THE DESIGN OF ENVIRONMENTALLY FRIENDLY ALTERNATIVE AIR CONDITIONING THAT USED LIQUID ANTIFREEZE AS A REFRIGERANT AND THERMOELECTRIC AS A COOL SOURCE

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ABSTRACT
The Results of this research is to get the performance of the air conditioning alternatives that meet the standards of indoor air temperature for human comfort that move therein. For long-term goals, this study will address the problems of global environment as mentioned above and can provide solutions for the availability of refrigeration in general to remote areas difficult to reach commercial power, because the cooling machine can be operated with a source of direct current electricity which can be supplied from solar cells. The method used to resolve the above problem is to conduct the research performance of the air cooling alternative to modifying the conventional air conditioning machine. The use of conventional refrigerant replaced by antifreeze fluid in this case the water-salt (brine) and glycol. Utilize the cooling source of the thermoelectric cold side, the use of the compressor is replaced with a circulating pump. Condenser in a conventional cooling machine will not be used again in this system. Evaporator modified into a ventilator that is cooled by circulating antifreeze fluid that has been cooled by four pieces of thermoelectric (TEC 12706). During the cooling cycle, no change of phase refrigerant so that the circulation of the refrigerant only done by the pump. The performance test these alternative refrigerants varying: a mixture of water and salt to obtain the water-salt refrigerant appropriate and the number of thermoelectric chips as a source of cool to get the cooling effect of the most effective and efficient. On the use of antifreeze liquid mixture of NaCl + H_2O average temperatures as low as 6,1^oC refrigerant obtained an average indoor temperature low of 12,2^oC with the highest COP value of 2.34 and the lowest was 0.70, while the use of antifreeze fluid mixture glycol + H_2O average temperatures as low as 3,3^oC refrigerant obtained an average indoor temperature low of 8,9^oC with the highest COP value of 2.10 and the lowest was 0.57. The Coefficient of Performance value (COP), which trended downward is caused by the temperature of the room to the stable state.
Keywords: Air conditioning, thermoelectric, refrigerant, antifreeze.

1. INTRODUCTION

The use of refrigerant on a variety of cooling machine today, both refrigerant synthesis containing CFC (chlorofluorocarbon) and alternative refrigerant to hydrocarbon-based may potentially cause global environmental problems namely the effects of ozone depletion and the greenhouse effect/global warming, also the use of energy is relatively large. In addition, the procurement price and operating costs of each unit is also relatively expensive. To solve the problem, should be considered an alternative air cooler that utilizes a liquid antifreeze as an environmentally friendly and thermoelectric refrigerant as a source of cold with the fewer number of components. Various research fields of refrigeration has been done in an effort to make energy savings in machine refrigeration include: the effect of speed shaft compressors against the performance of air conditioning (Effendi, 2005), the effects of mass variation refrigerant R-12 and round blower evaporator against the COP on the car conditioning air system (Wibowo, 2006), the and energy savings in cooling system building by using control fuzzy logic (Nasution, 2007), but all the research is still about how to improve the performance cycle refrigeration compression of steam, which is actually still use refrigerant as heat absorption media. Basically the use of environmentally friendly refrigerants has been widely used, but still as secondary refrigerant antifreeze liquid that is commonly used on ice factory, for example, water-salt (brine) and glycol. For this type of water-salt, Sumardi (2011) have done reformulation antifreeze fluid from the water-salt as secondary refrigerants for refrigeration system with optimal salt concentration is 25% with a freezing point -20^oC. While in the process of air cooling without using refrijeran or machine refrigeration compression of steam-which can cause environmental damage ease global, Chang, et al. (2008) has conducted experimental research for module air conditioning thermoelectric, on research Chang, et al. (2008) were able to get the air conditioning that can meet the needs comfort room temperature.

The results of this research is to get the performance of the air conditioning alternatives that meet the standards of indoor air temperature for human comfort that move therein. For long-term goals, this study will address the problems of global environment as mentioned above and can provide solutions for the availability of refrigeration in general to remote areas difficult to reach commercial power, because the cooling machine can be operated with a source of direct current electricity which can be supplied from solar cells

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2. THERMOELECTRIC COOLING MODULES

Cooling thermoelectric use components that implement the Peltier effect, by supplying a direct current through the connection of two materials which are not similar, causing the two sides of the connection to be cold (absorbs heat) and heat (can release heat), which depending on the amount of current flowing in the component.

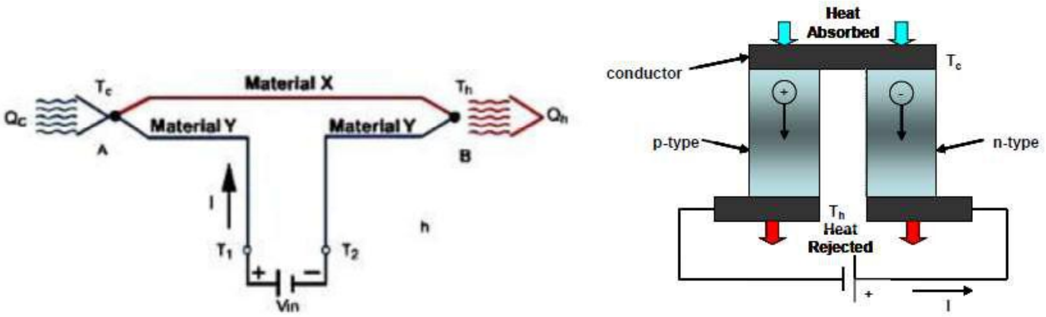

Figure 1. Diagram of thermoelectric system

In Figure 1, shows pair of thermo-elements is attached to each end with metal sheeting huddled at one end by a metal sheet so as to form a connection between the legs. The legs are forming a series circuit electrically but thermally form a parallel circuit. This unit is called a thermoelectric couple and is the basic building block of a thermoelectric cooling module. Material thermo-element is a semiconductor that is added to the n-type as a negative majority carriers (electrons) and the other p-type as a positive majority carriers (holes). The materials used as a coupling element thermoelectric cooling system is a mixture of bismuth, tellurium and antimony as the p element, and a mixture of bismuth, tellurium and selenium as the n element. Thermoelectric utilizing one effect when the thermocouple energized. If a current is passed through a thermocouple, there will be five the following effects: the Seebeck effect; the Joulean effect; the Conduction effect; the Thomson effect and the. Peltier effect. The Peltier effect is the main basis of the cooling system thermoelectric effect, ie if the direct current is passed through the thermocouple temperature at first both ends are the same, then the amount of heat to be released at one end and several more heat will be absorbed at the other end, causing the temperature difference on both ends of it. The heat transfer is affected by the current flowing, with relationships such as equality.

$$q_p = \emptyset I$$

where $\emptyset$ is the Peltier coefficient (volt). For cooling application, an direct current supply is given to the thermoelectric module, heat is transferred from one side to the other, and the result is that the module will become cooler at one side and hotter at the other side. To keep the temperatures remain low on one side (the cold side) then the other side (hot side) the temperature should be maintained by disposing of heat continuously.

3. LITERATURE REVIEW

Until now thermoelectric applications have been developed for a specific use and limited, it is based on the limitations of thermoelectric component specifications and supporting components. Therefore, theoretical studies and experiments continue to experience growth, among which have been implemented by Manor et al (2012) by using six TECs, they were used for achieving the cooling with a DC power supply through car battery. It had been shown from testing results that the cooling system is capable of cooling the air when recirculating the air inside the car with the help of blower. TEC cooling designed was able to cool an ambient air temperature from 32°C to 25.8°C. Onoroh, Francis. et. al. (2013) has conducted research focusing on simulation of a thermoelectric refrigerator maintained at 4oC. The performance of the refrigerator was simulated using Matlab under varying operating conditions. The system consisted of the refrigeration chamber, thermoelectric modules, heat source and heat sink. For targets larger thermoelectric applications by leveraging the availability of renewable energy sources, Yen-Lin Chen, et. al. (2014) was presents experimental explorations on cooling performance of thermoelectric chillers being driven by solar cells, as well as comparison results to the performance being driven by fixed direct current. Solar energy is clear and limitless and can be collected by solar cells. They use solar cells to drive thermoelectric chillers, where the cold side is connected to the water tank. It is found that 250 mL of water can be cooled from 18.5o C to13o C, where the corresponding coefficient of performance (COP) is changed between 0.55 and 1.05, when solar insulation is changed between 450 W/m and 1000 W/m2. The experimental results demonstrate that the thermoelectric chiller driven by solar cell is feasible and effective for energy saving issues. Whereas for

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supporting the needs of public health facilities, Sarath, Raj (2015) has developed a portable thermoelectric refrigeration system capable of maintaining vaccine temperatures between 8 °C and 13 °C. The main system consisted of thermoelectric module as cooling generator along with insulated cabin, battery and charging unit. The Recent studies on the use of thermoelectric that objectives to develop a working thermoelectric refrigerator to cool a volume of 40 L that utilizes the Peltier effect to cool and maintain a selected temperature range of 5oC to 25oC by using TEC1-12706 has been conducting by Sujith, G. et. al. (2016). Manoj Kumar Rawat, et. al. (2012) was developed first prototype of TER system with a refrigeration space of 1000 cubic centimeter (1 liter) by using four numbers of Peltier module (Qmax=19W) and four numbers of Heat sink fan assembly with thermal resistance of 0.50 C/W to increase heat dissipation rate. Experiments were conducted on developed prototype of thermoelectric refrigeration system and result shows a temperature reduction of 11.5 C in refrigeration space with respect to 30 C ambient temperature.

4. MATERIAL AND METHODS

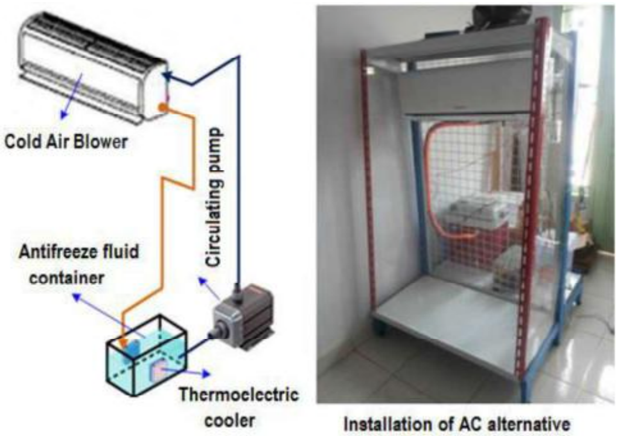

Figure 2. Installation of air conditioning alternatives to be studied

The detail specifications of the thermoelectric module (TEM) and heat exchanger are presented in (**Table 1** and **Table 2**).

Table 1: Specifications of used thermoelectric module

S/N	Specifications	Unit	Value
1.	Maximum Power (Q_{max})	(W)	19
2.	Maximum Current (I_{max})	(A)	3.9
3.	Maximum Voltage (V_{max})	(V)	7.8
4.	Maximum temperature difference (dT_{max})	(°C)	74
5.	Size (LxWxH)	(mm)	30x15x3.6
6.	Number of Couples	(N)	10

Table 2 : Specifications of used black anodized aluminum plate fin heat sink fan assembly

S/N	Specifications	Unit	Value
1.	Width of Heat Sink base	(mm)	60
2.	Length of Heat Sink base	(mm)	60
3.	Base thickness of Heat Sink	(mm)	4.6
4.	Fin length	(mm)	60
5.	Fin thickness	(mm)	1
6.	Fin height	(mm)	6.8
7.	Channel width	(mm)	1.8
8.	Numbers of fin	N_f	14
9.	Thermal resistance of Heat Sink	(°C/W)	0.50
10.	Fan DC power	(Watt)	1.8W (12V)

This research was done in stages that began with the manufacture of test equipment air conditioner that utilizes a liquid antifreeze and thermoelectric. Further testing equipment performance testing and ends with the evaluation of performance results. Test equipment used is to modify the air conditioner (AC) in the market with only utilize part evaporator system, which consists of fan blower, heat exchanger and chassis, this section referred to as cold ventilator. Antifreeze fluid from the tank that has been cooled by the thermoelectric system (cooler box) with a supply voltage of 12 V DC, circulated by a pump (aquarium pump) to cool ventilator and re-injected into the tank. Antifreeze fluid used is a mixture of 25% NaCl in a solution of water (H2O) and a mixture of 50% ethylene glycol in a solution of water (H2O). Installation design can be seen in Figure 5.

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5. RESULTS AND DISCUSSION

Experiment and Test Result Discussion

Analysis of the performance parameters of air conditioner alternative design results can be described as follows.

a. The calculation of heat received antifreeze liquid in the indoor air conditioning systems.

Temperatures antifreeze liquid coming into the indoor of alternative air conditioning system (TRIN) was 4.0°C, while the temperature of the liquid antifreeze out of the indoor system (trout) is 15.0°C. So the average temperature antifreeze liquid passing through the indoor cooling machine system is 9.5^{o}C and antifreeze liquid temperature difference in the indoor systems is 11.2^{o}C, hence the volumetric flow is obtained 0,1389 x10^{-3} m^3/s. From the thermodynamic properties table of liquid antifreeze in this case, a solution of water-salt (brine: 20% NaCl-H2O) at an average temperature of mixing 15oC is obtained: the specific heat cR = 3.310 [kJ / kg. K] and the density ρR = 1152 [kg / m3]. So the heat received by antifreeze liquid on the indoor of alternative air conditioning system is.

$$Q_R = \dot{m}_R c_R \Delta T_R \text{ atau } Q_R = \rho_R [AV]_R c_R \Delta T_R \text{ [kJ/s]},$$

$$Q_R = 1152 \left[\frac{kg}{m^3}\right] x \frac{1}{72} \left[\frac{lt}{s}\right] x \frac{1\, m^3}{1000\, lt} x 3{,}310 \left[\frac{kJ}{kgK}\right] x\ 11{,}0\ [K] = 0{,}583 \text{ [kJ/s]}.$$

In the same way, the final result further data are summarized in table calculation results.

The parameters and equations are the same as above, is also used for the calculation of the results of testing machines which use liquid cooling antifreeze from a mixture of water (H2O) with 50% ethylene-glycol, the thermodynamic properties as attached (Appendix 4), with a calorific value specific C_R = 3.570 [kJ / kg.K] and the density ρ_R = 1066 [kg / m3].

b. The air temperature conditions of testing room.

The air temperature changes in room refrigeration testing that is the object of this alternative AC system, was monitored at five points of measurement, in order to determine the effects of temperature decrease is that caused by the absorption of heat by the antifreeze liquid on indoor cooling system of alternative AC. The average temperature of the room is:

$$\bar{T}_R = \frac{T_{ur1} + T_{ur2} + T_{ur3} + T_{ur4} + T_{ur5}}{5}$$

$$\bar{T}_R = \frac{20.0 + 23.2 + 23.5 + 22.4 + 22.0}{5} = 22.22^o\text{C}$$

c. The use of electrical energy on the system of alternative AC

Based on the experiment data, power supply (voltage and current) to the blower in the indoor of alternative AC, which is the mechanism of the circulation of air from the surface of the pipe 'evaporator' (indoor) of the system of alternative AC to get to the room which is cooled, is one input systems work ie Work blower (Wb-ev).

Wb-ev = Vb-ev . Ib-ev = 220 Volt . 1,5 Ampere = 330 Watt = 0,33 kJ/s

The power supply (voltage and current) on the circulation pump for circulating antifreeze fluid between containers with indoor cooling machine, it also one of the input work system was called as a pump work (Wp).

$W_p = V_p \,.\, I_p$ = 220 Volt . 0,15 Ampere = 33 Watt = 0,033 kJ/s

The main power is the source of cool effects in this system is the power supply (voltage and current) to the thermoelectric cooling system. Direct current supply system is used to supply thermoelectric element itself so as effect of cold on one side and the effects of heat on the other side, on the side heat the power supply fan required for heat release so that the cold side maintained at a certain temperature. This work is referred to as the working Thermoelectric (W_{TE}).

$W_{TE} = V_{TE} \,.\, I_{TE}$ = 12 Volt . 8 Ampere = 216 Watt = 0,216 kW

Referring to the results table calculations, then plotted into two models chart are: 1) the relationship between the change in temperature of the room and fluid antifreeze versus operating time cooling machine (Figure 3), and 2) the relationship between changes in room temperature versus the coefficient of performance (COP) AC alternative (Figure 8) for each type of antifreeze fluid that has been used is a salt-water solution (25% NaCl-H2O) and glycol-water (50% EtilenGlicol-H2O).

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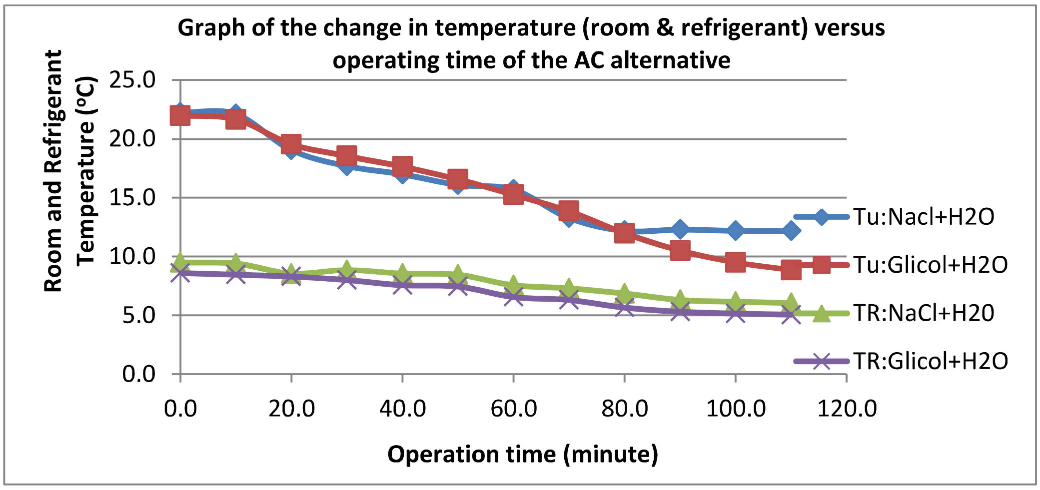

Figure 3. The graph of the change in temperature (room & refrigerant) versus operating time of the AC alternative

In Figure 7 above, shows that the longer operation time, the room temperature can be kept lowered toward minimum temperature (stable) approaching the average temperature antifreeze fluid as a source of cold that has been cooled by the thermoelectric system. On the use of antifreeze liquid mixture of $NaCl+H_2O$ lowest average temperature of the fluid antifreeze is 6,1oC, at the time earned the lowest average temperature of the room is 12.2°C, while the use of a mixture of glycol antifreeze fluid + H2O lowest average temperature is 3.3°C, at the same time the average lowest room temperature is 8.9°C.

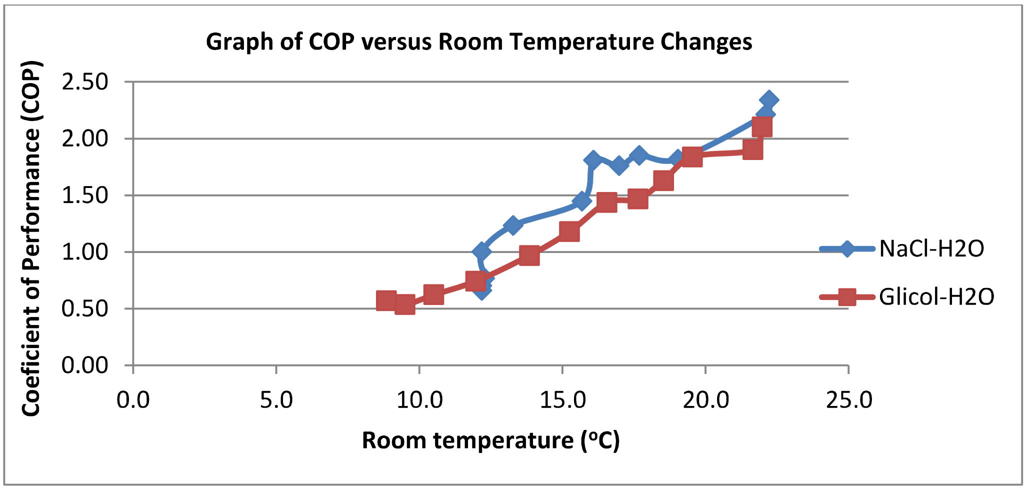

Figure 4. The graph of the changes in room temperature versus operation time of AC alternatives

In Figure 4 above, shows that the coefficient of performance (COP) alternative AC system will continue to fall with a decrease in ambient temperature to the lowest temperature (saturated). To use antifreeze liquid mixture of NaCl+H2O obtained the highest COP is 2.34 and the lowest was 0.70. As for the use of a mixture of glycol+H2O obtained the highest COP is 2.10 and the lowest was 0.57. The highest COP value obtained at the time of initial surgery due to the large engine coolant thermoelectric cooling effect at that time. To maintain the thermoelectric cooling effect on the hot side of the thermoelectric necessary in effective cooling.

Conclusion

We have designed an alternative AC system that does not implement a vapor compression refrigeration cycle and does not use conventional refrigerants. On the use of antifreeze fluid is a mixture of $NaCl+H_2O$, when the average temperature in the antifreeze liquid low of 6.1 ° C, obtained an average room temperature of the lowest is 12.2°C. While the use of antifreeze fluid is a mixture of glycol+H_2O, when the average temperature in the antifreeze liquid low of 3.3 ° C, the room temperature is obtained the lowest average is 8.9°C. COP highest value is 2.34 and the lowest was 0.7 for the use of a mixture of NaCl+H2O. As for the use of a mixture of glycol+H_2O obtained the highest COP is 2.10 and the lowest was 0.57. The coefficient of performance

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(COP), which tends to fall is caused by the temperature of the room to the stable state. For further research, it is important to test other antifreeze liquids which thermodynamic properties have been studied previously through the study of literature. to obtain the target temperature of cooling with optimum electrical power, it is important to vary the composition of the thermoelectric. To improve the system COP, important efforts to reduce blower power in the 'evaporator'

REFERENCE

Bayanullah, A. 2011. Penghematan Energi Pada Sistem Air Conditioning Untuk Kapal Penumpang http://digilib.its.ac.id/.../ITS-Undergraduate-9466-42011. Diakses 28 Mei 2013

Cengel, Y.A. dan Boles, M.A., 2002. Thermodynamics. 4th edition. Boston-USA: Mc. Graw Hill.

Chang, Yu-Wei. et al., 2008. An Experimental Investigation of Thermoelectric Air-Cooling Module. International Journal of Engineering and Applied Sciences Vol 4:3.

Dai YJ, Wang RZ, Ni L;. Experimental investigation and analysis on a thermoelectric refrigerator driven by solar cells. Sol Energy Mater Sol Cells 2003

Effendy,M. 2005. Pengaruh Kecepatan Putar Poros Kompresor Terhadap Prestasi Kerja Mesin Pendingin AC, Jurnal. Surakarta: Jurnal Media Mesin Vol.6 No.2 2005.

Huang, B. J., Chin, C.J., Duang, C.L. 2000. A design method of thermoelectric cooler. International Journal of RefrigerationVolume 23, Issue 3, May 2000, Pages 208–218.

Indartono, Y. S. 2006. Pendingin Alami City of The Viking King (III), Internet. http: //www.indeni.org, 23 Maret 2008, Berita Iptek.

Indartono, Y. S. 2006. Perkembangan Terkini Teknologi Refrijerasi (I), Internet. http: //www.beritaiptek.com, 23 Maret 2008.

Jamal & Firman. 2011. Analisis Kinerja Pendingin Udara Alternatif yang Memanfaatkan Energi Laten Es dengan Dua Heat Exchanger. Jurnal Teknik Mesin SINERGI No. 1, Tahun 9, April 2011.

Manoj S. Raut, Dr.P. V. Walke, "Thermoelectric Air Cooling For Cars", International Journal of Engineering Science and Technology (IJEST), Vol. 4 No.05 May 2012 ,ISSN : 0975-5462.

Manoj Kumar Rawat, Lal Gopal Das, Himadri Chattopadhyay and Subhasis Neogi (2012). An Experimental Investigation On Thermoelectric Refrigeration System : A Potential Green Refrigeration Technology. Journal of Environmental Research And Development Vol. 6 No.

MayankAwasthi and K V Mali, "Design and development of thermoelectric refrigerator", Int. J. Mech. Eng. & Rob. Res. 2012, Vol. 1, No. 3, October 2012, ISSN 2278 – 0149.

Mr. Swapnil B. Patond," Experimental Analysis of Solar Operated Thermo-Electric Heating and Cooling System", International Journal of Engineering Trends and Technology (IJETT) – Volume 20 Number 3 – Feb 2015 , ISSN: 2231-5381.

Nasution, H. 2007. Aplikasi Kendali Logika Fuzzy pada Sistem Pendingin Bangunan Sebagai Upaya Penghematan Energi, Jurnal. Jogja: Jurnal AES, 2007.

Nasution, H. 2007. Penghematan Energi pada Sistem Pendingin Bangunan Dengan Menggunakan Kendali Logika Fuzzy, Jurnal. Bandung: Jurnal Race, 2007.

Onoroh Francis, Chukuneke Jeremiah Lekwuwa, Itoje Harrison John (2013) Performance Evaluation of a Thermoelectric Refrigerator International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 7, January 2013 ISSN: 2277-3754

Sabah A. Abdul-Wahab , Ali Elkamel b, Ali M. AlDamkhi, Hilal S. Al-Rubai'ey, Abdulaziz K. Al-Battashi, Muhammad U. Chutani (2009), Design and experimental investigation of portable solar thermoelectric refrigerator; An International Journal for Renewable Energy.

Sujith G., Antony Varghese, Ashish Achankunju, Rejo Mathew, Renchi George, Vishnu V. (2016), Design and Fabrication of Thermoelectric Refrigerator with Thermosiphon System International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-4,April 2016 ISSN: 2395-3470.

Sarath, Raj (2015). Experimental Analysis, Design and Fabrication of Portable Thermoelectric Vaccine Preservator. International Journal of Mechanical and Industrial Technology Vol. 3, Issue 2, pp: (117-128), Month: October 2015 - March 2016, ISSN 2348-7593

Sumardi, K. 2011. Reformulasi Larutan Antibeku (Antifreezes) sebagai Refrigeran Sekunder pada Sistem Refrigerasi. http://repository.upi.edu/operator/upload/ kamin_reformulasi_larutan_anti_beku.pdf

Wibowo, D.B. dan Subri, M. 2006. Pengaruh Variasi Massa Refrigeran R-12 dan Putaran Blower Evaporator Terhadap COP pada Sistem Pengkondisian Udara Mobil, Jurnal. Bandung: Jurnal Traksi, Vol.4 No.1 2006.

Yen-Lin Chen, Zi-Jie Chien, Wen-Shing Lee, Ching-Song Jwo, and Kun-Ching Cho (2014). Experimental Investigation on Thermoelectric Chiller Driven by Solar Cell. Hindawi Publishing Corporation International Journal of Photoenergy Volume 2014, Article ID 102510, 8 pages http://dx.doi.org/10.1155/2014/102510

Yusuf, M.S. 2008. Lapisan Ozon Menipis Kehidupan Diambang Bahaya, Internet. http://www.bekasinews.com, 23 Maret 2008

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