Design for Improvement of COP from Waste Heat Utilization Through Air Conditioning System

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Abstract

Energy is in higher demand than ever before since there are an increasing number of applications for it; nevertheless, the existing sources are unable to supply it in sufficient quantities. Alternate energy sources should be utilized, and as a consequence, energy conservation should be achieved through the utilization of waste heat from air conditioning systems. The major objective of this piece is to make use of waste heat generated by residential air conditioning systems while simultaneously increasing the coefficient of performance (COP). In order to achieve this goal, an experimental setup is utilized. In this configuration, an indirect kind of heat recovery equipment is used, and a heat exchanger that converts heat from a refrigerant to water is positioned between the compressor and the condenser of the host refrigeration system. The hot refrigerant gas generated by the compressor is sent

via one side of the heat exchanger, while water is forced through the other side. The temperature of the water is raised as a result of the heated refrigerant gas. Because of this, the system's COP might potentially increase by up to 16%.

Keywords: Waste heat recovery, COP, heat exchanger, cooling effect, de-superheat, air-conditioning system.

1 Introduction

Energy is one of the most essential requirements for the expansion of human existence. The primary sources of energy used in commercial enterprises are hydroelectric power plants, nuclear power plants, and fossil fuels (including oil, coal, and natural gas). Due to atmospherically more destructive discharges of radiation in the form of nuclear waste, these kinds of energy are created based on the requirements of the nation. The focus shifts from alternative energy sources to more conventional ones, with an increased emphasis on energy conservation and responsible use.

At this point in time, the most important things to focus on are energy efficiency and conservation. The quantity of electricity that is used annually is steadily becoming higher as a direct result of the expanding market for window air conditioners. As a direct consequence of this, a brand-new standard for the energy efficiency of window air conditioners will be implemented in the not-too-distant future. To satisfy this criterion, it is necessary, as a result, to develop systems that are efficient in their use of energy. Therefore, the primary focus for developing energy-efficient systems need to be on enhancing the performance of the systems in question. This experimental device's goal is to create an air conditioner with several uses system that can simultaneously provide hot water (by reusing the heat that is recovered from the region that is being cooled) and an air conditioning effect (cooling the space). This project presents an experimental setup that warms water for household and business use utilizing the excess heat produced by window air conditioners. The water may be used for both domestic and professional purposes. According to the findings of study, for every degree Celsius that the condenser's temperature rises, an air conditioner's coefficient of performance (C.O.P.) decreases by 2 to 4%. As a result, an air conditioner's coefficient of performance (C.O.P.) might decrease by as much as forty percent when

the temperature is high. As a result, the coefficient of performance of the air conditioner will directly correlate to the quantity of power that will be consumed.

1.1 What is Waste Heat?

Even if heat is "exhausted" into the environment as the result of the combustion of fuel, a chemical reaction, or the operation of any other type of mechanical system, it is possible that it might still be used for another purpose that is both useful and efficient. It is more important to consider the quality of the waste heat than its amount. The amount of heat that can be recovered is determined both by the quality of the waste heat gases (temperature) and the economics that are linked with them. The production of considerable quantities of hot flue gases is accomplished by furnaces, mechanical systems, and boilers. Because of this re-covery, we will be able to conserve a significant quantity of fundamental fuels. Using waste heat recovery technologies, it is possible for us to reclaim part of the lost energy.

1.2 Waste Heat Recovery System

Recovery of the superheated heat requires window air conditioning systems make use of a desuperheater, which is a sort of heat recovery technology (also known as waste heat). In its most basic form, a desuperheater is a waste heat recovery system that also includes a condenser. Although desuperheaters can be utilized either directly or indirectly, the indirect method is the one that has been chosen to be used in the heat recovery system for this project.

1.3 Heat Exchangers

Heat exchangers are widely used in large-scale industrial activities that need for either heating or cooling the surrounding environment. The heat that is lost or squandered throughout the course of a number of different industrial processes may be recovered via the utilization of heat exchangers and then put to use in the process of heating up another stream. It is possible for businesses to save a large amount of money by making use of heat exchangers to feed heat to other streams rather than turning to an external source of heat that is both costly and harmful to the environment.

Figure 1   Heat exchanger coil.

Heat exchangers are used in many industries, including:

- Waste water treatment
- Refrigeration
- Wine and beer making
- Petroleum refining
- Nuclear power

2 Design of Heat Recovery System

Making a system for recovering waste heat through utilizing the window air conditioner's capacity for desuperheating the air. The rated condition of the window air conditioner is used to calculate the available waste heat, and the design of the heat exchanger is used to determine how much heat can be recovered from it.
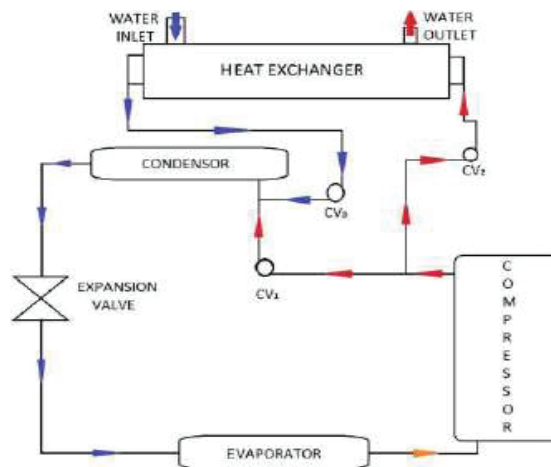
2.1 Design of Heat Exchanger Unit

Figure 2   Schematic diagram of waste heat recovery form air conditioner.

2.2 Technical Specification

Air conditioner

Model number:	AH5522E
Equipment rating:	Single phase, 220V, 50Hz, 8.5A
Power rating:	1.870kW
Refrigerant:	R-22 (CHClF2)
Normal capacity:	1.5 TR
Compressor:	Hermitically Shield Displacement Type
Condenser:	Force convection air cooled
Evaporator:	Force convection air cooled
Pressure gauge:	One for suction pressure & one for discharge pressure
Temperature Indicator:	Digital Thermometer

Controlvalve:

1. In between compressor dischargesand condenser (CV1).
2. In between heat exchanger suction and compressor (CV2).
3. In between heat exchanger outlet and condenser inlet (CV3).

2.3 Methodology

1. Calculation of energy supplied for refrigeration effect
2. Design of heat exchanger unit
3. Measurement of heat collected in heat exchanger unit.
4. Calculation of COP for normal air conditioning system
5. Calculation of COP for air conditioning system with exhaust heat collection using heat exchanger.
6. Comparison of COP in both above cases.
7. Conclusion

3 Design Process

3.1 Calculation of Energy Supplied for Refrigeration Effect

Input power of Air conditioner unit = 1.870 kW == 1870 W = 1870 J/sec.

3.2 Design of Heat Exchanger Unit

When the refrigerant is desuperheated, how much heat is removed?

At 35°C Ambient Temperature

Compressor inlet/suction pressure;
Pi = 60 psi
Pi = 60 × 6895 {1 psi = 6895 Pa}
Pi = 4.137 bar
Discharge pressure;
Po = 250 psi
Po = 250 × 6895
Po = 17.2375 bar
Condenser Temperature = 45°C = 318 K
Condenser pressure = 17.2375 bar
Compressor inlet = 4.137 bar
Compressor Outlet = 17.2375 bar
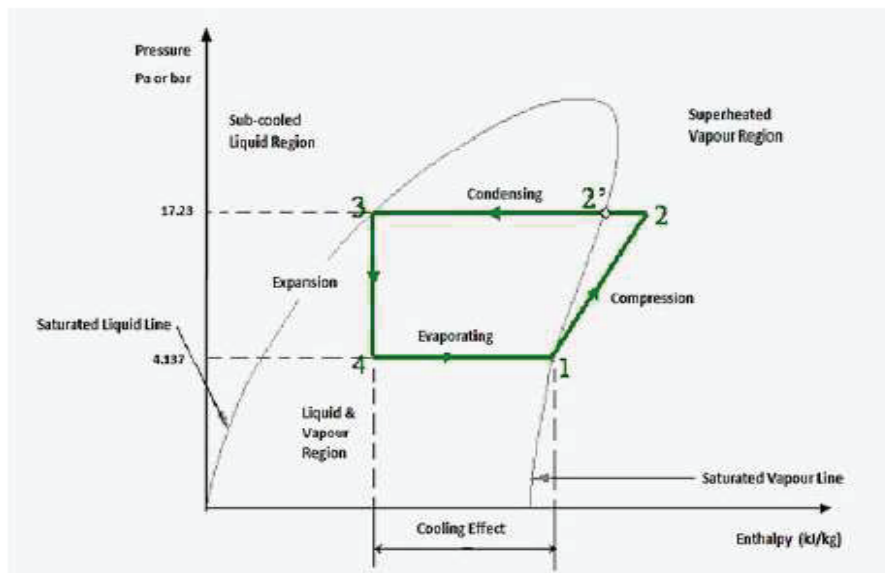Cooling capacity = 1.5 TR = 1.5 × 3.5 = 5.250 kW

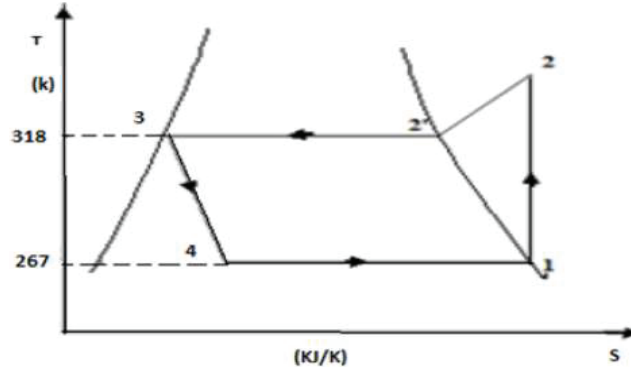**Figure 3**   Pressure enthalpy plot.

Figure 4 T-S diagram for refrigeration cycle.

By Interpolation

T1 = −6 + (4.13 − 4.09172)/(4.3797 − 4.09172) × 2 + 273
T1 = 267.266 K
T3 = T2′ = 45°C = 318 K
From R-22 Table: h 3 = hf3 = 105.58 kJ/kg. = h2
h 1 = hg1 = (250.30 + 249.46)/2 = 249.88 kJ/kg

Refrigerating Effect = h1 − h3

= (249.88 − 105.58) kJ/kg
R.E. = 144.3 kJ/kg

Mass Flow Rate of Refrigerant

mr˙ = (5.25 kJ/sec)/(144.3 kJ/kg)
mr˙ = 0.0364 kg/sec

For Superheated temperature (T2)

i.e S1 = S2
At P = 4.13 bar; S1 = Sg1 = 0.94105 kJ/kg
At P = 17.34 bar; S2 = 0.8755 kJ/kg
S2 = S2′ + Cp ln (T2/T2′)
S2 = 0.94105 = 0.8755 + 1.0256 ln (T2′/318)
T2 = 338.9882 K {(Cp) R-22 = 1.0256 KJ/Kg}
T2′ = 65.988°C ≈660C

Enthalpy of Superheated Refrigerant

h 2 = h2$'$ + Cp (T2 − T2$'$)

h 2 = 263.67 kJ/kg at P2 = 17.34 bar

h 2 = 263.67 + 1.0256 (338.9882 − 3.18)

h 2 = 285.2076 kJ/kg

Heat Available for Desuperheater (Qsup.)

Qsup. = mr$^.$ (h2 – h2$'$) = 0.0364 (285.2076 − 263.67)

Qsup. = 0.78397 kW = 783.9686 W

Heat Exchanger Unit

Given Data:

Material selected = copper

Thermal conductivity (k) = 380 W/mk

Inner diameter of tube (Di) = 6.4 mm

Outer diameter of tube (Do) = 8.0 mm

Fouling factor for refrigerant (Fr) = 0.000095

Fouling factor for water (Fw) = 0.000095

Thickness of tube (t) = 1.6/2 = 0.8 mm

Heat transfer co-efficient for refrigerant side; hi = 898 W/m^{2}K

Heat transfer co-efficient for water side; hw = 151.85 W/m^{2}K

Overall heat transfer co-efficient

1/U = 1/hi + 1/ hw + dx/Kcu + Fr + Fw

   = 1/898 + 1/151.58 + 0.8/380 + 0.000095 + 0.000095

U = 99.94 W/m^{2}K

To Find Out Area of Heat Exchanger

Find the water's outflow temperature now.

Initial temperature; Tw1 = 25°C

Qsup. = mw$^.$ *Cpw *ΔT

783.9686 = (0.5/60) × 4.2 × 103 (Tw2 − 25)

Tw2 = 47.3991°C ≈47°C

By Using Log Mean Temperature Difference (LMTD) method (△Tm)

$\Delta T1 = (66 - 47) \, °C = 19°C$
$\Delta T2 = (45 - 25) \, °C = 20°C$
$LMTD = (\Delta T1 - \Delta T2)/\ln(\Delta T1/\Delta T2) = (19 - 20)/\ln(19/20)$
$LMTD = 19.496°C$

Now, Area of Heat Exchanger

$Qsup. = U* A*LMTD(\Delta Tm)$
$783.9686 = 99.94*A*19.496$
$A = 0.4024 \, m^2$

To Find Length of Pipe

$A = \pi*Do *L$
$0.4024 = \pi * 8* L * 10^{-3}$
$L = 16.0095 \, m$ (i.e Figure 1)

Heat Absorbed by Water in Heat Exchanger

Table 1   Temperature of water

Flow Rate of Water LPM	Inlet Temp. of Water OC	Outlet Temp. of Water OC
0.5	25.3	52

Heat absorbs by water in heat exchanger

$Qw = mw^{\cdot} * cpw*\Delta T$
$= 0.5*4.2*10^3*(52 - 28.2)/60$
$Qw = 829.5 \, W$

4 Calculation of COP for Normal Air Conditioning System

(COP) th = Refrigeration Capacity/power input Cooling effect/power input = 5.25/1.870
(COP) th = 2.8075

Figure 5   Experimental set up.

5 Calculation of COP for Air Conditioning System with Exhaust Heat Collection Using Heat Exchanger

COP = (Refrigeration Capacity + heat absorb by water in heat exchanger)/input power to air conditioning unit = (5.25 × 103 W + 829.5 W)/ (1.870 × 103 W) (COP)th = 3.2511.

Percentage Increase in COP Theoretically

= (3.2511 − 2.8075) × 100/2.8075
= 15.7945% ≈16%

Validation and Discussion of Results

Within the scope of our investigation, we developed a heat exchanger that makes effective use of the waste heat produced by air conditioners (heating of water). The utilization of a desuperheater is an effective means by which temperature fluctuations brought on by superheating may be brought under control.

The air conditioner's COP (Coefficient of Performance) can be raised by using a heat exchanger. To do this, waste heat from the air conditioner is used to warm the water. We are able to increase the COP of AC by up to 16% thanks to the desuperheater.

Conclusions and Recommendations for Future Work

On the basis of the models and research on the waste heat recovery from air conditioners that were described in the chapters before this one, one may reach the following conclusions:

The addition of the heat exchanger and the air conditioner increases the system's C.O.P. (coefficient of performance) by 16%.

- There is less thermal pollution.
- Waste heat is put to use for something beneficial (heating of water).
- By controlling the rate at which water passes through the heat exchanger, it is possible to bring the temperature of the refrigerant down to the level that is needed.

Future Aspect of Our Project

- Given the limited availability of traditional energy sources, we have no choice but to make efficient use of the energy at our disposal. As a result, we will be able to make more productive use of the waste heat produced by this system, while simultaneously increasing the effectiveness of the air conditioner.
- It can be used in nursing homes, industrial settings, hotels, hotel mess areas, and other places that need hot water.
- The production of two hundred to five hundred watts of power through the use of a thermocouple that has been constructed appropriately and is built from a material that has a lower excitation temperature.

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Biography
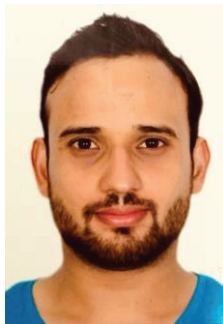
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