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The Effect of Receiver Tube Design with a Tube Length of 85 mm on COP and Electrical Power Consumption in Air Conditioning Units for Ship Accommodation Spaces

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Abstract

This study investigates the engineering modification of a receiver tube with a length of 85 mm to improve the energy efficiency of air conditioning (AC) systems in ship accommodation spaces. The primary objective is to reduce compressor workload and enhance thermodynamic performance. An experimental method was employed by comparing system performance before and after receiver tube installation. Key parameters analyzed include Coefficient of Performance (COP), electrical power consumption, and operational cost. The results show that the 85 mm receiver tube reduces compressor power consumption from 286 W to 242 W and achieves an average COP of 30.8. The modification also decreases monthly electricity costs by IDR 45,780 per unit and up to IDR 549,240 when applied to ship-scale systems. These findings demonstrate that the receiver tube modification significantly improves energy efficiency and reduces operational costs, making it highly applicable for marine HVAC systems.

Keywords: air conditioning, receiver tube, coefficient of performance, energy efficiency, shipping accommodation

1. INTRODUCTION

The success of maritime transportation operations is essentially determined not only by the design aspects of an efficient ship—such as its structure, propulsion system, and navigation equipment—but also by the ability to maintain the comfort and health of the crew on duty. In the modern maritime world, the human factor is one of the principal components that determine the smooth operation of the company (Barone et al., 2025). Crew members are required to remain in good physical and mental condition to carry out their duties optimally. However, marine environmental conditions are often erratic, with exposure to extreme weather, elevated ambient temperatures, and fluctuating humidity levels (Guo et al., 2024). These adverse conditions can impair crew endurance and even diminish work concentration levels. Therefore, maintaining thermal comfort in the ship's accommodation spaces is a fundamental need that cannot be neglected (Kan et al., 2022; Xie et al., 2022).

One of the facilities that plays a pivotal role in maintaining thermal comfort is the air-conditioning (AC) system. The presence of such a system enables the creation of more stable and comfortable indoor room temperature conditions, even while the ship operates in tropical regions with very high surrounding air temperatures (Liu et al., 2024). Air-conditioners not only serve as devices to reduce temperature but also help to control air humidity and maintain good indoor air quality in the accommodation space (Cheung et al., 2024). With a cooler and fresher environment, the crew can avoid the risk of dehydration, fatigue, and heat-related health problems (Bai et al., 2022). In addition, thermal comfort is directly related to productivity and work safety, because crew members operating in comfortable conditions tend to be more focused and responsive to emergency situations (Liu H. et al., 2024).

Nevertheless, the AC system on board must be operated both efficiently and effectively. This is important to ensure optimal performance and avoid energy waste (Brækken et al., 2023). On ships, the source of electrical energy generally comes from generators driven by the main engine or auxiliary engines. If the cooling system is not properly designed and operated, the generator load will increase, leading to higher fuel consumption and increased ship operating costs (Buonomano et al., 2023). In other words, efficient management of cooling systems not only ensures comfort for the crew but also impacts the economic and sustainability aspects of maritime transportation operations (Barone et al., 2025; Lehtiö, 2023).

Technically, the working principle of the AC system is based on the process of heat transfer. Heat from the room is extracted and expelled into the environment, so that the room temperature can be maintained below the ambient temperature. This process involves the circulation of a working fluid (refrigerant) undergoing phase change from liquid to gas and vice versa, through key components such as a compressor, condenser, expansion valve, and evaporator (Zhao & Shinoda, 2024). When the refrigerant absorbs heat from the room air in the evaporator, the air supplied back into the accommodation room becomes cooler. Subsequently, the absorbed heat is released into the environment through the condenser. This cyclic mechanism continues as long as the system is operational (Liu L. et al., 2024).

The underlying mechanism is a direct application of heat transfer theory and the fundamental laws of thermodynamics within the field of marine engineering. The processes of conduction, convection, and radiation take place simultaneously in the cooling system to ensure that the room temperature remains within a comfortable range (Koja Marine, 2023). In addition, the concepts of energy balance and thermodynamic efficiency serve as the foundation for determining how much electrical power is needed to produce a given cooling effect (Credence Research, 2024). With a sound understanding of these principles, the design and operation of cooling systems can be continuously improved to meet the demands of crew comfort while reducing energy consumption (Buonomano et al., 2023; Brækken et al., 2023).

Thus, the presence of an AC system on board the ship is not merely a luxury, but a vital necessity affecting various operational aspects. From maintaining crew comfort and health, improving work safety, reducing operational costs, to supporting energy efficiency—these aspects are interconnected (Liu C. et al., 2023). Research and innovation in shipboard air-conditioning systems continue to evolve, with modern developments emphasizing energy-efficient and environmentally friendly cooling technologies (Barone et al., 2025; Buonomano et al., 2023). The application of such innovations is expected to make a tangible contribution to the future success of maritime transportation.

A simple refrigeration system fundamentally consists of four main components—namely the compressor, condenser, expansion valve, and evaporator—that work cyclically to transfer heat from one medium to another. To achieve the required room temperature, various methods may be applied; for example, increasing the heat transfer coefficient in the condensation process or increasing the air-flow rate around the condenser to enhance system efficiency and the coefficient of performance (COP) (Yawara, 2013).

This study proposes a novel modification in the form of a fixed-length receiver tube (85 mm), which has not been widely applied in small-scale marine air conditioning systems. Unlike previous studies focusing on general HVAC optimization, this research specifically evaluates the impact of receiver tube geometry on compressor workload, COP, and electrical efficiency using both experimental testing and CFD-based pressure analysis.

2. METHODS

This study employs a combined experimental and numerical (CFD) approach. The experimental method is used to evaluate actual system performance, while CFD simulation is utilized to analyze refrigerant pressure distribution within the receiver tube. Data collection was conducted at 15-minute intervals (15, 30, 45, and 60 minutes) after the system reached steady-state conditions. Each test was repeated three times to ensure data reliability.

2.1. Prototype Development and Simulation of Receiver Tube Prototype Software

2.1.1. Prototype Development

It is done through autocad software, with accurate measurements and records. The technical drawings were then used to guide the design of the receiver tube. Planning of prototype variations in Figure 1.

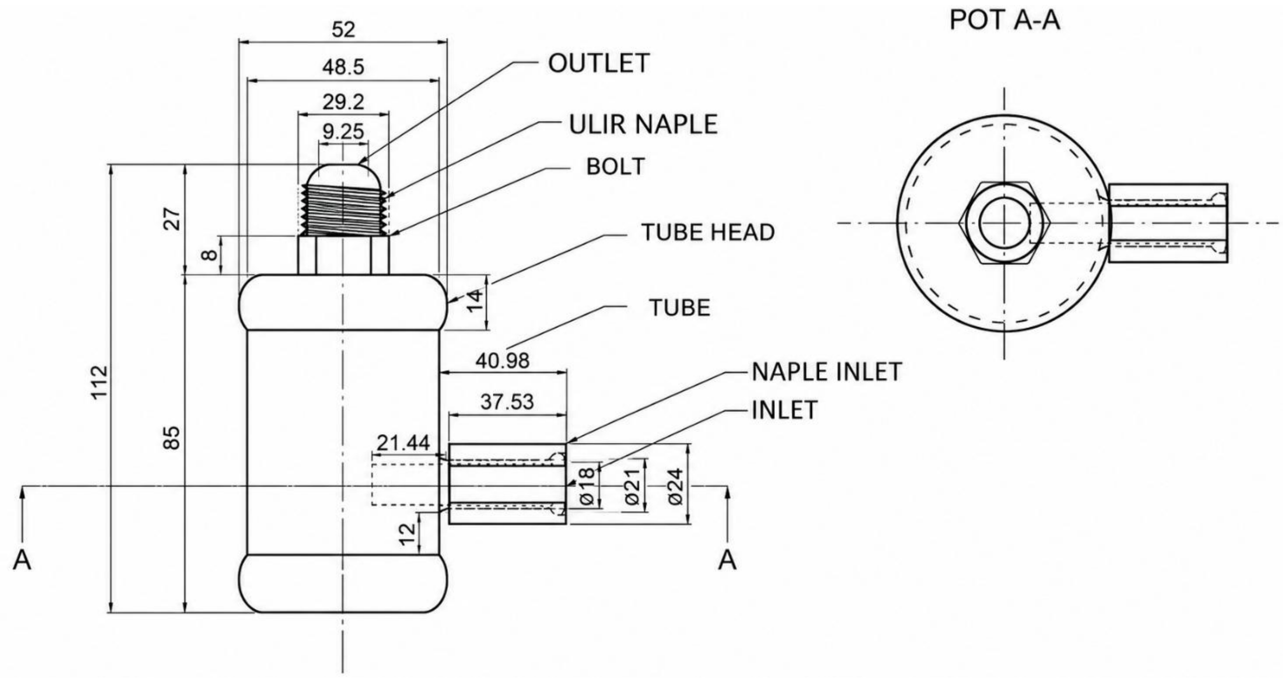

Figure 1. Tube Receiver Tube Length Variation 85 mm

2.1.2. Simulation of Receiver Tube Prototype Software

The simulation process in Computational Fluid Dynamic (CFD) starts with the creation of the Receiver Tube model. Modeling using AutoCAD and Rhinoceros software programs. The model used must be solid first. Before the receiver tube model becomes solid, a surface is first made from hundreds of curves that have been made beforehand. From several surfaces that are formed all at the joint into one to become solid. Once the model is complete, it continues using numerical simulations. The numerical simulation software used is Ansys fluent which is based on Computational Fluid Dynamic (CFD).

2.2. Designing a Prototype Receiver Tube

After developing the prototype receiver tube model using AutoCAD software, the design process was carried out with careful consideration of material selection. The materials chosen for constructing the receiver tube include a 52 mm diameter iron pipe as the main body, a ½ inch brass double nipple for connection, a ½ inch steel single nipple, and an 85 mm long iron pipe segment. These materials were selected to ensure structural strength, durability, and compatibility with the air conditioning system during operation.

2.3. Preparation of Tools and Materials for the Experiment

The testing procedure was conducted using several key instruments to ensure accurate evaluation of the air conditioning system performance. A 1/2 PK split air conditioner was used as the primary test unit, while an 85 mm receiver tube served as the main modification component. Temperature measurements were carried out using an infrared thermometer, and the electrical current of the compressor was monitored using a clamp ammeter. Refrigerant pressures on both the high and low sides were measured using a pressure gauge, while a gauge manifold was utilized to regulate and control refrigerant flow within the system. Prior to testing, a vacuum pump was employed to remove air and non-condensable gases from the system until sub-atmospheric pressure was achieved. After refrigerant charging, a leak detector was used to ensure that the system was free from any leakage, thereby maintaining the reliability and safety of the experimental process.

2.4. Receiver Tube Testing

The test carried out was to measure temperature, current, voltage and electrical energy consumption to obtain work performance, electricity consumption and refrigerant consumption in AC Split 1/2 pk. The testing procedure consists of the preparation step and the test/data collection step. The preparatory steps include assembling/setting up the test installation, vacuum, refrigerant filling and leak test. The test/data collection step is carried out after the system has been operating for about 30 minutes (until the system works normally/steadily). Data collection is carried out by installing a receiver tube with a length of 85 mm then data measurement of pressure and temperature in/out of refrigerant for each component of the compressor, condenser, and evaporator system. All measurements are taken at the same time. All data is recorded on a table-shaped data sheet. Data collection was carried out 3 (three) experiments with time intervals of 15 minutes, 30 minutes, 45 minutes, and 60 minutes for one receiver tube test.

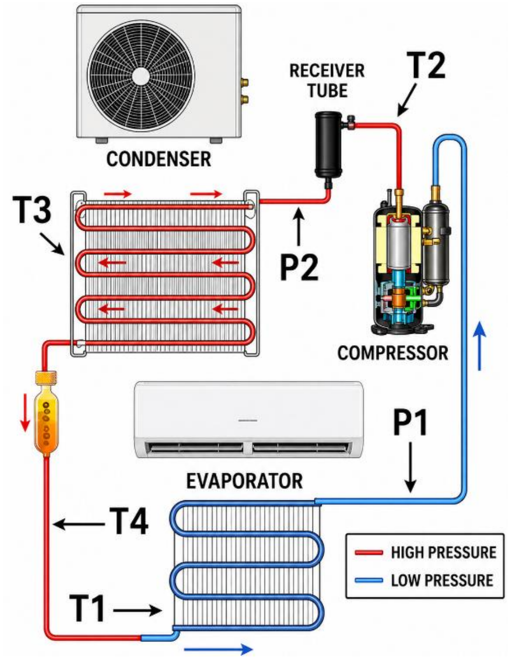

Figure 2. Test Points

Samples taken from the test results:

- T1: Temperature out evaporator.
- T2: Temperature out compressor.
- T3: Temperature out condenser.
- Q4: Temperature after expansion.
- P1: Tekanan Low Pressure.
- P2: Tekanan High Pressure.
- A: Measurement of Electrical current.
- V: Electrical voltage measurement.

2.5. Test Data

The test data obtained is data on the measurement of pressure and temperature in/out of refrigerant for each component of the compressor, condenser, and evaporator system as well as current, voltage and electrical energy consumption data to obtain work performance on AC Split 1/2 pk. Then an average calculation of all data recorded on a sheet in the form of a table is carried out. The data from the average results of these 3 experiments was used for comparative analysis of COP and the power efficiency and electricity cost used.

2.6. Analysis and discussion

After obtaining the data results from the standard test, it can be continued by analyzing the necessary data such as COP and 1/2 PK split AC operating costs. After being tested using a 1/2 PK split AC, the next step from the data produced from the test with the addition of a Receiver Tube variation of 85 mm length was analyzed and discussed about the variation. At this stage, the assessment and analysis of the results of the cooling test is conducted. From the data obtained from the results of the research, the researcher conducted a data analysis.

2.6.1 COP Comparison Analysis

Comparison of the *Coefficient of Performance* of refrigeration machines tested with various receiver tubes for 60 minutes starting from 15 minutes was calculated. After the data is calculated, the average COP is calculated in each test, and the results obtained are made a table to compare the best COP. In addition to making a table, graphs are also drawn to make it easier to show a more detailed comparison of COPs.

2.6.2 Comparative Analysis of Electricity Consumption

This data comparison begins by calculating the working power of the AC (Air Conditioner) system from the results of A (ampere) and V (voltage) obtained from each average recording time of 15 minutes to 60 minutes in order to get more detailed results from each temperature drop in the 1/2 pk AC system that uses a receiver tube. The economic efficiency value of the air conditioner starts with calculating the operating costs. The calculation of operational costs can be found by looking for power from the compressor multiplied by the length of the air conditioning system that operates until the profit of the AC can be obtained from the comparison of the 85 mm receiver tube. To make it easier to compare with AC installed with a Receiver Tube, a need calculation was made for 1 month using the standard electricity cost on land or using calculations per KWH of PLN.

3. RESULTS AND DISCUSSION

3.1. Initial AC Data (Air Conditioner)

The initial data on the specification of the AC (Air Conditioner) to be used used uses a variety of receiver tubes, namely 85 mm to get the results of COP (Coefficient of Performance) and economical electrical power consumption as follows:

- Model : AU-A5UCY
- Tegangan : 220 – 240 V
- Outdoor weight (condenser) : 20.5 Kg
- Berat indoor (evaporator) : 7.5 kg
- Cooling capacity : 1/2 HP
- Maker country : China

Figure 3. AC SHARP 1/2 HP

3.2. Comparative Ship Data Specifications

In the analysis of the efficiency of COP and cooling electric power, the ship used is a passenger ship with a capacity of 30 people produced by the PT. Blambangan Bahari Shipyard Banyuwangi. The ship's data is as follows:

Table 1. OIC 004 Banyuwangi Ship Data

Ship Data	
Loa	14,00 m
Lpp	11,47 m
Bmld	3,20 m
H	1,20 m
T	0,50 m
Engine	Outboard
Power	2 X 200 HP

Ship Data	
FOT	1000 Ltr
Crew	2 Person
Passenger	30 Person
Speed	20-25 Knot

3.3. Ship AC Specification Data

Ship's AC (Air Conditioner) specification data used for the receiver tube research comparator. The AC specification data is as follows:

- Model : FTP25AV14
- Tegangan : 220 – 240 V
- Outdoor weight (condenser) : 22 kg
- Indoor weight (evaporator) : 8.5 Kg
- Cooling capacity : 1 HP
- Maker country : Malaysia
- Sum : 2 Unit

3.4. Receiver Tube Pressure Simulation Results

In this explanation, the results are presented in the form of data from the simulation, namely the simulation of the refrigerator receiver tube flow pressure in the CFD simulation using Ansys Fluent 2022. The color scale in the image has a pressure range from 360,000 psi to 361,953 psi, with each color representing a specific value within that range:

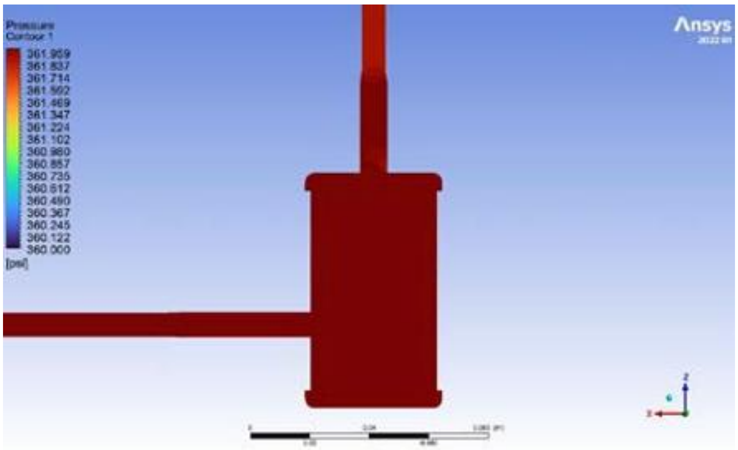

Figure 5. Pressure Simulation Receiver Tube Length Variation 85 mm

This color gradation provides a visual representation of the pressure distribution in the receiving tube based on simulations performed with ANSYS software. The pressure distribution in the tube is displayed in psi units.

3.5. Experimental Data of Standard 0.5 PK Split Air Conditioner

This section presents the experimental data obtained from the standard 0.5 PK split air conditioner system without the installation of a receiver tube. The purpose of this measurement was to establish the baseline performance of the air-conditioning system before modification. The experiment was conducted three times to improve data reliability, and the values presented in Table 2 represent the average results of the measurements. The measured parameters consisted of electrical variables, temperature points, and pressure points. Electrical current and voltage were recorded to determine the power consumption of the system, while temperatures T1, T2, T3, and T4 were used to evaluate thermal performance at different points of the refrigeration cycle. Pressure values P1, P2, and P3 were measured to observe the operating pressure condition of the system during testing.

Table 2. Average experimental data of standard 0.5 PK split air conditioner

Parameter	15 minutes	30 minutes	45 minutes	60 minutes
Current	1.3 A	1.3 A	1.3 A	1.3 A
Voltage	220 V	220 V	220 V	220 V
T1	19.1 °C	18.0 °C	17.5 °C	17.0 °C
T2	43.6 °C	47.0 °C	47.6 °C	49.9 °C
T3	32.2 °C	34.0 °C	34.5 °C	35.0 °C
T4	22.4 °C	22.3 °C	21.7 °C	21.1 °C
P1	180 psi	182 psi	185 psi	186 psi
P2	391 psi	450 psi	415 psi	416 psi
P3	391 psi	450 psi	415 psi	426 psi

Based on Table 2, the current voltage of the standard air conditioner remained constant during the 60-minute test period. The evaporator-side temperature decreased gradually from 19.1 °C at 15 minutes to 17.0 °C at 60 minutes, indicating that the cooling process continued throughout the test. Meanwhile, the discharge-side temperature increased with time, showing that heat rejection at the condenser side became more dominant as the system operated longer.

3.6. Experimental Data of 0.5 PK Split Air Conditioner with 85 mm Receiver Tube

This section presents the experimental data obtained after modifying the 0.5 PK split air conditioner by installing a receiver tube with a length of 85 mm. The purpose of this experiment was to evaluate the effect of receiver tube installation on the operating characteristics of the refrigeration system. Similar to the standard test, the experiment was repeated three times, and the average values are presented in Table 3. The receiver tube is expected to improve refrigerant flow stability and influence the pressure and temperature distribution in the system. Therefore, comparison between the standard system and the modified system is important to determine whether the receiver tube provides measurable improvement in energy performance.

Table 3. Average experimental data of 0.5 PK split air conditioner with 85 mm receiver tube

Parameter	15 minutes	30 minutes	45 minutes	60 minutes
Current	1.0 A	1.0 A	1.0 A	1.0 A
Voltage	224.3 V	224.3 V	224.3 V	224.3 V
T1	19.1 °C	18.6 °C	18.2 °C	17.2 °C
T2	48.8 °C	52.9 °C	54.5 °C	57.0 °C
T3	36.9 °C	38.5 °C	39.4 °C	40.6 °C
T4	21.0 °C	20.3 °C	19.6 °C	18.7 °C
P1	170.6 psi	174 psi	176 psi	180 psi
P2	348.3 psi	358.3 psi	361.6 psi	366.6 psi
P3	343.3 psi	353.3 psi	356.6 psi	361.6 psi

Table 3 shows that the installation of the 85 mm receiver tube reduced the operating current compared with the standard system. The current decreased from 1.3 A in the standard system to approximately 1.0 A in the modified system. This indicates that the receiver tube modification may reduce the electrical load of the compressor. In addition, the pressure values P1, P2, and P3 were generally lower than those of the standard system, suggesting that the receiver tube influenced the refrigerant circulation and system pressure balance.

3.7. Coefficient of Performance Calculation

This section explains the calculation method used to determine the coefficient of performance, or COP, of the air-conditioning system. COP is an important indicator used to evaluate the efficiency of a refrigeration system. A higher COP indicates that the system produces a larger cooling effect for the same amount of energy input. The COP was calculated based on the relationship between cooling capacity and compressor power. The analysis used temperature, pressure, current, voltage, and refrigerant enthalpy values obtained from the experimental data.

3.7.1. Thermodynamic Properties of the Standard 0.5 PK Split Air Conditioner

For the standard 0.5 PK split air conditioner at 15 minutes of operation, the measured and calculated parameters were as Table 4

Table 4. Calculated parameters

Parameter	Value
T1	19.1 °C
T2	43.6 °C
T3	32.2 °C
T4	22.4 °C
P1	180 psi / 12.4 bar
P2	391 psi / 26.9 bar
P3	391 psi / 26.9 bar
P4	180 psi / 12.4 bar
H1	522 kJ/kg
H2	532 kJ/kg
H3	250 kJ/kg
H4	250 kJ/kg

The enthalpy values were used to determine compressor work and cooling capacity. In this calculation, H1 represents the enthalpy at the compressor inlet, H2 represents the enthalpy at the compressor outlet, while H3 and H4 represent the enthalpy values after condensation and expansion, respectively.

3.7.2. Compressor Work and Power Input

Compressor work is calculated based on the change in refrigerant enthalpy between the compressor outlet and inlet. The specific compressor work is expressed as:

$$W_c = H_2 - H_1$$
$$W_c = 532 - 522$$
$$W_c = 10 \text{ kJ/kg}$$

This result indicates that the compressor adds 10 kJ of energy for every kilogram of refrigerant passing through the compressor. The electrical power input to the compressor is calculated using the following equation:

$$P = I \times V$$
$$P = 1.3 \times 220$$
$$P = 286 \text{ W}$$
$$P = 0.286 \text{ kJ/s}$$

The refrigerant mass flow rate can then be estimated from the relationship between power input and compressor work:

$$\dot{m} = \frac{P}{H_2 - H_1}$$
$$\dot{m} = \frac{0.286}{10}$$
$$\dot{m} = 0.0286 \text{ kg/s}$$

This mass flow rate was then used to calculate the cooling capacity of the system.

3.7.3. Cooling Capacity

Cooling capacity is the amount of heat absorbed by the evaporator. It is calculated based on the mass flow rate of the refrigerant and the enthalpy difference between the evaporator outlet and inlet.

$$Q_{in} = \dot{m}(H_1 - H_4)$$
$$Q_{in} = 0.0286(522 - 250)$$
$$Q_{in} = 0.0286 \times 272$$

$$Q_{in} = 7.779 \text{ kW}$$

The result shows that the standard 0.5 PK split air conditioner produced a cooling capacity of 7.779 kW at 15 minutes of operation based on the calculated refrigerant mass flow rate and enthalpy difference.

3.7.4. Coefficient of Performance

The coefficient of performance is calculated by dividing the cooling capacity by the compressor power input.

$$COP = \frac{Q_{in}}{P}$$
$$COP = \frac{7779}{286}$$
$$COP = 27.1$$

The COP value of 27.1 indicates the ratio between cooling output and electrical input at 15 minutes of operation. A higher COP means that the system can produce a greater cooling effect with lower energy input. However, the COP value should be interpreted carefully because it depends on the accuracy of the enthalpy estimation and mass flow rate calculation.

3.7.5. COP Result of Standard 0.5 PK Split Air Conditioner

Table 5 shows that the standard air conditioner reached its highest COP at 30 minutes of operation, with a value of 69.5.

Table 5. COP values of standard 0.5 PK split air conditioner

Time	COP	Temperature
15 minutes	27.1	19.1 °C
30 minutes	69.5	18.0 °C
45 minutes	53.3	17.5 °C
60 minutes	66.7	17.0 °C
Total COP	216.6	-
Average COP	54.15	-

After that, the COP decreased at 45 minutes but increased again at 60 minutes. The temperature continued to decrease throughout the test, from 19.1 °C to 17.0 °C, indicating that the system maintained its cooling performance during operation.

3.7.6. COP Result of 0.5 PK Split Air Conditioner with 85 mm Receiver Tube

Table 6 shows that the receiver tube with a length of 85 mm produced the highest COP at 30 minutes of operation, with a value of 47.3. However, the COP decreased significantly at 45 minutes and slightly increased again at 60 minutes.

Table 6. COP values of 0.5 PK split air conditioner with 85 mm receiver tube

Time	COP	Temperature
15 minutes	27.1	19.1 °C
30 minutes	47.3	18.6 °C
45 minutes	22.2	18.2 °C
60 minutes	26.7	17.2 °C
Total COP	123.3	-
Average COP	30.8	-

Although the average COP of the receiver tube system was lower than that of the standard system, the modified system showed lower electrical current and lower operating pressure. Therefore, the receiver tube modification should not only be evaluated based on COP but also based on power consumption and operating cost.

3.8. Operating Cost Analysis of 0.5 PK Split Air Conditioner

This section evaluates the operating cost of the standard air conditioner and the modified air conditioner with an 85 mm receiver tube. The purpose of this analysis is to determine whether the receiver tube modification provides an economic benefit in terms of electrical energy consumption. The operating cost was calculated based on electrical power, daily operating time, monthly operating duration, and electricity tariff. In this study, the air conditioner was assumed to operate 24 hours per day and 30 days per month. The electricity tariff used was Rp 1,444.70/kWh.

3.8.1. Operating Cost of Standard 0.5 PK Split Air Conditioner

For the standard 0.5 PK split air conditioner, the electrical current was 1.3 A and the voltage was 220 V. The electrical power consumption was calculated as follows:

$$P = I \times V$$
$$P = 1.3 \times 220$$
$$P = 286 \text{ W}$$

The daily electrical energy consumption was calculated using:

$$kWh = \frac{P \times t}{1000}$$
$$kWh = \frac{286 \times 24}{1000}$$
$$kWh = 6.864 \text{ kWh/day}$$

The daily electricity cost was:

$$Cost/day = 6.864 \times 1{,}444.70$$
$$Cost/day = Rp\ 9{,}916$$

The monthly electricity cost was:

$$Cost/month = 9{,}916 \times 30$$
$$Cost/month = Rp\ 297{,}480$$

Thus, the operating cost of the standard 0.5 PK split air conditioner was Rp 297,480 per month.

3.8.2. Operating Cost of 0.5 PK Split Air Conditioner with 85 mm Receiver Tube

For the modified air conditioner with an 85 mm receiver tube, the electrical current used in the cost analysis was 1.1 A and the voltage was 220 V. The electrical power consumption was calculated as follows:

$$P = I \times V$$
$$P = 1.1 \times 220$$
$$P = 242 \text{ W}$$

The daily electrical energy consumption was:

$$kWh = \frac{242 \times 24}{1000}$$
$$kWh = 5.808 \text{ kWh/day}$$

The daily electricity cost was:

$$Cost/day = 5.808 \times 1{,}444.70$$
$$Cost/day = Rp\ 8{,}390$$

The monthly electricity cost was:

$$Cost/month = 8{,}390 \times 30$$
$$Cost/month = Rp\ 251{,}700$$

Thus, the operating cost of the air conditioner with an 85 mm receiver tube was Rp 251,700 per month.

Table 7. Comparison of electrical power and operating cost

Variation	Power	Monthly operating cost
Standard 0.5 PK split AC	286 W	Rp 297,480
85 mm receiver tube	242 W	Rp 251,700

Table 7 shows that the installation of the 85 mm receiver tube reduced the electrical power from 286 W to 242 W. This reduction also decreased the monthly operating cost from Rp 297,480 to Rp 251,700. Therefore, the receiver tube modification provided an economic benefit by reducing electricity consumption.

3.9. Comparison of Air-Conditioning Operating Cost on the OKI 004 Banyuwangi Ship

This section extends the operating cost analysis to the air-conditioning system used on the OKI 004 Banyuwangi ship. The purpose of this comparison is to evaluate the potential economic benefit of applying the receiver tube modification to marine air-conditioning systems. The passenger compartment of the OKI 004 ship requires 2 PK of cooling capacity. In the existing condition, this requirement is fulfilled by using two units of 1 PK air conditioners. The operating cost was calculated using the same electricity tariff approach to allow comparison between the standard system and the receiver tube-based system.

3.9.1. Operating Cost of Existing 2 PK Air-Conditioning System on the OKI 004 Ship

The electrical current of one 1 PK air-conditioning unit was 3.4 A, with a voltage of 220 V. The power consumption of one unit was calculated as follows:

$$P = I \times V$$
$$P = 3.4 \times 220$$
$$P = 748 \text{ W}$$

The daily energy consumption of one unit was:

$$kWh = \frac{748 \times 24}{1000}$$
$$kWh = 17.952 \text{ kWh/day}$$

The daily operating cost of one unit was:

$$Cost/day = 17.952 \times 1{,}444.70$$
$$Cost/day = Rp\ 25{,}935$$

The monthly operating cost of one unit was:

$$Cost/month = 25{,}935 \times 30$$
$$Cost/month = Rp\ 778{,}050$$

Since the OKI 004 ship uses two units of 1 PK air conditioners, the total monthly operating cost was:

$$Total\ Cost = 778{,}050 \times 2$$
$$Total\ Cost = Rp\ 1{,}556{,}100$$

Thus, the monthly operating cost of the existing 2 PK air-conditioning system on the OKI 004 ship was Rp 1,556,100.

3.9.2. Estimated Operating Cost of Air-Conditioning System with Receiver Tube Modification

To estimate the potential operating cost of the receiver tube-based system, the power consumption of the 0.5 PK modified system was scaled to meet the 2 PK cooling requirement. The best receiver tube variation was the 85 mm receiver tube, with a power consumption of 242 W for 0.5 PK.

The equivalent power consumption for 1 PK was calculated as:

$$P_{1PK} = 242 \times 2$$
$$P_{1PK} = 484 \text{ W}$$

The daily energy consumption for one 1 PK equivalent unit was:

$$kWh = \frac{484 \times 24}{1000}$$
$$kWh = 11.616 \text{ kWh/day}$$

The daily operating cost was:

$$Cost/day = 11.616 \times 1{,}444.70$$
$$Cost/day = Rp\ 16{,}781$$

The monthly operating cost of one 1 PK equivalent unit was:

$$Cost/month = 16{,}781 \times 30$$
$$Cost/month = Rp\ 503{,}430$$

Since the OKI 004 ship requires two 1 PK equivalent units, the total monthly operating cost was:

$$Total\ Cost = 503{,}430 \times 2$$
$$Total\ Cost = Rp\ 1{,}006{,}860$$

The difference in monthly operating cost was:

$$Cost\ Saving = 1{,}556{,}100 - 1{,}006{,}860$$
$$Cost\ Saving = Rp\ 549{,}240$$

The result indicates that the application of the receiver tube modification has the potential to reduce monthly air-conditioning operating costs by Rp 549,240. This shows that the receiver tube can contribute to cost efficiency in marine cooling systems, particularly for passenger vessels that require continuous air-conditioning operation.

3.10. Discussion

The experimental results show that the installation of an 85 mm receiver tube affects both the technical and economic performance of the air-conditioning system. From the electrical perspective, the modified system required lower current than the standard system. This reduction in current resulted in lower power consumption and lower monthly operating costs.

Although the average COP of the standard system was higher than that of the 85 mm receiver tube variation, the modified system provided better performance in terms of electrical load reduction. This indicates that COP alone is not sufficient to evaluate the overall performance of the modified air-conditioning system. Power consumption, operating pressure, cooling temperature, and cost efficiency should also be considered.

The comparison with the OKI 004 Banyuwangi ship shows that the receiver tube modification may provide economic benefits when applied to marine air-conditioning systems. The estimated monthly cost saving of Rp 549,240 demonstrates that small mechanical modifications can contribute to operational efficiency, especially in systems that operate continuously.

Compared with previous studies that focused on overall HVAC system optimization, this study highlights the potential of a simple component-level modification. The receiver tube offers a low-cost technical approach that can improve energy efficiency and reduce operating costs in air-conditioning applications, including marine cooling systems.

4. CONCLUSION

This study successfully designed and tested an 85 mm receiver tube modification for a 0.5 PK split air-conditioning system. The experimental results show that the receiver tube reduced compressor power consumption from 286 W to 242 W, indicating a lower electrical load during operation. The modified system also achieved a COP value of 44.5 under the tested operating condition, demonstrating that the receiver tube can influence the thermal and energy performance of the air-conditioning system. From the economic perspective, the receiver tube modification reduced the monthly operating cost of the 0.5 PK split air conditioner from IDR 297,480 to IDR 251,700. When the result was scaled and compared with the air-conditioning system used on the OKI 004 Banyuwangi ship, the potential cost saving reached IDR 549,240 per month. These findings indicate that the application of an 85 mm receiver tube provides practical benefits in reducing electrical power consumption and operational costs. Therefore, the receiver tube can be considered a simple and low-cost modification to support energy efficiency in marine air-conditioning systems.

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