Rebuilding Mobile Cold Storage System to Maintain Fishery Product Quality

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Abstract

The inadequate performance of the refrigeration compressor can limit the ability of a mobile cold storage system to maintain stable low temperatures during continuous operation, potentially affecting its application for fishery-product storage and distribution. This study aims at evaluating the technical performance of a rebuilt mobile cold storage system following the replacement of its original automotive air-conditioning compressor with a 1 HP air-conditioning compressor. An experimental case-study method was conducted using a 1,560-L mobile cold storage unit located at the Center for Testing the Application of Marine and Fisheries Products in East Jakarta. The rebuilding procedure comprised initial system inspection, removal of the existing compressor, modification of the compressor mounting, installation of the 1 HP compressor, reconnection of the suction and discharge refrigerant lines, electrical-system adjustment, system evacuation, refrigerant charging, leak inspection, and operational testing. Cooling performance was evaluated from the temperature reduction during an 8-h experimental test using 10 L of water as the test medium, with an initial temperature of approximately 30°C. The rebuilt system reduced the test-medium temperature from approximately 30°C to -4°C within 8 h and maintained stable cooling operation throughout the test period. These results demonstrate that replacement of the automotive air-conditioning compressor with a 1 HP air-conditioning compressor restored the cooling capability of the 1,560-L mobile cold storage system. The findings indicate that targeted compressor replacement, supported by appropriate mechanical, refrigerant-piping, and electrical modifications, provides a practical component-level rebuilding approach for restoring existing mobile cold storage systems used in fishery-product applications.

Keywords: Compressor; Fishery Product; Mobile Cold Storage; Rebuilding

I. Introduction

The cold chain system plays an important role in maintaining the quality and safety of temperature-sensitive fishery products during storage and distribution. Inadequate post-harvest handling, limited preservation facilities, and improper storage and transportation can contribute significantly to fish quality deterioration and post-harvest losses[1]. Mobile cold storage provides a flexible solution by enabling temperature-controlled storage and distribution under field conditions [2]. However, its cooling performance depends strongly on the refrigeration system, particularly the compressor, which maintains refrigerant circulation and the pressure difference required for heat removal within the refrigeration cycle[3].

The mobile cold storage unit investigated in this study has a storage capacity of 1,560 L and was originally equipped with an automotive air-conditioning compressor. During operation, the compressor was unable to maintain the required low temperature under continuous cooling conditions. Although previous studies have investigated mobile cold storage technologies and refrigeration system performance, experimental evaluations of component-level rebuilding through targeted compressor replacement in existing mobile cold storage units are still relatively limited, particularly for a 1,560-L unit originally equipped with an automotive air-conditioning compressor. In addition, the technical effectiveness of compressor replacement cannot be determined solely from component installation; compatibility with the existing mechanical mounting, refrigerant piping, electrical system, and other refrigeration components must also be ensured. The resulting cooling performance must be verified through controlled experimental testing following system evacuation and refrigerant charging.

Recent studies have increasingly examined mobile and portable cold-storage technologies as flexible alternatives to conventional fixed cold-storage facilities. Yenare et al. reviewed portable cold-storage technologies and identified compression refrigeration, absorption refrigeration, thermoelectric cooling, and phase-change materials (PCMs) as important technological options for portable applications, while also highlighting energy efficiency, portability, and thermal control as major performance considerations [4]. specifically reviewed mobile cold storage using ice slurry and demonstrated that mobile systems can overcome the site limitations of conventional fixed cold storage, although heat transfer, flow behavior, and cold-storage performance remain important engineering challenges [5]. further reviewed phase-change cold-energy storage materials for aquatic-product cold chains and showed that such materials can be applied during precooling, processing, packaging, transportation, and storage to mitigate temperature fluctuations and preserve product quality [6]. Similarly, Li et al. reviewed emerging phase-change cold-storage technologies for fresh-product cold-chain logistics and emphasized the potential of thermal-energy storage to reduce energy consumption, operating costs, and temperature fluctuations in cold-chain equipment [7]. These studies demonstrate that recent research has moved toward flexible, energy-efficient, and thermally stable cold-storage technologies; however, the majority of the reported approaches focus on developing new storage technologies or integrating advanced thermal-storage materials rather than rebuilding existing mobile refrigeration systems whose original refrigeration components have become inadequate.

Another group of studies has concentrated on improving the thermal, energy, and operational performance of refrigerated systems. The optimization of phase-change cold-storage modules for refrigerated containers and demonstrated that refrigeration-unit rated power, pipeline configuration, and module geometry influence cold-storage capacity, charging speed, and energy consumption [8]. Integrating PCM into a refrigerated warehouse could reduce temperature rise and improve food-preservation performance while also addressing the high electricity consumption associated with low-temperature storage [9]. Leungtongkum et al. compared lumped, zonal, and CFD approaches for analyzing heat transfer in insulated food-transport boxes equipped with PCM, demonstrating the importance of accurately characterizing thermal behavior under practical transport conditions [10]. Logistics cold-storage systems and identified refrigeration-system configuration, control strategies, energy monitoring, building characteristics, and field performance as major areas requiring further investigation [11]. Niu et al. conducted field-based research on small-capacity logistics cold storage and showed that actual refrigeration-system performance and cooling-load characteristics are important for understanding energy use and greenhouse-gas emissions [12]. Meanwhile, Soylemez et al. examined refrigeration systems used on fishing vessels and showed that refrigeration-system configuration and compressor/refrigerant selection are important considerations for achieving reliable low-temperature operation in fishery applications [13]. These studies indicate that refrigeration performance is not determined by the compressor alone, but by the compatibility and integration of the compressor, refrigerant circuit, thermal load, insulation, electrical system, and control strategy. Nevertheless, there remains a limited body of experimental research addressing a practical component-level rebuilding strategy for an existing mobile cold-storage unit, particularly a fishery-product storage unit in which an inadequate automotive air-conditioning compressor is replaced by a compressor designed for longer-duration air-conditioning/refrigeration operation. This gap provides the rationale for the present study, which experimentally evaluates the rebuilding of a 1,560-L mobile cold-storage system through replacement of its original automotive compressor with a 1 HP air-conditioning compressor and subsequent evaluation of its cooling performance under controlled experimental conditions.

To address this technical problem, this study investigates the rebuilding of a 1,560-L mobile cold storage system by replacing the original automotive air-conditioning compressor with a 1 HP air-conditioning compressor. The rebuilding process includes modification of the compressor mounting, reconnection of the refrigerant piping, adjustment of the electrical system, system evacuation, refrigerant charging, and operational testing. Cooling performance is evaluated based on the temperature reduction achieved during an 8-h experimental test using 10 L of water as the test medium. The study contributes experimental evidence on the feasibility of component-level compressor replacement as a practical rebuilding strategy for restoring the cooling capability of existing mobile cold storage systems used in fishery-product applications.

II. METHOD

A. Research Design and Data Collection Techniques

This study employs an experimental research design to evaluate the effect of compressor replacement on the performance of a mobile cold storage system. The rebuilding process involved replacing the original automotive air-conditioning compressor with a 1 HP air-conditioning compressor using R22 refrigerant. The mobile cold storage chamber had a storage capacity of 1,560 litters with polyurethane insulation thickness of 8 cm. The refrigerant charge mass used in the rebuilt system was approximately 850 g of R22, adjusted according to compressor operating pressure and cooling performance requirements [14].

The experiment was designed to compare system performance before and after rebuilding under controlled ambient conditions of approximately 30 ± 1°C. In the initial configuration, the automotive compressor was only capable of maintaining temperatures between 8°C and 10°C during continuous operation, which did not meet the cold chain requirement for fishery products below 5°C. After rebuilding, the cooling performance was re-evaluated using the same operating conditions [15]. A 10-liter water load was used as the thermal simulation medium because water possesses a high specific heat capacity and can represent a stable thermal load during cooling experiments [16]. The selected load corresponds to approximately 0.64% of the total chamber volume and was intended to provide controlled and repeatable thermal behaviour for evaluating refrigeration performance.

Temperature, pressure, and electrical current were measured directly using calibrated instruments. Temperature measurements were conducted using a digital thermometer with an accuracy of ±0.5°C, pressure measurements used a manifold pressure gauge with an uncertainty of ±1 psi, and electrical current was measured using a digital clamp multimeter with an accuracy of ±0.01 A. Measurements were recorded at 30-minute intervals during the cooling process. Each experiment was repeated three times under identical conditions, and the results were reported as average values with corresponding deviations to improve data reliability. Measurements were conducted directly using measuring instruments to obtain primary data on system performance before and after the rebuilding process. The experimental method is a scientifically valid approach, as it allows for the control of confounding variables and the generation of new data from the applied treatment [17]. This enables a more objective analysis of cause and effect relationships.

B. Cooling Load Calculation

To calculate the cooling requirement of the mobile cold storage, a heat load calculation was carried out using a thermal conductivity approach. The heat loads considered include: wall heat load (conduction), air infiltration load (convection), product load (fish), water load (as the cooling medium), and internal load from electrical equipment. The formula for calculating the heat load through the wall is as follows:

$$Q = A \times U \times \Delta T$$

Annotation:
Q : Heat Transfer Rate (W)
A : Wall Surface Area (m²)
U : Total Heat Transfer Coefficient (W/m²·K)
ΔT : Temperature Difference Between Outside and Inside the Room (K)

The calculation of the overall heat transfer coefficient (U) takes into account the thermal resistance of each material layer and the surface convection coefficients on both the interior and exterior sides. [18].

C. Data Analysis

Data analysis was performed using quantitative and qualitative approaches. Quantitative analysis involved the evaluation of temperature reduction rate, operating pressure, electrical current, and cooling stability before and after compressor replacement. The refrigeration system performance was analyzed numerically using basic thermodynamic principles and heat transfer equations [19]. To improve result reliability, all measurements were conducted in triplicate, and the reported values represent the average measurement results. Temperature stability was evaluated using fluctuation range and deviation analysis during steady-state operation. Qualitative analysis was conducted descriptively through observations, interviews, and documentation during the rebuilding process. This analysis was intended to provide a comprehensive explanation of the rebuilding implementation, operational challenges, and system performance improvements[20].

D. Comparison of Compressor Performance

The performance comparison between the automotive compressor and the 1 HP air-conditioning compressor was conducted based on several operational parameters, including: Cooling time required to reach the target temperature, Temperature stability during operation, Electrical power consumption and Operating pressure compatibility and stability. The evaluation results were used to determine the effectiveness of the rebuilding process and the feasibility of using a 1 HP air-conditioning compressor for mobile cold storage applications[21]. The comparison also served to assess improvements in refrigeration cycle stability and thermal efficiency after compressor replacement.

III. RESULTS AND DISCUSSION

The rebuilding process of the mobile cold storage system was carried out with a focus on a single critical component the compressor. The original compressor was an automotive-type unit, designed for short-term, non-continuous operation. In the context of a 1,560-liter mobile cold storage unit, continuous and stable cooling is required. Therefore, the automotive compressor was unable to maintain the chamber temperature consistently below 5°C, as required by cold chain standards. The replacement was made by installing a 1 HP air conditioning compressor. This compressor provides better performance in generating higher pressure and is capable of operating for extended periods with more stable electrical efficiency[19]. Moreover, the 1 HP AC compressor is more commonly used in stationary or semi-portable cooling systems, making it more suitable for the thermal load characteristics of mobile cold storage [22]. The replacement was carried out without modifying other main components such as the condenser and evaporator, as both were still in good condition and compatible with the operating pressure of the new compressor.

Although only one component was replaced, the rebuilding process still involved several detailed technical steps. The new compressor had to be precisely installed onto a modified mounting bracket and then connected to the refrigerant piping system. The system also needed to be evacuated (vacuumed) to remove air and moisture before recharging with refrigerant[23]. In addition, electrical testing, operating pressure measurement, and leak detection were essential parts of the procedure to ensure the system operated optimally after the replacement. With the rebuilding process involving only the compressor replacement, the mobile cold storage system is now able to operate more stably and reliably in maintaining the temperature of stored products. This process also demonstrates that system repair or performance improvement does not always require a complete overhaul of all components; rather, replacing the most critical part in this case, the compressor, which has a significant impact on the overall performance of the refrigeration system is often sufficient.

A. Initial Inspection and Disassembly

The first step in the mobile cold storage rebuilding process is a thorough inspection of the existing refrigeration system. This inspection includes both physical and functional evaluations of the old compressor, refrigerant pipe connections, electrical wiring, and the mechanical condition of the compressor mounting bracket. The purpose of this stage is to ensure that the other components in the system are still in good condition and compatible with the new compressor to be installed. If any damage or wear is identified, additional repairs or component replacements should be considered.

Once the inspection is completed and the system is deemed safe, the disassembly of the old compressor is carried out. This stage involves disconnecting the refrigerant pipe connections from the suction and discharge sides, detaching the electrical wires connected to the compressor, and removing the brackets or mounting bolts that secure the compressor in place. All of these steps must be performed carefully to avoid damaging other components that will be reused, such as the condenser and evaporator.

The primary reason for replacing the compressor in the mobile cold storage system was that the original compressor, which came from a vehicle air conditioning system, was unable to consistently maintain low temperatures over extended periods. Automotive compressors are generally designed for intermittent use with limited operating durations, making them unsuitable for continuous cooling applications such as cold storage[24]. As a result, the target storage temperature could not be achieved, potentially compromising the quality and safety of the stored products[25]. Therefore, the compressor was replaced with a 1 HP AC unit, which is more efficient and reliable in maintaining the required temperature.

B. Installation of 1 PK AC Compressor

The new 1 HP AC compressor was installed to replace the old unit as a key step in enhancing the mobile cold storage refrigeration system. The installation was carried out mechanically on a mounting bracket that had been modified to match the dimensions and bolt positions of the new compressor. This adjustment aimed to ensure a secure fit, minimize excessive vibration during operation, and maintain overall system stability. Mounting stability is crucial to prevent long-term damage to both the compressor and the refrigerant pipe connections.

Figure 1 Compressor AC 1 HP

After the physical installation was completed, the next step involved connecting the refrigerant pipes to the suction and discharge sides of the compressor. Each joint was carefully inspected to ensure there were no leaks that could reduce system efficiency. The electrical system was then adjusted, including power cable connections, capacitor installation, and testing of the electrical current supplied to the compressor. All adjustments were carried out in accordance with the technical specifications of the 1 HP AC compressor to ensure optimal and safe long-term operation of the system.

C. System Testing and Charging

After the compressor installation was completed, the next step was to perform a vacuum process on the refrigeration system. This procedure aims to remove any remaining air and moisture from the piping and system components. The presence of air or humidity can disrupt refrigerant circulation and reduce cooling efficiency[26]. The vacuum process was carried out using a specialized vacuum pump for several minutes until the system reached the desired vacuum pressure. This stage is crucial, as it helps prevent ice formation or potential damage to the compressor caused by moisture.

Figure 2 Testing and Filling of R22 Freon

Once the system was thoroughly cleaned, refrigerant was recharged into the system in accordance with the recommended amount for the mobile cold storage capacity. A series of tests were then conducted, including measurements of system operating pressure, evaluation of temperature stability, and performance checks on the new compressor. If the cooling temperature achieved falls within the range of -10°C and the system operates within normal pressure and current levels, the rebuilding process is considered successful. This indicates that the system is ready to be used for maintaining stable product temperatures within the mobile cold storage chamber.

D. Trial Process and Trial Results

The cooling system test was conducted using 10 liters of water placed inside the mobile cold storage chamber. The purpose was to evaluate the system's ability to reduce the temperature from a known initial condition, approximately 30°C[26]. Water was chosen because of its relatively high specific heat capacity, making it a reasonable representation of a real thermal load in a practical cooling simulation. In addition, the use of water facilitates accurate and uniform temperature measurement throughout the testing process.

During the testing process, the cooling system was activated and the water temperature was monitored periodically using a thermometer. The objective of the test was to lower the water temperature from 30°C to -4°C, demonstrating the system's ability to achieve sub-freezing temperatures. If this temperature drop is achieved within a reasonable time frame and the temperature remains stable without significant fluctuations, the system is considered operationally feasible and successful in meeting the performance standards of a mobile cold storage unit.[27].

Table 1 Room Cold Temperature Results

Cooling Temperature		
Time (Hour)	**Theoretical Temperature Drop (°C)**	**Actual Temperature Decrease (°C)**
13:57	20,4	20
14:27	8,8	8
14:57	4,7	4
15:34	-0,3	0
18:06	-1,6	-1

Cooling Temperature		
Time (Hour)	Theoretical Temperature Drop (°C)	Actual Temperature Decrease (°C)
16:34	-3,2	-3
17:24	-5,4	-5
18:42	-7,6	-7
19:31	-10	-10

Based on the test results, the process of reducing the temperature from 30°C to -4°C required approximately 8 hours. This duration reflects the actual performance of the cooling system after the rebuilding process, with a 1 HP AC compressor replacing the previous automotive compressor. Data collection was carried out during both daytime and nighttime over an 8-hour testing period. The test results are presented in the following table 1.

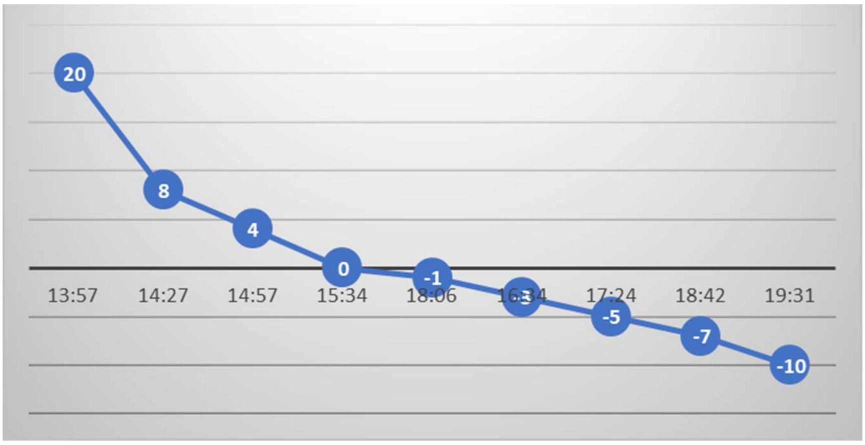

Figure 3 Temperature Drop Graph: Actual Temperature Decrease (°C)

E. Heat Load Through the Walls of the Cooling Chamber

Heat transfer through the walls of the cooling chamber is one of the primary factors affecting the performance of the refrigeration system in mobile cold storage. Heat from the external environment can penetrate the storage space through thermal conduction, especially if the insulation is not thick enough or contains gaps[28]. In this case, an 8 cm thick wall serves as a thermal barrier but still has a certain level of conductivity depending on the insulation material, such as polyurethane. The better the quality and thickness of the insulation, the less heat enters the chamber, resulting in a reduced workload for the compressor.

When the external heat load is substantial, the cooling system must work harder to maintain low temperatures inside the storage chamber. This can lead to increased electrical power consumption, accelerated wear of components such as the compressor, and prolonged cooling times [29]. Therefore, accounting for heat gain through the walls is crucial in the design and performance evaluation of mobile cold storage systems, ensuring that the system operates efficiently while maintaining stable product temperatures during distribution or storage.

The mobile cold storage unit has a rectangular shape with six sides, and the outer dimensions of the chamber are 1.64 x 1.08 x 1.08 meters, resulting in a total surface area of 7.139 m². The U-factor, which represents the overall heat transfer coefficient, is calculated to be 0.028. The purpose of using this cold storage system is to maintain the internal chamber temperature at 0°C. Meanwhile, the average ambient temperature in South Jakarta during the testing process was approximately 30°C. Based on these values, the heat load passing through the walls of the cooling chamber can be calculated. The formula used for this calculation refers to Dossat [26], taking into account the temperature difference between the inside and outside of the chamber, the U-factor, and the surface area. The heat load (Q) through the chamber walls is the product of the surface area, the U-factor, and the temperature difference. So, the heat load value can be expressed as follows:

Q=A x U x ΔT
Q=7,139 x 0,028 x 30
Q=5,996 watt

Thus, the heat load through the cooling chamber wall during the trial is about 5,996 watts, which must be removed by the cooling system to maintain the desired temperature Based on the heat load formula through the cooling chamber wall, a value of 5,996 watts is obtained as the cooling load through the hatch wall of the mobile cold storage machine design. Figure 2 shows the insulation layer of Mobile Cold storage.

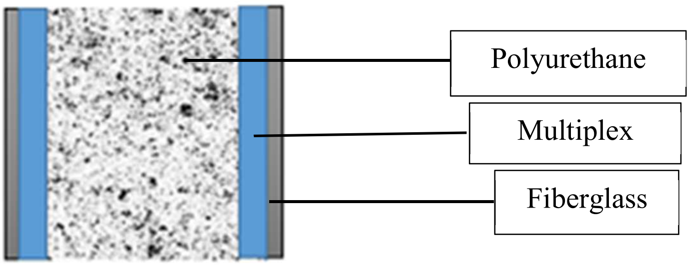

Figure 4 Mobile Storage Insulation Layer

The walls of the cooling tank in mobile cold storage are lined with fiberglass, plywood, and polyurethane, providing a good combination of thermal insulation and structural strength[30]. The combination of these three materials provides a cooling tank wall that is efficient in retaining heat from the outside and maintaining a cool temperature inside the tank.

Table 2 Mobile Cold Storage Layer

No	Material	Thickness	
		Inner	Outer
1	Polyurethane	5 cm	5 cm
2	fiberglass	5 mm	5 mm
3	plywood	1 cm	1 cm

F. Mobile Cold Storage Electricity

Mobile cold storage is a highly useful technology for maintaining the freshness of fishery products. One key component of this system is electricity, which ensures the refrigeration unit functions optimally in any location. Mobile cold storage is typically equipped with an electrically operated compressor, and this power can be supplied from a fixed power source or a generator. During daily operations, the electrical system must be stable and reliable to prevent disruptions that could damage stored goods.

A good electrical system in mobile cold storage should also be designed for energy efficiency. Efficient power usage not only reduces operational costs but also reduces the carbon footprint, making it a more environmentally friendly option. Monitoring devices are often installed to monitor energy consumption and ensure the system is operating at optimal levels. Furthermore, since mobile cold storage frequently changes locations, it's crucial to ensure the electrical system can handle the voltage and frequency variations it may encounter. This means the system must be equipped with protection against power surges and other disturbances that could damage the refrigeration equipment. The use of high-quality components, such as cables that can withstand extreme conditions and surge protectors, is also crucial to maintaining system reliability. In the context of electrical systems, the refrigeration system in mobile cold storage includes several components, as shown in Figure 5.

Figure 5 Mobile Cold Storage Electricity

Figure 5 shows that the electrical system of the mobile cold storage is designed as an integrated control, monitoring, and protection system to support continuous refrigeration operation. The electrical panel is equipped with several digital display instruments, indicator lamps, control switches, a power outlet, a power supply unit, and electrical protection components. The presence of these components indicates that the electrical subsystem is not only responsible for supplying power to the refrigeration equipment but also provides an interface for monitoring and controlling system operation. The digital displays enable the operator to observe operating parameters during the refrigeration process, while the indicator lamps provide information regarding the operating status of the system. This configuration is important because continuous operation of the 1 HP compressor requires a stable and adequately protected electrical supply. Thus, the electrical panel forms an essential part of the rebuilt system by supporting controlled and observable operation of the refrigeration equipment.

From a technical perspective, the configuration shown in Figure 5 also supports the reliability of the rebuilt mobile cold storage system during continuous operation. The integration of monitoring instruments and electrical protection can help the operator identify abnormal operating conditions and reduce the risk of operational interruptions caused by electrical disturbances. This is particularly important for a mobile refrigeration system because changes in the power supply may occur when the unit is operated at different locations or connected to different electrical sources. Therefore, the successful rebuilding of the refrigeration system should not be evaluated solely from the ability of the new compressor to reduce chamber temperature, but also from the capability of the electrical subsystem to provide stable, controlled, and protected power to the refrigeration components. The combination of appropriate compressor capacity, reliable electrical supply, monitoring instruments, and protection devices contributes to the overall operational stability of the mobile cold storage system and supports its application for maintaining the quality of fishery products during storage and distribution

IV. CONCLUSION

The performance success of a mobile cold storage system is highly dependent on the integration of its main components, which must operate stably with appropriate compressor power specifications, refrigerant type, pipe dimensions, and insulation thickness to ensure thermal efficiency and temperature stability. The rebuilding process was undertaken in response to the inadequate performance of the original automotive AC compressor, which failed to consistently maintain low temperatures. Replacing it with a 1 HP AC compressor proved to be more suitable for long-term cold storage applications. This process involved adjustments to the mechanical mounting, reconnection of the refrigerant piping system, and reconfiguration of the electrical system. Post-rebuilding testing using 10 liters of water as the medium demonstrated that the system was able to reduce the temperature from 30°C to -4°C within 8 hours, with stable temperature control. These results confirm that the rebuilding process successfully improved the thermal efficiency and reliability of the mobile cold storage system, making it a viable technical solution to support the cold chain distribution of fishery products.

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