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Thermodynamic Performance Analysis of Food Refrigeration Machine on MT. YN Busan Ship in Supporting Food Quality During Sailing

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ABSTRACT

This study examines the performance of the food refrigeration system on the MT. YN Busan tanker during international voyages across Korean, Yellow Sea, Chinese, and Japanese waters. The main objectives are to calculate the compressor work capacity (W_{comp}), the heat absorption capacity of the evaporator (q_{evap}), the heat rejection capacity of the condenser (q_{con}), and the Coefficient of Performance (COP). In addition, the study evaluates the quality of food stored in the refrigerated compartments. Data were collected through measurements of compressor pressure and temperature, expansion valve temperature, and refrigerated room temperature. The analysis was conducted using the R-404A refrigerant ph diagram and evaluated based on the Minimum Energy Performance Standards (MEPS) for air conditioners and refrigeration systems. The results show that the highest $W_{comp}$was 28.9 kJ/kg in Korean waters at 12:00, while the lowest was 27.7 kJ/kg in Chinese waters at 20:00. The highest $q_{evap}$was recorded at 236 kJ/kg in the meat storage room in the Yellow Sea, while the lowest was 231.5 kJ/kg in Korea. The highest $q_{con}$was 263.6 kJ/kg in both the Yellow Sea and China, with the lowest value of 260.3 kJ/kg in Korea. The highest COP was observed in the meat storage room, reaching 8,551 in the Yellow Sea, while the lowest was 8,038 in Korea. All COP values were ≥ 6, thus classified as excellent performance. However, food quality testing revealed that only 5 out of 16 temperature measurement points in the meat storage room and 7 out of 16 points in the vegetable storage room met the refrigeration system specifications. In conclusion , the refrigeration system demonstrated excellent performance, but the temperature distribution in the storage compartments was not yet uniform. This uneven distribution could affect food quality during the voyage and requires further optimization.

Keywords: *COP, Refrigeration System, W_{comp}, q_{evap}, q_{con}*

I. INTRODUCTION

Indonesia, as an archipelagic country , has thousands connected islands through sea areas so that making it a maritime nation . In context said , transportation sea play a role as bone back main activity economy , both at the level national and international . The ship is known as fashion efficient transportation Because capable transport cargo in amount big with cost relatively low (Aslang et al., 2017). Success Sailing is very dependent on smoothness operational For reach objective with safe , precise time , and effective . For support matter mentioned , it is needed facility adequate support , including infrastructure operational , technology machinery , as well as aspect welfare crew ship . One of the factor crucial in guard welfare crew boat is availability food nutritious and proper consumption . Quality material good food will support health , condition physical , as well as performance crew boat during shipping (Grappasonni et al., 2018). Supply food on board generally divided into two categories , namely material food dry and material food wet . Food ingredients wet like meat , fish, vegetables and fruit need treatment specifically to keep it fresh and worthy consumed during storage (Kim et al., 2015). Cooling is the most effective method For slows down the decay process , so that storage in room cooling on board become solution best in guard quality food (Somba, 2021). Adequacy guaranteed food during cruise impact directly on performance crew ship . Therefore that , handling material easy food damaged , especially meat , fish, vegetables and fruit , must supported by the system suitable cooler standard operational (Haryadi, 2020; Suryaman & Prayogo , 2018). Machine cooler boat functioning guard stability temperature room

storage so that quality food can maintained although saved in term long time (Harjuansyah et al., 2017). According to specifications in the machine manual MT. YN Busan cooler , ideal storage temperature meat and fish is -20°C, while vegetables stored at +4°C. However , conditions in the field show that temperature current often No in accordance with standard . In space storage meat and fish, temperature sometimes down up to -25°C, while in the room storage vegetables only capable reach around +10°C. The difference This potential lower quality material food during voyage . Based on description said , research This done with Analysis performance machine cooler food on board Mt. Yn Busan For evaluate performance system coolant and its impact to quality material stored food .

II. RESEARCH METHOD

2.1 Types of research

This research is an experimental research conducted on the MT. YN Busan Ship and is direct observing the characteristics of the machine cooler food and temperature distribution in space cooling . This vessel was selected because it has operational characteristics that suit the research objectives, and is equipped with facilities and technical conditions that support direct data collection in a real and dynamic environment. The research schedule is adjusted to the operational conditions of the vessel to ensure the smoothness and accuracy of the research . This study uses a quantitative approach to process and analyze the experimental data.

2.2 Research Procedures

The data collection stages are carried out in stages to obtain relevant information regarding the performance of the cooling system, with the following steps:

1. Identify the specifications of the refrigeration machine, including the type of refrigerant used.
2. Pressure measurement at the compressor inlet and compressor outlet .
3. Temperature measurements at several points, namely the cooling chamber, compressor inlet , compressor outlet , and the hose before entering the expansion valve.
4. Preparation of a pressure–enthalpy (ph) diagram based on the type of refrigerant used (R-404A) to obtain the enthalpy value as the basis for thermodynamic analysis.

2.3 Research Tools and Materials

The tools and materials used in this research function as data collection instruments, including:

1. A set of refrigeration machines – the main object of research.
2. Thermometer – to measure the temperature in the cooling chamber, compressor inlet , compressor outlet , and hose before the expansion valve.
3. Infrared Thermometer Gun – for fast and accurate temperature measurement.
4. Barometer – to measure the pressure at the compressor inlet and outlet .
5. Compressor oil – as a compressor motor lubricant.
6. Refrigerant R-404A – the working fluid of the refrigeration machine used on the MT. YN Busan ship.

III. RESULTS AND DISCUSSION

Based on calculations The values of q_{ev} , q_{kond} , and COP also have 2 values because they are differentiated between the *meat room* and *vegetables* . Table 1 Calculation results during shipping in China .

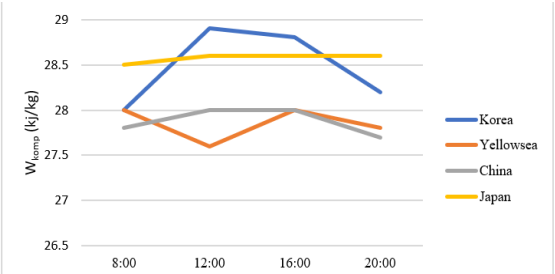

Figure 2. Graph Comparison of W_{komp} Value Results

Picture 2 is a graph The compressor working capacity value for each shipping area. Based on the graph above, the highest W_{comp} value is in the Korean shipping area at 12:00 with a value of 28.9 kJ /kg, while the $W_{comp\ value\ is}$ The lowest is the China shipping area at 20:00 with a value of 27.7 kJ / kg. Based on the graph above, each shipping area does not have a consistent increase or decrease in the $W_{comp\ value}$, because the pressure and temperature values in each shipping area change over time.

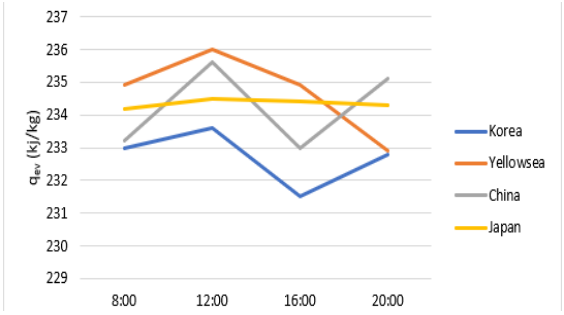

Figure 3. Graph Comparison of q $_{ev}$ value results in space cooler *meat*

Graphic image 3 shows the comparison of the evaporator calorific value (qev) in the meat cooling room (meat room) on the MT. YN Busan Ship at several shipping locations (Korea, Yellow Sea, China, and Japan) with data collection at four time points (08:00, 12:00, 16:00, and 20:00). In general, the value q_{evap}describes the heat absorption capacity of the evaporator, which indicates the ability of the cooling machine to maintain storage temperature. The sailing period to Korea shows a q_{evap} relatively lower value compared to other locations. The lowest value occurs at 16:00, which is around 231.5 kJ/kg. The sailing period to Korea Yellow Sea has the q_{evap} highest value, namely 236 kJ/kg at 12:00. After that, there is a decrease to 233 kJ/kg at 20:00. This condition indicates that during the day the cooling system works more optimally in absorbing heat in the meat room. The sailing period to Korea China shows a fluctuating pattern. The value q_{evap} increased to 235.5 kJ/kg at 12:00 PM, then decreased significantly at 4:00 PM (233 kJ/kg), and then increased again at 8:00 PM. This indicates a fairly dynamic variation in cooling load in the region. The sailing time to Korea Japan appeared to be the most stable compared to other locations. The value q_{evap}ranged between 234–234.5 kJ/kg throughout the measurement period. This stability indicates that the cooling system was relatively consistent in maintaining its heat absorption capacity while the ship was in Japanese waters.

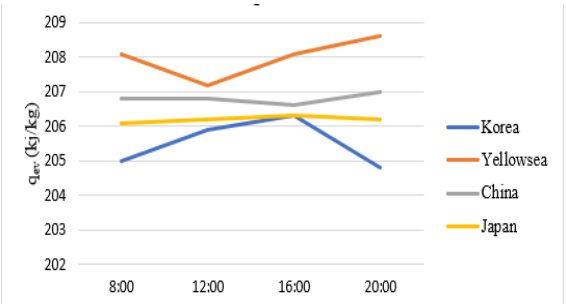

Figure 4. Graph Comparison of Value Resultsq_{evap} in space cooler *vegetables*

Graphic image 4 is the heat absorption capacity of the evaporator in the *meat* and *vegetable cooling compartment* in each shipping area. Based on the graph above, markq_{evap} The highest *meat value is the* Yellowsea shipping area at 12:00 with a value of 236 kJ /kg, and the highest value isq_{evap} *vegetables* The highest value was in the Yellowsea shipping area at 8:00 PM with a value of 208.6 kJ /kg. Then the q_{evap} lowest *meat value was in the Korea shipping area at 4:00 PM with a value of 231.5 kJ/kg, and the lowest value was in the Korean shipping area at 4:00 PM with a value of 231.5* kJ /kg.q_{evap} The lowest *vegetables* were in the Korean shipping area at 20:00 with a value of 204.8 kJ /kg. Each shipping area does not have consistent rise and fall in value q_{evap}, because the pressure and temperature values in each shipping area change all the time.

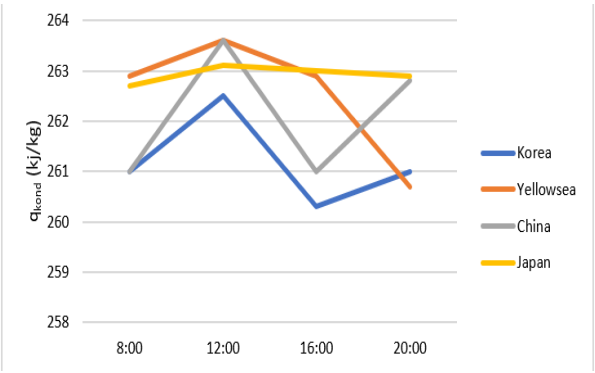

Figure 5. Graph Comparison of the results of the q- value $_{condition}$ in space cooler *meat*

Figure 5. Shows variation mark heat condenser q_{con} in space cooler meat in some location voyages (Korea, Yellow Sea, China, and Japan) on four point time (08:00, 12:00, 16:00, and 20:00). Screen time to Korea own mark q_{con} lowest compared to other locations, with the lowest point being around 260.5 kJ/kg at 16:00. The screen time to Yellow Sea show mark q_{con} highest, reaching 263.6 kJ/kg at 12:00, but decreased sharply to around 261 kJ/kg at 20:00. The screen time to China show pattern fluctuating , rising to 263.6 kJ/kg at 12:00 , then down at 16:00, and back up at 20:00. Layer period to Japan is relatively stable , with range value of 262.5–263.2 kJ/kg throughout time measurement .

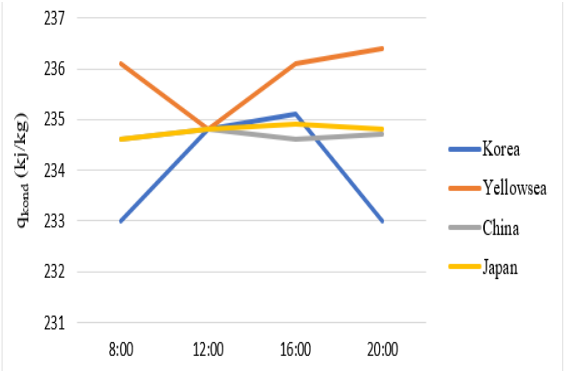

Figure 6. Comparison graph of results values q_{con}in the *vegetable cooling room*

Figure 6 shows the variation in the heat absorption capacity of the condenser in the *meat* and *vegetable cooling chamber* in each shipping area. Based on the graph, the valueq_{con} The highest *meat value is the* Yellowsea and China shipping area at 12:00 with a value of 263.6 kj /kg, and the highest value isq_{con} *vegetables* The highest value is the Yellowsea shipping area at 20:00 with a value of 236.4 kJ /kg. Then the valueq_{con} The lowest *meat* value is the Korean shipping area at 16:00 with a value of 260.3 kJ /kg, and the lowest ...q_{con} The lowest *value of vegetables* is in the Korean shipping area at 08:00 and 20:00 with a value of 233 kJ / kg. Based on the graph above, each shipping area does not consistently increase or decrease in value q_{con}, because the pressure and temperature values in each shipping area change over time.

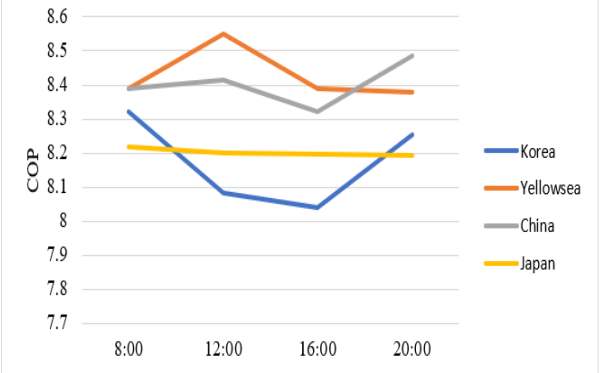

Figure 7. Comparison graph of COP value results in the *meat cooling room*

Figure 7. Graph show variation mark Coefficient of Performance (COP) in space cooler meat (*meat room*) in some location voyages (Korea, Yellow Sea, China, and Japan) on four time observation (08:00, 12:00, 16:00, and 20:00). Screen time to Korea has the lowest COP compared to other locations . Lowest value happened at 16:00 (around 8.05) and started increase return at 20:00 . Screen time to Yellow Sea shows the highest COP value , reaching around 8.55 at 12:00 , then A little decrease until range 8.35–8.40 in the afternoon until Evening day . Screen time to China shows fluctuations moderate . Relative COP value high at 12:00 (±8.42), decreased at 16:00, then rose again to 8.50 at 20:00 . Screen time to Japan looks the most stable with COP value is constant in the range of 8.20–8.23 throughout observation .

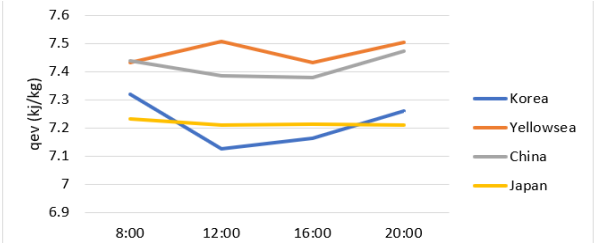

Figure 7. Comparison graph of COP value results in the *vegetable cooling room*

Figure 7. The graph shows the *coefficient* value *of Performance of the meat* and *vegetable* cooling room in each shipping area. The highest COP value *for meat was in* the Yellowsea shipping area at 12:00 PM with a value of 8.551, and the highest COP value *for vegetables was in the Yellowsea shipping area at 12:00 PM with a value of 8.551.* The

highest COP value is the Yellowsea shipping area at 12:00 PM with a value of 7.507. Then the lowest COP value *for meat is the Korean shipping area at 4:00 PM with a value of 8.038, and the lowest COP value for vegetables* is the Korean shipping area at 12:00 PM with a value of 7.125. Based on the graph above, each shipping area does not have a consistent increase or decrease in COP value, because the pressure and temperature values in each shipping area change over time.

IV. CONCLUSION

Based on results research, writer can interesting conclusion as following:

1. Capacity Work compressor (W_{comp}) show mark highest as big as 28.9 kJ/kg in the shipping area Korea at 12:00, while mark lowest as big as 27.7 kJ/kg occurs in the shipping area China at 8:00 PM. Variations mark This caused by changes pressure and temperature in each shipping area .
2. Capacity absorption evaporator q_{evap}heat ( ) in space cooler meat reach mark highest 236 kJ/kg in the Yellow Sea at 12:00, while mark lowest 231.5 kJ/kg happened in Korea at 4:00 PM. In the room cooler vegetables , value highest recorded 208.6 kJ/kg in the Yellow Sea at 20:00 and the value lowest 204.8 kJ/kg in Korea at 8:00 PM.
3. Capacity release hot condenser (q_{cond}) in the room cooler meat highest reach 263.6 kJ/kg in the Yellow Sea and China at 12:00, and the lowest 260.3 kJ/kg in Korea at 4:00 PM. In the room cooler vegetables , value highest 236.4 kJ/kg in the Yellow Sea at 20:00, while mark lowest 233 kJ/kg happened in Korea at 08:00 and 20:00.
4. Coefficient performance (COP) in space cooler meat highest reach 8,551 in the Yellow Sea at 12:00, while mark lowest 8,038 happened in Korea at 4:00 PM. In the room cooler vegetables , value highest recorded 7,507 in Yellow Sea at 12:00, while mark lowest 7,125 in Korea at 12:00.
5. In a way general , all mark COP ≥ 6 **,** so that performance machine cooler can categorized Very good **.** However , the results measurement temperature room cooler show that No all point measurement in accordance with standard machine manual , so that distribution temperature Not yet evenly **.** Condition This potential influence quality material food , especially in the living room storage vegetables .

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