Troubleshooting Analysis of The Gandroom Cooling System on The KM. Lambelu

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Abstract.

The ship's refrigeration system is crucial for the preservation of crew food during the voyage, but a failure on KM. Lambelu resulted in temperatures of only -5°C (fish) and -6°C (meat) versus the target of -18°C. This study aims to analyze troubleshooting using mixed methods convergent parallel with FMEA for RPN, repair impact, and post-replacement evaluation of the compressor. The population is KM. Lambelu's engineering officers, a purposive sample of 30 respondents. Instruments are Likert questionnaires (S, O, D), logbooks, photographs; validity/reliability test analysis, RPN = S × O × D, qualitative reduction. The results show the highest RPN 50 compressor, replacement restores pull-down from 25°C to -23°C. Conclusion: replacement effectively restores optimal function, prioritize preventive inspections.

Keywords: *Compressor Failure; FMEA Analysis; Gandroom Refrigeration; Pull-Down Test and Troubleshooting.*

I. INTRODUCTION

The ship's refrigeration system plays a crucial role in maintaining the quality of food for crew and passengers during long voyages. In Indonesia, an archipelagic nation, maritime transport vessels such as the KM Lambelu rely on the reliability of this system to meet safety and welfare regulations as stipulated in Law No. 17 of 2008 concerning Shipping. The vapor compression cycle, with key components such as the compressor, condenser, expansion valve, and evaporator, ensures freezer temperatures reach -18°C or lower, preventing food degradation and health risks.The reliability of shipboard refrigeration systems is becoming increasingly critical given their non-stop operation in extreme marine environments, where failures can disrupt the food logistics chain. Optimal preventive maintenance, including on the compressor as the "heart" of the system, is necessary to extend its lifespan and maintain performance (Haryadi, 2020) (Singgih, 2024). A functional failure in the KM. Lambelu's refrigeration system reached temperatures of only -5°C in the fish room and -6°C in the meat room, well above the standard of -18°C according to the logbook dated May 31, 2025. This condition entered the temperature danger zone, triggering microbial growth and food nutrient degradation, which impacted the health of the crew and additional logistics costs. Observations indicated internal mechanical damage to the SABROE BFF5 compressor, requiring complete disassembly of the piston and crankshaft (Erita et al., 20210).(Al-Ayyubi & Putri, et al).

The FMEA analysis identified the compressor with an RPN of 50 as the highest risk, confirming the priority of troubleshooting on this component. Factors such as poor lubrication and liquid slugging often cause similar failures in shipboard systems, worsening overall performance.(Al-Ayyubi & Putri, nd). The impact is not only operational but also economic, because sudden replacement at sea is difficult (Singgih, 2024) (Shevchenko et al., 2023).Post-repair evaluation through compressor replacement demonstrated a temperature pulldown from 25°C to -23°C, validating functional recovery. However, the lack of complete documentation of the failure path leading up to the evaluation in previous studies left a gap.This study aims to analyze the troubleshooting of the KM Lambelu's gantry cooling system failure using mixed methods with FMEA for RPN, troubleshooting impact, and post-compressor replacement performance evaluation. The urgency lies in the need for ship logistics reliability in Indonesia, where similar failures frequently threaten crew food safety [Haryadi, 2020]. Its novelty is the complete documentation of a major failure analysis case study, integrating quantitative RPN data and visual qualitative data, which complements previous preventive research (Erita et al., 2021) and (Azhari et al., 2023).

II. METHODS

This study uses a mixed methods approach with a convergent parallel design within a case study framework, which integrates quantitative data from a Failure Mode and Effect Analysis (FMEA)-based questionnaire to calculate the Risk Priority Number (RPN) and qualitative data from daily logbooks and photographic documentation of the troubleshooting process of the gantry cooling system on the KM. Lambelu. This approach was chosen because it combines the strengths of both methods for a comprehensive understanding of failure risks and post-repair evaluations, as Sugiyono explained that mixed methods produce more valid and complete data through a combination of quantitative and qualitative. Sudaryono emphasized that the convergent parallel design allows for simultaneous data collection and comparison of results to confirm findings, while Creswell in the latest edition emphasizes seven mixed methods designs including convergent for technical case studies such as this. Azhari et al. also support the use of mixed methods for in-depth analysis of ship technical problems.The main instruments included a Likert-scale questionnaire for the Severity, Occurrence, and Detection variables in FMEA distributed to 30 mechanical officer respondents (Chief to 4th Engineer), direct participant observation of operational parameters, and photo documentation of the SABROE BFF5 compressor disassembly and temperature logbook.

Quantitative data analysis techniques involved validity tests (Pearson Correlation >0.361, sig. <0.05) and reliability (Cronbach's Alpha >0.60) followed by the calculation of $RPN=S \times O \times D$, while qualitative analysis used data reduction, presentation, and verification to confirm internal mechanical damage to the compressor. Emzir explained that non-test instruments such as questionnaires and observations are suitable for mixed methods in the engineering field, while Sugiyono recommended descriptive statistics for processing FMEA data for risk prioritization. Sudaryono and Spradley-Huberman added that instrument triangulation increases reliability in qualitative content analysis. The study population was all engineering officers and technicians on KM. Lambelu who were responsible for the gantry cooling system, with a focus on engineers experienced in the operation and maintenance of Ice Machine Number 2 during the Sea Practice (PRALA) July 2024-July 2025. A purposive sample of 30 respondents consisting of Chief Engineer, 2nd-4th Engineer, and Foreman, selected based on direct expertise in compressor troubleshooting, represented 100% of the key population without broad generalizations.

Creswell stated that purposive sampling is ideal for mixed methods case studies to access expert informants, while Sugiyono and Sudaryono emphasized that this technique is effective for limited populations in the ship environment with considerations of accessibility and relevance. The procedure begins with initial observation of temperature failures (-5°C fish, -6°C meat vs target -18°C) on May 11, 2025, followed by simultaneous data collection: questionnaire distribution, compressor teardown photo documentation, and logbook recording; separate analysis (quantitative FMEA confirming RPN 50 compressor, qualitative verification of piston/crank damage); implementation of compressor replacement solutions; and post-repair pull-down evaluation (25°C to -23°C). These stages follow a logical convergent design flow for convergence of results, with validation through triangulation. Emzir and Creswell outline a step-by-step mixed methods procedure like this for a technical case study, supported by Sugiyono for a systematic sequence from collection to verification.

III. RESULT AND DISCUSSION

Overview of Research Object

The research location took place on board the KM. Lambelu, a passenger ship operated by PT. Pelayaran Nasional Indonesia, a State-Owned Enterprise (BUMN) also known as PT. PELNI (Persero). PT. PELNI itself was established on April 28, 1952, based on the Decree of the Minister of Transportation No. M2/1/2. PELNI manages 26 passenger ships serving 1,058 routes and anchoring at 71 ports, as well as operating 42 pioneer ships. The KM. Lambelu fleet was built in 1996 at the Jos L. Meyer shipyard, Papenburg, Germany.

Fig 1. KM. Lambelu

Qualitative Data Analysis

1. Observation

Table 1. Trouble Temperature Records

Date	O'clock	Room	Recorded Temperature (°C)	Information
May 11, 2025	Morning	Fish Room	-5	Failed to Reach Target
May 11, 2025	Morning	Meat Room	-6	Failed to Reach Target
May 11, 2025	Morning	Vegetable Room	+10	Normal
May 11, 2025	Morning	Dry Room	+15	Normal

a. Problematic freezing rooms: The Fish and Meat Rooms showed temperatures of -5°C and -6°C, respectively, which are categorized as "Failed to Reach Target." These temperatures tend to be higher than the standard for frozen storage (typically below -18°C for fresh meat and fish), thus risking premature spoilage, bacterial growth, or product quality degradation.

b. Overall pattern: Of the four rooms, 50% failed to meet targets, particularly in areas requiring extreme cooling. This could be due to factors such as compressor failure, freon leaks, electrical overload, or frequently opening doors.

2. Documentation

Visual evidence showing the complete teardown of the old compressor unit (SABROE BFF5 in green).

Fig 2. Compressor Components

Quantitative Data Analysis

Table 1. Refrigerator Components

No.	Component
1	Compressor
2	Condenser
3	Expansion Valve
4	Evaporator
5	Dryer
6	Oil Separator
7	Solenoid Valve

1. Determining Severity Level

*Severity level*is the level of severity when a failure occurs expressed in the form of a score with a value of 5 specific categories which will be used in the questionnaire.

Table 2. Likert Severity Scale

Tabel Skala Likert untuk Severity (S)		
Skor	**Tingkat Keparahan**	**Deskripsi**
1	Sangat Rendah	Dampak kegagalan sangat kecil, tidak memengaruhi operasi atau keselamatan.
2	Rendah	Dampak kegagalan kecil, hanya memengaruhi efisiensi minor.
3	Sedang	Dampak kegagalan cukup signifikan, memengaruhi operasi tetapi tidak kritis.
4	Tinggi	Dampak kegagalan serius, mengganggu operasi dan memerlukan perbaikan segera.
5	Sangat Tinggi	Dampak kegagalan sangat serius, mengancam keselamatan atau menyebabkan kerugian besar.

2. Determining the Occurrence Level

*Occurrence level*or the frequency level which shows how often failures occur is expressed in the form of a score with 5 specific categories which will be used in the questionnaire,

Table 3. Likert Scale Occurrence

Tabel Skala Likert untuk Occurrence (O)		
Skor	**Tingkat Kemungkinan**	**Deskripsi**
1	Sangat Jarang	Kegagalan hampir tidak pernah terjadi, kemungkinan sangat kecil.
2	Jarang	Kegagalan jarang terjadi, kemungkinan kecil.
3	Kadang-Kadang	Kegagalan terjadi sesekali, kemungkinan sedang.
4	Sering	Kegagalan sering terjadi, kemungkinan tinggi.
5	Sangat Sering	Kegagalan hampir selalu terjadi, kemungkinan sangat tinggi.

3. Determining the Detection Level

The detection level describes the likelihood of a failure or the consequences of a failure. The detection level can be reviewed through existing control systems to detect potential failures. Table 4 shows the measurement/Likert scale used in the detection assessment, with five specific categories to be used in the questionnaire, as follows:

Table 4. Likert Detection Scale

Skala Likert untuk Detection (D)		
Skor	**Tingkat Kemampuan Mendeteksi**	**Deskripsi**
1	Sangat Mudah Dideteksi	Kegagalan dapat dideteksi dengan sangat mudah dan hampir pasti teridentifikasi sebelum terjadi.
2	Mudah Dideteksi	Kegagalan dapat dideteksi dengan mudah melalui inspeksi rutin atau sistem monitoring.
3	Cukup Mudah Dideteksi	Kegagalan dapat dideteksi dengan beberapa upaya, seperti pemeriksaan berkala atau alat khusus.
4	Sulit Dideteksi	Kegagalan sulit dideteksi dan memerlukan alat atau metode khusus yang tidak selalu tersedia.
5	Sangat Sulit Dideteksi	Kegagalan sangat sulit dideteksi, hampir tidak mungkin teridentifikasi sebelum terjadi.

The respondents in this questionnaire were 30 engineers whose duties and responsibilities include supervising, operating, and maintaining all machinery on board ships. Respondents' positions can be classified as primary positions on board, such as Chief Engineer, 2nd Engineer, 3rd Engineer, 4th Engineer, and Foreman. Each position has different expertise and responsibilities, thus providing a comprehensive picture of the actual conditions on board.

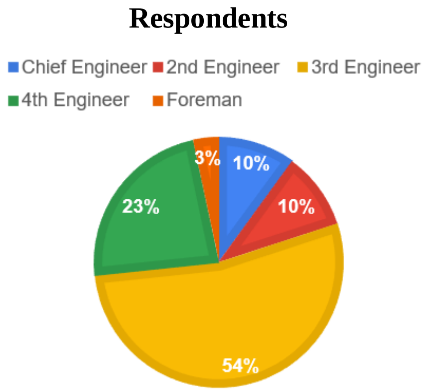

Fig 3. Respondents

The majority of respondents were 3rd-tier Engineers. Therefore, the data obtained in this study reflects direct experience and actual conditions in the field. Therefore, this study was conducted based on experience related to refrigerator systems and the maintenance procedures performed.

4. Validity Test

Table 5. Results of Severity Validity Test

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Total Score	Standard
Pearson Correlation	.361*	.591**	.407*	.722**	.630**	.595**	.375*	1	0.361
Sig. (2-tailed)	0.050	0.001	0.026	0,000	0,000	0.001	0.041		0.05
N	30	30	30	30	30	30	30	30	
Test Results	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	

From the validity test results for the 7 question items listed in the severity validity test table with a Sig. value of 0.05 and an r table value of 0.361, it has met the requirements and is considered valid and can be used for further testing.

Table 6. Results of the Occurrence Validity Test

	O_1		O_3	O_4	O_5	O_6	O_7	Total Score	Standard
Pearson Correlation	.396*	.624**	.699**	.548**	.621**	.770**	.740**	1	0.361
Sig. (2-tailed)	0.030	0,000	0,000	0.002	0,000	0,000	0,000		0.05
N	30	30	30	30	30	30	30	30	
Test Results	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	

From the validity test results for the 7 question items listed in the Occurrence validity test table with a Sig. value of 0.05 and an r table value of 0.361, it has met the requirements and is considered valid and can be used for further testing materials.

Table 7. Results of Detection Validity Test

	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Total Score	Standard
Pearson Correlation	.499**	.478**	.656**	.461*	.614**	.428*	.479**	1	0.361
Sig. (2-tailed)	0.005	0.008	0,000	0.010	0,000	0.018	0.007		0.05
N	30	30	30	30	30	30	30	30	
Test Results	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	

From the validity test results for the 7 question items listed in the Detection validity test table with a Sig. value of 0.05 and an r table value of 0.361, it has met the requirements and is considered valid and can be used for further testing materials.

5. Reliability Test

Table 8. Results of Severity Reliability Test

	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Scale Mean if Item Deleted	19.30	20.70	20.77	20.60	20.77	20.67	20.60
Scale Variance if Item Deleted	11,734	10,355	11,633	8,938	9,771	9,747	11,697
Corrected Item-Total Correlation	0.083	0.396	0.197	0.531	0.415	0.334	0.123
Cronbach's Alpha if Item Deleted	0.609	0.496	0.562	0.429	0.482	0.514	0.589
Standard	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Reliability Test	Reliable	Reliable	Reliable	Reliable	Reliable	Reliable	Reliable

From the results of the reliability test in the Severity table, it can be stated that the research variables in each question item in the questionnaire meet the requirements, namely if the Cronbach's Alpha value for each question item is > 0.60, then the data is considered reliable or consistent so that it can be used as data for the next test.

Table 9. Results of the Occurrence Reliability Test

	O_1	O_2	O_3	O_4	O_5	O_6	O_7
Scale Mean if Item Deleted	18.73	20.17	20.23	20.53	20.53	20.17	19.90
Scale Variance if Item Deleted	13,168	11,454	10,392	11,568	11,016	10,557	10,369
Corrected Item-Total Correlation	0.248	0.468	0.528	0.338	0.427	0.659	0.600
Cronbach's Alpha if Item Deleted	0.756	0.717	0.703	0.749	0.728	0.676	0.676
Standard	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Reliability Test	Reliable	Reliable	Reliable	Reliable	Reliable	Reliable	Reliable

From the results of the reliability test in the Occurrence table, it can be stated that the research variables in each question item in the questionnaire meet the requirements, namely if the Cronbach's Alpha value for each question item is > 0.60, the data is considered reliable or consistent so that it can be used as data for the next test.

Table 10. Results of Detection Reliability Test

	D_1	D_2	D_3	D_4	D_5	D_6	D_7
Scale Mean if Item Deleted	17.57	16.73	16.73	16.53	16.90	16.93	16.40
Scale Variance if Item Deleted	5,289	5,582	4,616	5,775	5,059	5,720	5,559
Corrected Item-Total Correlation	0.188	0.247	0.403	0.272	0.404	0.172	0.241
Cronbach's Alpha if Item Deleted	0.546	0.512	0.440	0.506	0.450	0.540	0.514
Standard	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Reliability Test	Reliable	Reliable	Reliable	Reliable	Reliable	Reliable	Reliable

From the results of the reliability test in the Detection table, it can be stated that the research variables in each question item in the questionnaire meet the requirements, namely if the Cronbach's Alpha value for each question item is > 0.60, the data is considered reliable or consistent so that it can be used as data for the next test.

6. S,O,D assessment

Table 11. Severity Assessment

No.	Component	Severity Score (S)	Category
1.	Compressor	5	Tall
2.	Condenser	4	Currently
3.	Expansion Valve	3	Currently
4.	Evaporator	4	Currently
5.	Dryer	3	Currently
6.	Oil Separator	4	Currently
7.	Solenoid Valve	3	Currently

Based on Table 8, the highest severity rating is given to the compressor component. The highest severity score is given if a failure mode has a very serious impact on the performance of the gantry cooling system.

Table 12. Occurrence Assessment

No.	Component	Occurrence Score (O)	Category
1.	Compressor	5	Tall
2.	Condenser	3	Currently
3.	Expansion Valve	3	Currently
4.	Evaporator	2	Currently
5.	Dryer	2	Currently
6.	Oil Separator	3	Currently
7.	Solenoid Valve	3	Currently

In table 9, the highest occurrence assessment results are found in the compressor component, which means it has a very high or recurring frequency of occurrence within a certain operating period.

Table 13. Occurrence Assessment

No.	Component	Detection Score (D)	Category
1.	Compressor	2	Currently
2.	Condenser	3	Currently
3.	Expansion Valve	3	Currently
4.	Evaporator	3	Currently
5.	Dryer	3	Currently
6.	Oil Separator	2	Currently
7.	Solenoid Valve	3	Currently

The highest detection score is awarded to failure modes that are very difficult to detect early on before they cause system disruption. The table shows that a score of 3 for the relative detection assessment indicates that the failure mode is not particularly difficult to detect.

7. RPN Value Calculation

Table 14. S,O,D Assessment

No.	Component	Severity Score (S)	Occurrence Score (O)	Detection Score (D)	RPN Value
1.	Compressor	5	5	2	50
2.	Condenser	4	3	3	36
3.	Expansion Valve	3	3	3	27
4.	Evaporator	4	2	3	24
5.	Dryer	3	2	3	18
6.	Oil Separator	4	3	2	24
7.	Solenoid Valve	3	3	3	27

FMEA analysis of the KM. Lambelu's gantry cooling system showed the compressor as the top troubleshooting priority with the highest Risk Priority Number (RPN) of 50, followed by the condenser (36), expansion valve/solenoid (27), evaporator/oil separator (24), and dryer (18) with the lowest. The compressor's highest RPN confirmed its internal mechanical failure as the cause of the temperature failure (-5°C/-6°C vs target -18°C), making unit replacement a crucial action that proved effective through pull-down to -23°C post-repair. Other components such as the condenser were at risk of increased system pressure due to fin fouling, the expansion valve causing over/underfeeding of refrigerant, the evaporator being susceptible to excessive frost, the oil separator interfering with lubrication, and the dryer being a potential clogging risk despite the low risk; these results provide an objective basis for targeted handling and routine preventive maintenance to ensure operational reliability.

Discussion

1. RPN (Risk Priority Number) calculation results

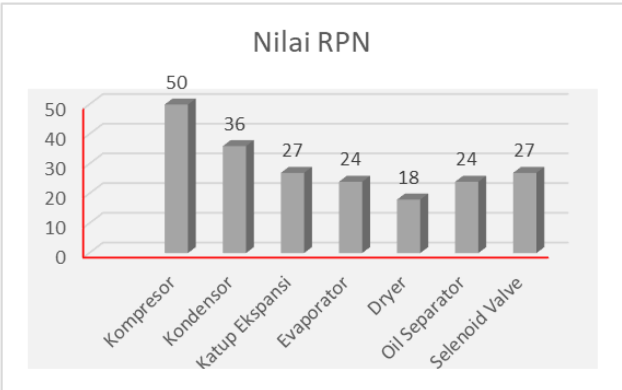

Fig 4. RPN Value

From the assessment, it has been grouped into 3 categories with low category, medium category, and high category. The results of the RPN value calculation that has been done, it can be seen that the calculation relatively gets a medium category of 5 components, a high category with 1 component, and a low category with 1 component. The component included in the high category is the compressor component with an RPN value of 50. These results indicate that the compressor has a high risk of failure and must be a top priority in carrying out maintenance. The other five components fall into the moderate category: the condenser, expansion valve, evaporator, dryer, and oil separator. If a component in the moderate category fails, it will still disrupt the performance of the garage refrigerator system, but it won't be as severe as the component with the highest RPN. Furthermore, components in the low category have a relatively low failure potential because they are easy to detect, including the solenoid valve.

2. The Impact of Troubleshooting on Cooling System Performance

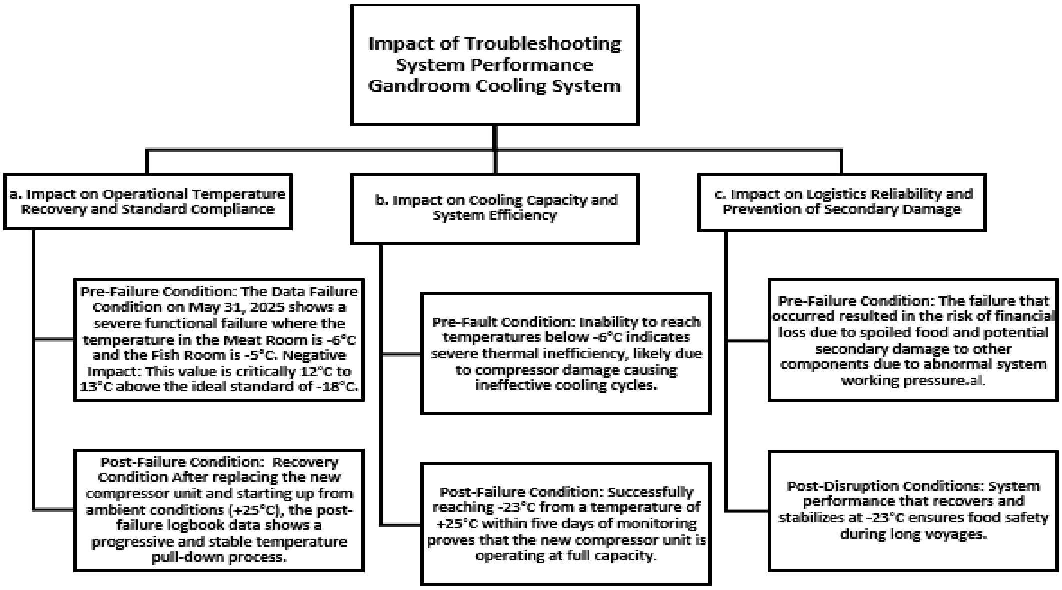

Table 5. Troubleshooting Impact

a. Operating Temperature Recovery
Before the repair, temperatures reached only -6°C (meat) and -5°C (fish), well above the standard of -18°C, threatening food preservation. After the replacement, the system pulled down from +25°C to -23°C in 5 days, exceeding the design target and ensuring compliance with standards.

b. Capacity and Efficiency Improvement
The failure of the old compressor caused severe thermal inefficiency, resulting in an ineffective refrigeration cycle. The new unit optimized heat transfer, restoring full capacity and overall system operational efficiency.

c. Logistics Reliability
Pre-disruption conditions risked financial losses from spoiled food and secondary damage. A stable recovery at -23°C ensured a safe food supply for the long voyage, preventing costly chain failures in the future.

3. Evaluation of Gandroom Cooling System Performance After Repair

Table 12. System Performance Data Before Compressor Repair

Date	Room	Temperature (°C)	Normal Temperature (°C)	Information
May 11, 2025	Fish Room	-5	(-18) – (-22)	Abnormal
May 11, 2025	Meat Room	-6	(-18) – (-24)	Abnormal
May 11, 2025	Vegetable Room	+10	(+9) – (+15)	Normal

Table 13. System Performance Data Post-Compressor Replacement (Pull-Down)

Date	Meat Room Temperature (°C)	Fish Room Temperature (°C)	Vegetable Room Temperature (°C)	Information
May 16, 2025	+25	+25	+30	Abnormal (adjustment)
May 16, 2025	+2	0	+17	Abnormal (adjustment)
May 17, 2025	-15	-15	+9	Abnormal (adjustment)
May 18, 2025	-19	-17	+9	Normal
May 19, 2025	-23	-21	+9	Normal

The new system's ability to reduce the Meat Room temperature from +25°C (New component adjustment) to -23°C within four days, as shown in Table 4, demonstrates that all major components function synergistically. This qualitative result demonstrates that the new compressor unit is at full capacity and capable of operating at, or even exceeding, the operational design standard of -18°C. This performance indicates high heat transfer efficiency throughout the cycle.

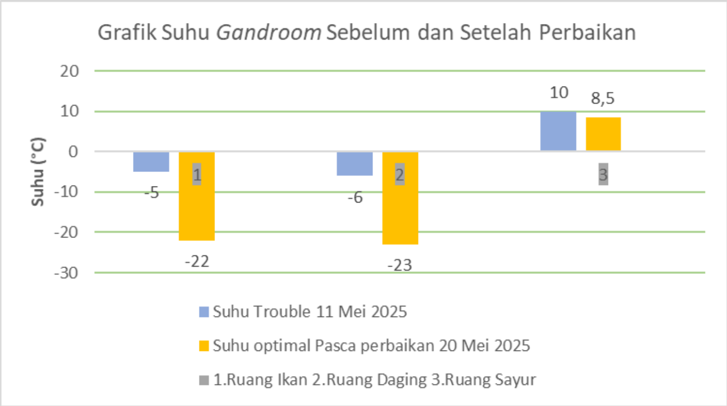

Fig 6. Gandroom temperature graph before and after repair

The graph in Figure 6 visually confirms the steady, progressive temperature drop curve, a key indicator of a healthy refrigeration system. This graph illustrates the system's capacity to remove a large initial heat load from the room and gradually reach a deep freeze. No temperature stagnation was observed, indicating the absence of secondary system issues post-installation.By critically comparing the failure data in Table 1 (performance at -6°C) with the post-repair evaluation data in Figure 4.8 (performance at -23°C), this case study conclusively proves the success of the disruption. The sharp contrast between the two data validates that the replacement

IV. CONCLUSION

This study found that the failure of the SABROE BFF5 compressor in the KM. Lambelu's gandroom cooling system, with the highest Risk Priority Number (RPN) of 50 based on FMEA analysis, was the main cause of the inability to achieve the target temperature of -18°C, only reaching -5°C to -6°C in the fish and meat room. Compressor replacement was proven effective through a pull-down test that restored the temperature to -23°C from +25°C in a short time, supported by qualitative data from logbooks and teardown photos as well as quantitative data from 30 engineer officer respondents who passed the validity and reliability tests. This finding was confirmed by mixed methods convergent parallel, emphasizing the priority of troubleshooting on the compressor as the heart of the ship's refrigeration system.However, limitations of the study lie in the limited purposive sample of 30 respondents from a single vessel, so generalization to other fleets requires broader validation, and the lack of long-term post-repair analysis in extreme marine environments. Suggestions for further research include a multi-vessel comparative study with real-time IoT monitoring and fuzzy FMEA simulation for early failure prediction. Practically, the study's implications encourage routine preventive inspection protocols on compressors, such as lubrication and piston checks, to improve the reliability of crew food logistics in accordance with Indonesian shipping regulations, reducing downtime costs and health risks.

REFERENCES

[1] al-Ayyubi, MZN, & Putri, IAJ (ND). Analysis of the Impact of Damage to the Gea Bfo-5 Refrigeration Machine Components on the Increase in the Temperature of the Food Cooling Room Above Km. Lambelu Using the FMEA Method.

[2] Azhari, DS, Afif, Z., Kustati, M., & Sepriyanti, N. (2023). Mixed method research for dissertation. INNOVATIVE: ***Journal of Social Science Research***, 3(2), 8010–8025.

[3] Berlian Dwi CA, M. Darwis, & Rika Fitriani. (nd). Analysis of the Causes of the Declining Performance of the Refrigerator System of the MV. Tanto Bagus Ship. Diploma IV TRPK Study Program, Surabaya Maritime Polytechnic.

[4] Creswell, J. W., & Plano Clark, V. L. (2024). Designing and conducting mixed methods research (4th ed.). SAGE Publications.

[5] Djasman, A., & Hermawan, R. (2022). Performance analysis of the C160 R centrifugal compressor before and after overhaul (pp. 2–6).

[6] Erita, E., Darza, SE, Kurniawan, AP, & Nofrizal, N. (2021). The main refrigeration compressor on KM. Sabuk Nusantara 37 at PT. Pelni. Jogja Maritime Science Magazine, 19(2), 20–34.

[7] Emzir. (2024). Quantitative and qualitative educational research methodology. [Publisher details from Google Scholar].

[8] Haryadi, S. (2020). Analysis of the effect of maintenance on the performance of ship refrigeration systems. ***Journal of Maritime Transportation Science and Technology***, 2(1), 30–35.https://doi.org/10.51578/j.sitektransmar.v2i1.16

[9] Shevchenko, Wiweko, A., Sapril Siregar, M., & Pelayaran Malahayati, P. (2023). Causes of declining cooling engine performance on the MV. Vancouver. ***Mutiara Indonesian Multidisciplinary Scientific Journal***, 1(2), 89–100.https://jurnal.tiga-mutiara.com/index.php/jimi/index

[10] Singgih, M. (2024). Optimizing the maintenance of refrigeration compressors to maintain the quality of food ingredients at MT. Papandayan.http://repository.pip-semarang.ac.id/5894/2/561911227272T_SKRIPSI_OPEN_ACCESS.pdf

[11] Spradley, P., & Huberman, M. (2024). A theoretical review of data analysis techniques in qualitative research. ***Journal of Management, Accounting and Administration***, 1(2), 77–84.https://pub.nuris.ac.id/journal/jomaa/article/view/93

[12] Sudaryono. (2023). Research methodology [Latest edition]. [Publisher from Google Scholar].

[13] Sugiyono. (2021). Quantitative, qualitative, and R&D research methodology. Alfabeta Publisher.

[14] Law of the Republic of Indonesia Number 17 of 2008 concerning Shipping. (2008).https://peraturan.bpk.go.id