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Improving Coefficient Of Performance Using Heat Exchanger

Alsalhin G. Khalifa[1], Majdi A. Razig[1], Adam E. Mohammed[1*]
[1] Mechanical Engineering Department, College of Engineering Technologies – Al Qubbah, Libya

تحسين معامل الأداء باستخدام المبادل الحراري

الصالحين جمعة خليفة [1]، مجدي عبد المنعم جادالله[2], آدم الصادق محمد[3*]
[3,2,1] قسم الهندسة الميكانيكية، كلية التقنيات الهندسية، القبة، ليبيا

*Corresponding author: adal80@yahoo.com

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Abstract:
The system was charged with Freon gas (R-134a) and operated under two distinct conditions: first, with the integration of a heat exchanger, and second, without it. To ensure the retention of the refrigerant within the system, the valves were securely closed. This study elucidates the role of the heat exchanger in enhancing the performance of the compression refrigeration cycle. For the condition without the heat exchanger, the valves were closed following 30 minutes of operation with the heat exchanger to stabilize the system. Subsequently, the recorded data were mapped onto the pressure-enthalpy (p-h) chart to compute key performance metrics, including the cooling capacity, compressor energy input, and the coefficient of performance (COP). The analysis of COP values demonstrated a marked improvement in cycle efficiency when the heat exchanger was utilized, with superior performance metrics compared to the system operating without it.

Keywords: Heat Exchanger, Pression Refrigeration Cycle, COP.

الملخص
تم شحن النظام بغاز الفريون (R-134a) وتشغيله في حالتين متميزتين: الأولى باستخدام مبادل حراري، والثانية من دونه. ولضمان احتفاظ النظام بكمية الغاز، تم إغلاق الصمامات بإحكام. تسلط هذه الدراسة الضوء على دور المبادل الحراري في تحسين أداء دورة التبريد الانضغاطي. وفي الحالة التي تم فيها تشغيل النظام دون المبادل الحراري، أُغلقت الصمامات بعد 30 دقيقة من تشغيل المبادل الحراري لتحقيق استقرار النظام. بعد ذلك، تم استخدام البيانات المسجلة ورسمها على مخطط الضغط-الإنثالبية (p-h) لحساب المؤشرات الأساسية للأداء، بما في ذلك قدرة التبريد، ومدخلات طاقة الضاغط، ومعامل الأداء (COP). وقد أظهرت التحليلات المتعلقة بمعامل الأداء تحسنًا ملحوظًا في كفاءة الدورة عند استخدام المبادل الحراري، مع تحقيق قيم أداء أعلى مقارنة بالحالة التي لم يُستخدم فيها المبادل الحراري.

الكلمات المفتاحية: المبادل الحراري، دورة التبريد بالضغط، معامل الأداء.

Introduction
The coefficient of performance (COP) serves as a critical parameter for evaluating the efficiency of refrigeration and air conditioning systems. As global energy demand continues to rise, improving COP has become a key focus in the pursuit of energy-efficient and sustainable thermal systems. One of the

most effective strategies for enhancing COP is the incorporation of heat exchangers into system designs. Heat exchangers facilitate the transfer of thermal energy between media, optimizing thermal management and reducing energy wastage [1-5]. By redistributing heat from components where it is unnecessary to those where it can be effectively utilized, heat exchangers not only improve system performance but also contribute to significant energy savings.

Numerous studies underscore the role of heat exchangers in enhancing COP. For instance, research has demonstrated that integrating heat exchangers can achieve substantial improvements in cooling capacity and overall system efficiency. Under ideal operating conditions, increases in COP of up to 22.4% have been reported, highlighting the transformative potential of this approach [6-11]. Furthermore, experimental findings reveal that the strategic use of heat exchangers can reduce compressor workload, lower electricity consumption, and enhance subcooling degrees—each of which contributes to higher system efficiency.

Numerous studies have demonstrated that the performance metrics achieved with the incorporation of a heat exchanger exceed those obtained without one by approximately 10% [12-16]. Research further indicates the potential for significant energy savings, reduced compressor workload, and enhanced efficiency of water-cooling systems through the installation of a tube-in-tube heat exchanger positioned between the water suction line and the return line for discharged water [17-22]. Additionally, investigations exploring heat exchangers of varying lengths have shown that longer heat exchangers yield higher degrees of subcooling. This increase in subcooling not only enhances cooling capacity but also reduces compressor inlet power and significantly improves the coefficient of performance (COP) of air conditioning systems [23-26].

Main parts:

Compressor:

A compressor is a vital component in refrigeration and air conditioning systems, designed to increase the pressure of the refrigerant gas and facilitate its circulation through the system. By compressing the refrigerant, the compressor raises its temperature and pressure, allowing it to release heat in the condenser and absorb heat in the evaporator.

Figure (1): The Compressor.

Compressors play a critical role in the refrigeration cycle by ensuring the refrigerant moves efficiently, facilitating heat exchange, and maintaining the desired cooling or heating effect.

Condenser:

In the condenser, the refrigerant gas is cooled and condensed into a liquid by expelling the excess heat to the outside air.

Figure (2): The Condenser.

Capillary tube:

It is the most common or used and is considered one of the simplest devices used to regulate the supply of refrigerant liquid that enters the evaporator.

Figure (3): The Capillary tube.

Evaporators Air conditioning and refrigeration units

The evaporator is the part located on the low-pressure side of the refrigeration circuit through which unwanted heat passes, absorbing it and introducing it into the circuit .

Figure (4): The Evaporators.

Secondary parts:

- **Indicator bottle:**

It is installed in the liquid line to enable the supervisor of the operation of the refrigeration equipment to know the status and quantity of the refrigerant charge present inside the circuit.

- **Refrigeration circuit dryer:**

Dryers are used in the refrigeration circuit to lift water vapor or moisture from inside the circuit.

- **Measuring devices:**

One of the most important tools we use in refrigeration and air conditioning is the gauge, which is usually used to check the pressures of the refrigeration circuit and in the charging and discharging processes of the refrigeration circuits.

It is a high-pressure gauge, a low-pressure gauge (suction pressure).

- **Condenser fan:**

Helps the condenser to accelerate the heat dissipation and increase the condensation of the refrigerant.

Auxiliary parts that connect to the sealed compressor motor in the system.

- **Closed reciprocating compressor:**

It is used to protect the sealed compressor motor, which is a circuit breaker to protect against an abnormal rise in its temperature by means of special circuit breakers installed in the body of its outer casing, and it is also installed with what is called (relay), which is an automatic connection device to disconnect the motor rectification coils after it reaches its normal rotation speed, and the relay used in the system works under the influence of current.

- **Capacitor:**

The capacitor is used as a capacitor in the circuits of sealed compressor motors that operate with a single-phase variable current to create an electrical angle in the motor coils to produce the necessary rectification torque, as well as to create another phase with a current that works to increase the torque.

Work steps:

- A 1m long and 50cm wide iron table was prepared.
- The main parts of the system were fixed on the base.
- Different lengths were chosen as well as different elbows and connections
- We welded the discharge line pipe with a diameter of 1/4 and made a connection with a nut, and a three-way connection was connected and a ((valve)) was installed to measure the discharge line pressure before entering the condenser
- We welded a connection with a 1/4 diameter pipe inside the condenser.

Heat exchanger in the cycle:

- It is a tube 23cm long and 5/16 in diameter, and it was perforated equally at both ends, and another tube with a diameter of 1/2 was inserted into it, and a capillary tube was wrapped around it to facilitate the heat transfer process (heat exchange).

Figure (5): The Heat exchanger.

- A statement bottle was installed with a (1/2) diameter tube inside the heat exchanger, and this tube inside the heat exchanger was wrapped with a capillary tube to facilitate the heat exchange process or (heat transfer.(
- We connected the tube inside the heat exchanger with a diameter of (5/8) and connected it to the filter, and a capillary tube (expansion tool) was wrapped on the filter and connected to its outlet to a (1/4) diameter tube inside the evaporator, and a three-way connection and a ((valve)) were installed to measure the exit pressure from the heat exchanger, meaning the exit pressure from the expansion tool (capillary tube.(
- A (1/4) diameter tube was welded from the evaporator outlet and connected to a (5/16) diameter tube, and a three-way connection and a ((valve)) were installed to measure the exit pressure from the evaporator, and this tube returns and is connected to the heat exchanger, knowing that we connected a tube of the same diameter next to it in the heat exchanger and connected it to the suction line.
- Two manual valves of the dual type (inlet + outlet) were installed. The first valve was installed in the suction line (heat exchanger inlet), and the second valve was installed at the heat exchanger outlet (i.e., compressor inlet). Its purpose is to control the operation and use of the system:

1. With heat exchanger.
2. Without heat exchanger.

The incorporation of valves within the system enables precise testing and evaluation without any loss of gas. These valves serve to isolate specific sections of the system, thereby preserving the integrity of the charge and ensuring accurate assessments of system performance.

Measurements:

Upon finalizing the assembly of the cooling system integrated with the heat exchanger, as illustrated in Figure 6.

Figure (6): Compression refrigeration cycle readings using heat exchanger.

The system was charged with Freon gas (134a) and operated. After half an hour, the following data was taken:

Table 1: The readings using the heat exchanger.

Element	Readings
Condenser pressure	0.4MPa
Evaporator pressure	0.18MPa
Capillary tube inlet temperature	25.3c°
Compressor outlet temperature	44.3c°
Compressor inlet temperature	7.5c°
Condenser temperature	43.7c°
Evaporator temperature	8c°

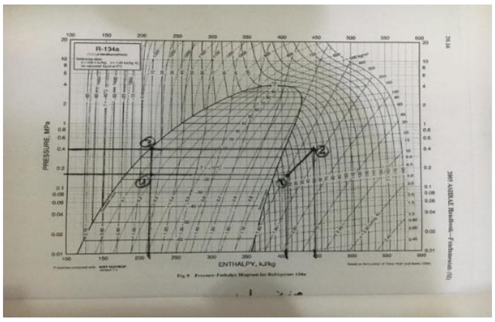

Figure (7): The readings were applied to the (p.h) chart.

Figure (8): The readings without using the heat exchanger (after closing the valves**).**

After taking the readings, they were applied to the (p.h) chart to find the cooling effect, compression energy and cycle performance coefficient, as shows in Figure 7. The valves were closed to operate the system without the heat exchanger as shows in figure 8, and readings were taken as shows in table 2.

Table 2: the readings without using the heat exchanger:

Element	Readings
Condenser pressure	0.12MPa
Evaporator pressure	0.8MPa
Capillary tube inlet temperature	31c°
Compressor outlet temperature	50c°
Compressor inlet temperature	4.5c°
Condenser temperature	36c°
Evaporator temperature	4c°

After taking the readings, they were applied to the (p.h) chart to find the cooling effect, compression energy and cycle performance coefficient, as shows in Figure 9.

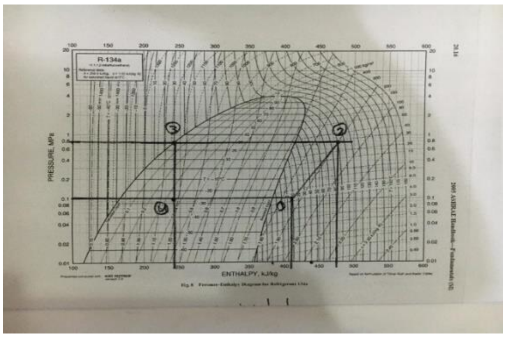

Figure (9): The readings were applied to the (p.h) chart.

Firstly: The readings were taken from the schematic of the cooling system with the heat exchanger. Table 3 shows the readings from the (p.h) chart no (1), to find the cooling effect, compression energy and cycle performance coefficient.

Table 3: The readings from the (p.h) chart no (1), to find the cooling effect, compression energy and cycle performance coefficient.

Element	Readings	symbol
Enthalpy energy at compressor inlet	400 KJ, Kg	Hci
Enthalpy energy at compressor outlet	450 KJ, Kg	Hco
Enthalpy energy at evaporator inlet	212 KJ, Kg	Hei
Enthalpy energy at evaporator outlet	400 KJ, Kg	Heo

After taking the readings, calculations were made to find the cooling effect, compression energy and cycle performance coefficient. The mass flow rate of the refrigerant was disregarded in the computations since the flow rate of the refrigerant in the compressor and the evaporator is equal.

$$RE = m^{\cdot} (h_1 – h_4)$$

$$WC = m^{\cdot} (h_2 – h_1)$$

$$C.O.P = \frac{RE}{WC}$$

$$C.O.P = \frac{h_1 - h_4}{h_2 - h_1}$$

cooling effect RE = Heo - Hei

RE = 400 - 212 = 188 kj /kg

Compression energy Wc = Hco - Hci

Wc = 450 – 400 = 50 kj /kg

coefficient of performance $\mathrm{c.o.p} = \frac{RE}{WC}$

$$c.o.p = \frac{188}{50} = 3.8$$

Table 4. The calculations of the cooling effect, compression energy and cycle performance coefficient.

Element	symbol	Result
Cooling effect	RE	188 kj /kg
Compression energy	WC	50 kj /kg
Coefficient of performance	c.o.p	3.8

Secondly: The readings were taken from the schematic of the cooling system without a heat exchanger.

Table 5: The readings from the (p.h) chart (2), to find the cooling effect, compression energy and cycle performance coefficient.

Element	Readings	symbol
Enthalpy energy at compressor inlet	405 kj /kg	Hci
Enthalpy energy at compressor outlet	475 kj /kg	Hco
Enthalpy energy at evaporator inlet	240 kj /kg	Hei
Enthalpy energy at evaporator outlet	405 kj /kg	Heo

After taking the readings, calculations were made to find the cooling effect, compression energy and cycle performance coefficient.

cooling effect RE = Heo - Hei

RE = 405 – 240 = 165 kj /kg

Compression energy Wc = Hco - Hci

Wc = 475 – 405 = 70 kj /kg

coefficient of performance $\mathrm{c.o.p} = \frac{RE}{WC}$

$$c.o.p = \frac{165}{70} = 2.4$$

Table 6: The calculations of the cooling effect, compression energy and cycle performance coefficient.

Element	symbol	Result
Cooling effect	RE	165 kj
Compression energy	WC	70 kj /kg
Coefficient of performance	C.O.P	2.4

Conclusion:

The findings from the research, practical implementation, and system operation with the inclusion of a heat exchanger, supported by the quantitative data derived from calculations, clearly demonstrate that the system achieves a significantly higher performance factor compared to its operation without a heat exchanger. It can be concluded that integrating a heat exchanger is a highly advantageous and economically viable approach. Furthermore, designing an optimized system that incorporates a heat exchanger not only enhances overall system performance but also significantly improves energy efficiency, contributing to more sustainable and cost-effective thermal management solutions.

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