Journal of Applied Science and Advanced Technology
Journal Homepage : https://jurnal.umj.ac.id/index.php/JASAT

Design of Water Heating By Utilizing Waste Heat of Air Conditioner

Hasan Basri[1,*], Ery Diniardi[2], Anwar Ilmar Ramadhan[2]
[1]Department of Automotive and Heavy Equipment, Faculty of Engineering, Universitas Muhammadiyah Jakarta, Indonesia
[2]Department of Mechanical Engineering, Faculty of Engineering, Universitas Muhammadiyah Jakarta, Indonesia

ARTICLE INFO

JASAT use only:
Received date : 25 January 2021
Revised date : 20 February 2021
Accepted date : 26 March 2021

Keywords:
Freshener system
energy
condenser
air conditioning

ABSTRACT

This plan aims to minimize wasted energy in the air freshener system and utilize the wasted energy to heat water. Here using a split type air conditioner system which is commonly used. The author slightly modified the air conditioning system which previously used an air conditioning condenser, here the author added a condenser with a water cooler that functions as a condenser and at the same time as a water heater. The energy used to heat the water is obtained from the heat released by the refrigerant so as to minimize the energy wasted when only using an air conditioning condenser. But the air conditioning condenser is still used in this system, because when hot water is not needed, the water in the heater does not flow and of course cannot take heat from the refrigerant. In this condition the air conditioning condenser can work to help the process of releasing heat from the refrigerant. This tool can heat water up to 43°C with a flow rate of 1 liter per 9 seconds which can be used at home, SOHO, office for bathing, washing face, washing hands, etc.

INTRODUCTION

The development of human civilization is always followed by the increasing need for energy. At first humans used animal energy to help do their work. since around the 13th century began to find a new source of energy, namely coal, since then humans began to use it to fuel steam engines, trains and so on. Then came a newcomer, namely petroleum, and oil began to replace coal.But are only the energies mentioned above that can be used directly?, is this energy efficient?, and is this energy suitable for humans who have various activities and also various needs? [1-4].

Actually energy is wherever we are, such as solar heat, wind, water flow, etc., so it depends on human creativity that changes the form of energy into efficient and effective energy.So the author will study and plan a water heater for household needs by utilizing the heat output from the Air Conditioner (AC) condenser [5-6].

If we look at an air conditioning system that is widely used by the community today, it is not efficient because it still emits energy (heat) that is wasted in the condenser around 50-55°C. In this paper the author will plan a device that utilizes wasted energy (heat) in the AC condenser as a water heater for household needs. So it can reduce wasted energy [7-8].

Here the author slightly modified the Air Conditioner (AC) system. The heat flow that occurs in the AC condenser is as follows: from the freon to the inner wall of the condenser tube there is convection heat transfer, from the inner wall to the outer wall there is conduction heat transfer, from the outer wall to the outer air there is convection heat transfer. In this condition, the heat is wasted around 50-55°C which is quite high temperature, right?.Here the author adds a water cooling condenser which also functions as a water heater. Before going through the condenser, the refrigerant passes through the heater first, so that the heat contained in the refrigerant is absorbed by the water, so the water becomes hot which is planned to be up to 43°C. Thus the wasted heat in the AC condenser can be reduced because it is used to heat water [10-13].

* Corresponding author.
E-mail address: hasan.basri@umj.ac.id
DOI: https://dx.doi.org/10.24853/JASAT.3.3.89-96

EXPERIMENTAL METHOD

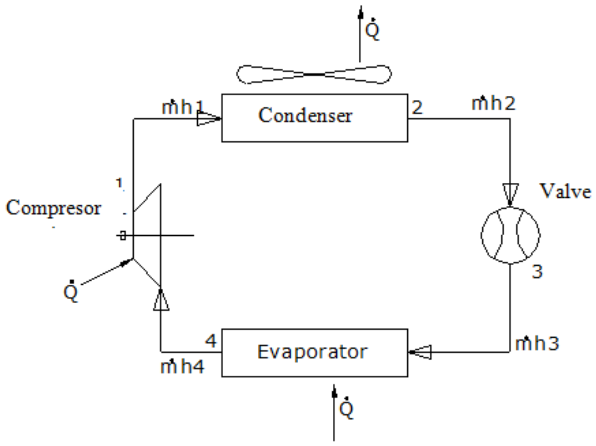


Fig. 1. Air freshener system chart

An air freshener system is a system that is used to freshen the air to make it feel cooler, or in other words transfer heat from inside the room out of the room.The air freshener system consists of several supporting components, namely a compressor; condenser; evaporators; expansion valve; etc. Refrigerant air freshener system as a working fluid that transfers heat from inside the room through the evaporator out of the room through the condenser.

The way the air freshener system works is: refrigerant is compressed in the compressor to high pressure and temperature and changes phase into superheated steam. The superheated steam then passes through the condenser and releases the heat it contains until it changes to a saturated liquid phase, but the pressure remains high. The process of releasing heat in the condenser is assisted by air flowing around the condenser. The air absorbs the heat released in the condenser. Then the refrigerant passes through the evaporator, in the evaporator the refrigerant pressure has been reduced to a mixed phase, and in the evaporator the refrigerant absorbs heat in the room because the evaporator is placed in the room. The refrigerant absorbs heat in the evaporator until it changes phase into saturated vapor which then goes to the compressor to be compressed again, and so on.

RESULTS AND DISCUSSION

Logarithmic Mean Temperature Different (LMTD)

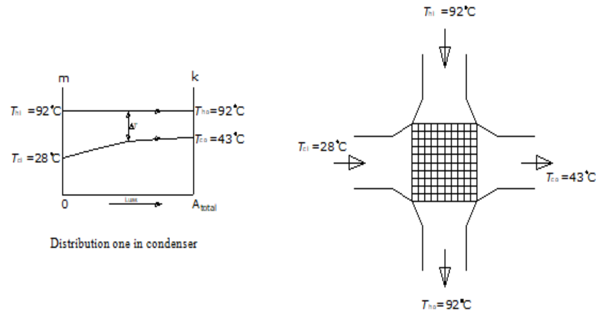
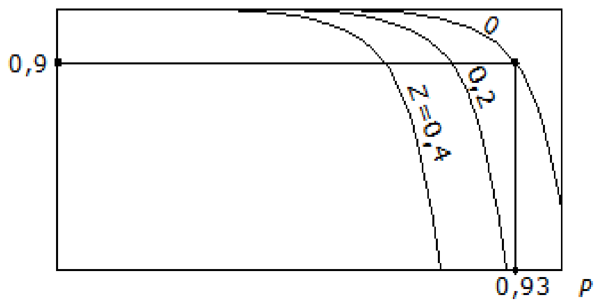


Fig. 2. Logarithmic Mean Temperature Difference (LMTD)

$$LMTD = \frac{\Delta T_{min} - \Delta T_{max}}{\ln \frac{\Delta T_{min}}{\Delta T_{max}}} = \frac{1-16}{\ln \frac{1}{16}} = \frac{-15}{-2{,}77} = 5{,}4$$

For a cross-flow heat exchanger with one mixed fluid and another immiscible fluid there is a correction factor F for LMTD

So that $Q = U.A.F.LMTD$



$$Z = \frac{T_{hi} - T_{ho}}{T_{co} - T_{ci}}$$

$$P = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}}$$

Fig. 3. LMTD correction factor

$$Z = \frac{T_{hi} - T_{ho}}{T_{co} - T_{ci}} = \frac{92-92}{43-28} = \frac{0}{15} = 0$$

$$P = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}} = \frac{43-28}{44-28} = \frac{15}{16} = 0{,}93$$

From figure 3 correction factor LMTD (*F)* = 0.9

Calculation Of Heat Transfer Area

a. The heat released in the condenser based on the energy balance is :

Cooling capacity + compressor power

= 5.1 kW + 1.8 kW = 6.9 kW

6.9 kW = heat released in the condenser = heat received by water

6.9 kW = $\dot{m}\Delta h$ = $\dot{m}cp\Delta t$

$$6.9\ \text{kW} = \dot{m}.89\frac{BTU}{lbm} = \dot{m}.4{,}2\frac{kJ}{kg°C}.(43-28)°C$$

$$\dot{m}.208\frac{kJ}{kg} = \dot{m}.63\frac{kJ}{kg}$$

Based on the above equation:

b. The refrigerant flow rate in the heating tube

$$\dot{m} = \left(6{,}9\frac{kJ}{s}\right).\left(\frac{1kg}{208kJ}\right) = 0{,}033\frac{kg}{s} = 119\frac{kg}{h} = 0{,}0007\frac{m^3}{s}$$

where is the specific volume of Freon 22 in the condenser on the saturated vapor line

$$0.3\frac{Ft^3}{lbm} = \frac{0.0085m^3}{0{,}45kg} = 0.02\frac{m^3}{kg}$$

c. Heater shell side water flow rate

$$\dot{m} = \left(6{,}9\frac{kJ}{s}\right).\left(\frac{1kg}{63kJ}\right) = 0{,}11\frac{kg}{s} = 396\frac{kg}{h} = 0{,}4\frac{m^3}{h} = 400\frac{liter}{h} = \frac{1liter}{1/_{400}h} = \frac{1liter}{0{,}0025h}$$

$$= \frac{1liter}{9s}$$

where is the density of water at 43 °C = 990 $\frac{kg}{m^3}$

d. Effective diameter

Effective diameter for flow $\frac{1Liter}{9\det ik}$ in inches is:

$$De = 3{,}9.q^{0{,}45}\left(Ft^3/s\right).\rho^{0{,}13}\left(lbm/Ft^3\right)$$

$$= (3{,}9).(0{,}0038)^{0{,}45}.(62{,}4)^{0{,}13}$$

$$= 0.41\ \text{in}$$

Then take the diameter 0.5 in = 0.0127 mm

e. The area through which the water passes on the shell side

(3.25 mm + 12.7 mm + 12.7 mm + 12.7 mm + 3.25 mm) x 49 mm = 2185 mm^2 = 2185.10^{-6} m^2

f. The velocity of the water flowing through the area

$$v = \frac{\dot{m}}{Luas} = \frac{1{,}1.10^{-4}\, m^3/s}{2185.10^{-6}m^2} = 0{,}052\, m/s$$

g. Reynolds number

$$\text{Re} = \frac{v.D_o.\rho}{\mu} = \frac{0{,}052\,m/s.0{,}0127m.990\,kg/m^3}{6{,}16.10^{-4}\,kg/m.s} = 1021$$

h. Nusselt number

$$Nu = 0{,}023.\text{Re}^{0{,}8}.\text{Pr}^{0{,}4} = (0{,}023).(1021)^{0{,}8}.(4{,}04)^{0{,}4} = (0{,}023).(255).(1{,}75) = 10{,}3$$

i. Outside heat transfer coefficient

$$h_o = \frac{k}{D_o}.Nu = \frac{0{,}636\,W/m.°C}{0{,}0127m}10{,}6 = 516\,W/m^2.°C$$

The area through which the refrigerant passes is the cross-sectional area of the inner circle of the tube. From chapter III the cross-sectional area of the inner circle of the tube is 935.10^{-7} m^2 so:

j. refrigerant flow rate in tube

$$v = \frac{\dot{m}}{\pi(r_i)^2} = \frac{0{,}0007\,m^3/s}{935.10^{-7}m^2} = 7{,}5\,m/s$$

k. Reynolds number

$$\text{Re} = \frac{v.D_i.\rho}{\mu} = \frac{7{,}5\,m/s.0{,}01m.64{,}3\,kg/m^3}{15.10^{-6}\,kg/m.s} = 321500$$

l. Nusselt number

$$Nu = (0{,}023).(\text{Re})^{0{,}8}.(\text{Pr})^{0.4}$$
$$= 0{,}023.(321500)^{0.8}.(4730)^{0.4}$$
$$= 0{,}023.(25453).(30)$$
$$= 17562$$

m. Inside heat transfer coefficient

Where is the thermal conductivity of the refrigerant R22 on 197 F = 91,7°C = 0,122 *W/m °C*

$$h_i = \frac{k}{D_i}.Nud = \frac{0{,}012\,W/m.°C}{0{,}011m}.17562 = 21074\,W/m^2.°C$$

n. Overall heat transfer coefficient based on tube outer diameter

$$U_o = \frac{1}{\frac{1}{h_o} + \frac{r_o \ln \frac{r_o}{r_i}}{k} + \frac{r_o}{r_i . h_i}}$$

$$= \frac{1}{\frac{1}{516 \, W/m^2.°C} + \frac{0{,}00635m.\ln \frac{0{,}00635m}{0{,}0055m}}{205 \, W/m.°C} + \frac{0{,}00635m}{0{,}0055m.21074 \, W/m^2.°C}}$$

$$= \frac{1}{0{,}00194 \, m^2.°C/W + \frac{0{,}000913m}{205 \, W/m.°C} + 0.000055 \, m^2.°C/W}$$

$$= \frac{1}{0{,}002 \, m^2.°C/W}$$

$$= 500 \, W/m^2.°C$$

o. Heat conduction area (A)

$$q = AU_o.LMTD.F$$

$$A = \frac{q}{U_o.LMTD.F} = \frac{6900W}{500 \, W/m^2.°C . 5{,}4°C.0{,}9} = 2{,}84 \, m^2$$

Shell Wall Thickness Calculation

To calculate the thickness of the shell wall we need to calculate the pressure acting on the shell wall, but first find the total pump head in meters.

a. Pump total head

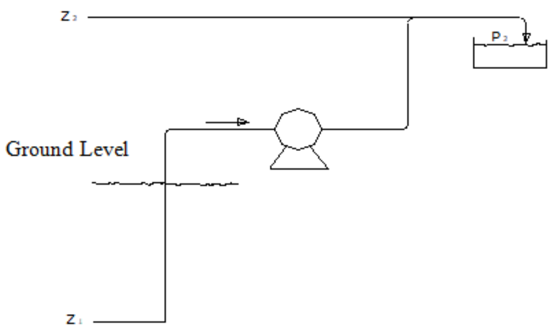


Fig. 4. pump installation

$$H = (Z_2 - Z_1) + \left(\frac{v_2^2 - v_1^2}{2.g}\right) + \left(\frac{P_2 - P_1}{\rho}\right) + (h_f)$$

V_1 ignored because it is so small compared to V_2

$P_1 = P_2 = 1$ atm

h_f = loss - loss head

b. Friction loss head in pipe

$$h_f = \lambda.\frac{l}{De}.\frac{v^2}{2.g}$$

$$V = \frac{\dot{m}}{A} = \frac{0{,}4 \, m^3/h}{\frac{\pi}{4}.(0{,}0127m)^2} = 3159\frac{m}{h} = 0{,}88\frac{m}{s}$$

$$Re = \frac{vD\rho}{\mu} = \frac{0{,}88 \, m/s .0{,}0127m.990 \, kg/m^3}{6{,}16.10^4 \, kg/m.s} = 17961$$

For turbulent flow $\lambda = 0{,}02 + \frac{0{,}0005}{De} =$

$$0{,}02 + \frac{0{,}0005}{0{,}0127} = 0{,}06$$

$$\text{So, } h_f = 0{,}06.\frac{34m}{0{,}0127m}.\frac{(0{,}88 \, m/s)^2}{2.(9{,}8 \, m/s^2)} =$$

(0,06).(2677).(0,04) = 6,4 m

c. Head loss in pipeline (end of inlet pipe)

$$h_f = f.\frac{v^2}{2.g} = (0{,}5).(0{,}04) = 0{,}02 \text{ m}$$

d. Head loss in the hot water trajectory turns 90°

$$h_f = f.\frac{v^2}{2.g}$$

$$f = \left[0{,}131 + 1{,}847\left(\frac{De}{2.R}\right)^{3{,}5}\right].\left(\frac{\theta}{90}\right)^{0{,}5}$$

$$= \left[0{,}131 + 1{,}847\left(\frac{0{,}0127}{2.0{,}02}\right)^{3{,}5}\right].\left(\frac{90}{90}\right)^{0{,}5}$$

$$= [0{,}16].(1)$$

= 0.16

So, $h_f = f.\frac{v^2}{2.g} = (0{,}16).(0{,}04)$ = 0,0064 . 13 turn = 0,08

e. Head loss in the hot water trajectory turns 180°

$$h_f = f.\frac{v^2}{2.g}$$

$$f = \left[0{,}131 + 1{,}847\left(\frac{D_H}{2.R}\right)^{3,5}\right].\left(\frac{\theta}{90}\right)^{0,5}$$

$$= \left[0{,}131 + 1{,}847\left(\frac{4.A/p}{2.0{,}049}\right)^{3,5}\right].\left(\frac{180}{90}\right)^{0,5}$$

$$= \left[0{,}131 + 1{,}847\left(\frac{4.2096.10^{-6}/0{,}183}{2.0{,}049}\right)^{3,5}\right].\left(\frac{180}{90}\right)^{0,5}$$

$$= [0.26].(0{,}414)$$
= 0.11

So, $h_f = f.\frac{v^2}{2.g} = (0{,}11).(0{,}04)$ = 0,0044 . 24 turn = 0.1 m

f. Total loss head

hl = 6.4 m + 0.02 m + 0.08 m + 0.1 m = 6.6 m

g. Pump total head

$$H = (Z_2 - Z_1) + \left(\frac{v_2^2 - v_1^2}{2.g}\right) + \left(\frac{P_2 - P_1}{\rho}\right) + (h_f)$$

$$= (17m) + \left(\frac{0{,}88\,m/s}{2.9{,}8\,m/s^2}\right) + (0) + (6{,}6m)$$
= 23.6 m

h. The compressive force acting on the shell (*F*)

p = $H.\rho_{air}.g$ = (23.6 m).(990 kg/m^3).(9.8 m/s^2) = 228967 N/m^2

based on the shape of the shell above the greatest pressure acting on the shell is in the XZ plane, with an area of 423,7mm x 600mm = 254220 mm^2 = 0,25 m^2

So the Style that works on the shell (*F*) is: 228967 N/m^2 . 0.25 m^2 = 57242 *N*

The area of the resisting wedge is Axz (shaded)

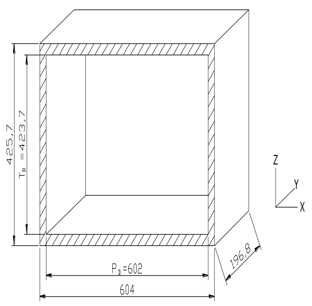


Fig. 5. Thick slice of shell wall dinding

The magnitude of the force that splits the shell (*N*) ≤ Permissible tensile stress of shell material (N/m^2) x The area of the wedge that resists the force (m^2)

$$F = \sigma_y.A$$

Using Aluminum shell material with σ_y = 20.10^3 psi = 29.10^7 $\frac{N}{m^2}$

So that the shell does not break in the field XZ

$$F \le (A_{xz}).(\sigma_y)$$

$$F \le \{[(T_D.t).2] + [(P_D.t).2] + (4.t^2)\}.\sigma_y$$

($4.t^2$) ignored karma is considered very small

$$F \le [(T_D.t) + (P_D.t)].2.\sigma_y$$

$$\frac{F}{2.\sigma_y} \le (T_D + P_D).t$$

$$\frac{F}{2.\sigma_y(T_D + P_D)} \leq t$$

$$t \geq \frac{57242 \text{ N}}{(2).(29.10^7 \frac{N}{m^2}).(0,42m + 0,6m)}$$

$$t \geq \frac{57242 \text{ N}}{59.10^7 \frac{N}{m}}$$

$$t \geq 97.10^{-6} m$$

$$t \geq 97.10^{-3} mm$$

$$t \geq 0,097 mm$$

Then take the thickness of the shell wall = 1 mm

Pump Power Calculation

Pump power required to circulate hot water

$$P = \dot{Q}.\rho.g.H$$

$$P = 0,00011 m^3/s .990 kg/m^3 .9,8 m/s^2 .23,6m$$

$$P = 25,2 J/s$$

CONCLUSION

After completing the planning of a water heater using Split Type Room Air Conditioner with a Cooling capacity of 5.1 kW, Compressor power is 1.8 kW, so some conclusions can be drawn:

a. The heat transfer process that occurs in this device is the heat released by the refrigerant absorbed by the inner tube wall, namely convection heat transfer, then conduction heat transfer occurs from the inner wall of the tube to the outer wall of the tube, then convection heat transfer occurs from the inner wall. outside the tube to the water on the shell side so that the water temperature becomes 43°C.
b. In this plan, it is still using an air conditioning condenser. Process number 1 takes place in the heater, so when you don't need hot water, the heat released by the refrigerant is absorbed by the air flowing on the outside of the air conditioning condenser tube, because the water in the heater does not flow.
c. This tool can produce water with a discharge of 1 liter per 9 seconds, or $\frac{400 liter}{jam}$.
d. The surface area of heat conduction in this tool is 2.84 m^2.
e. The capacity of this tool is 39.8 dm^3 air.
f. With this tool, the AC system requires as much Freon as 6.8 dm^3.
g. The dimensions of this tool are: Length = 678.5 mm, width = 230.8 mm, high = 459.7 mm.
h. The shell wall thickness is 1mm.

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