenoid valve lift power in both normal and abnormal conditions, data on the solenoid valve amperage is essential. However, since the object under study lacks an ammeter, one potential solution could be to estimate the amperage by using other equipment or methods, such as checking for voltage fluctuations or using external sensors to monitor current flow. Alternatively, conducting further research to install an ammeter on the system would provide more accurate and direct measurements.

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