Solar Energy Utilization Instead of Oil Energy

I. G. Faiadh*, F. L. Rashed*, S. A. Salman**
*Ministry of Science & Technology
** College of Science/ Department of Physics/ University of Diyala

Receiving Date: 2011/5/2 **- Accept Date:** 2011/6/19

Abstract

In this work solar collector had been used as thermal collector for old oil system refrigerator driven by oil (spent gas) after developing it's diffusion-absorption hest pump.

Glycerin liquid boiling 290 °C was used instead of water in the pipe which surround the, generator with a pipe of 30 cm height and 5 cm in diameter. The ammonia vapor generator at fluid temperature of 140 °C up to 190 °C where the pipe near the condenser become hot, this mean that the ammonia vapor generator up to the condenser.

The requirement calculation were performance for this work are the volume of storage hot fluid required to operate the refrigerator for one day, the flow rate required to supply heat input to generator, and the solar collector absorber area.

Keywords:
Solar Energy, Gas circulation, Air-conditioning system, Power refrigerating system.

Solar Energy Utilization Instead of Oil Energy

I. G. Faiadh, F. L. Rashed, S. A. Salman

إستغلال الطاقة الشمسية بدل الطاقة النفطية

ابراهيم كيطان فياض*، فرحان لفتة رشيد*، د.صباح أنور سلمان**

*وزارة العلوم و التكنولوجيا

** كلية العلوم/ قسم الفيزياء/ جامعة ديالى

الخلاصة

في هذا العمل، تم استخدام خلية شمسية كمجمع حراري لمنظومة نفطية تعمل بالنفط بعد تحوير المضخة الحرارية امتصاصية-انتشارية لها.

تم استخدام سائل الكليسرين بدل الماء في الأنبوب المحيط بالمولد ذو درجة غليان عالية 290 م وبانبوب ذي ارتفاع 30 م وبقطر 5 سم حيث قد تم تبخر الامونيا بمعدل درجة حرارة 140-190 م.

ان الحسابات المطلوب انجازها لهذا العمل هي كمية المائع المار مطلوب خلال مدة يوم واحد كامل، وبمعدل جريان الحرارة للمولد وكذلك الحسابات المتعآقة بالمساحة الامتصاصية للمجمع الشمسي.

الكلمات المفتاحية:

طاقة شمسية، تدوير الغاز، منظومة تكييف الهواء، منظومات تبريد قدرة.

Introduction

The significant milestones assumptions of solar energy as an energy resource to meet the needs of developing countries. Firstly, most of the countries called developing are in adjacent to the tropics and have good solar radiation available. Secondly, energy is a critical need of these countries but they do not have widely distributed, readily available supplies of conventional energy resources. Thirdly, most of the developing countries are characterized by arid climates, dispersed and inaccessible populations and a lack of investment capital and are thus faced with practically insuperable obstacles to the provision of energy by conventional means, for example, by electrification. In contrast to this solar energy is readily available and is already distribution to the potential users. Fourthly, because of the diffuse nature of solar energy the developments all over the world have been in smaller units which fits well into the pattern of rural economics. [1-8]

The important problem in this technique it's energy supply to refrigeration and airconditioning systems. If solar radiation is high the cooling load is generally high. Together with existing technologies, solar energy can be converted to both electricity and heat, either of which can be used to power refrigeration systems. [9]

Cooling unit:

The absorption diffusion refrigerator machine is designed according to operation principles of the refrigeration machine mono pressure. This machine used three operation fluid, water (absorber), the ammonia (refrigerant), and hydrogen as inert gas used in order to maintain the total pressure constant, represented on left hand of the figure (1) is composed of the principle elements, such as boiler, condenser, evaporator, absorber, and fuse. [10]

Solar Collectors:

The major energy gains in the absorber in a solar collector are from the direct absorption of visible light from the sun and, additionally, the absorption of infrared radiation from the warm glass. Important energy losses are infrared radiation emission, convective heat due to natural convection between the absorber and glass, as well as conduction of heat through the rear and sides of the collector. Therefore, the efficiency of the solar collector depends on all of these factors. The efficiency of the solar collector sub-system can be defined as the ratio of useful heat output to the total incident solar radiation (isolation).

In the following efficiency definition,[11] it is assumed that radiation is in the hemispherical region, all rays reach the absorber, and the multiple reflections between the cover and absorber are neglected. The solar collector efficiency can be written as,

$$\eta = F_m\left(\eta_{opt} - \frac{U_L\left(T_{abs,avg} - T_a\right)}{I}\right) \qquad (1)$$

$\eta_{opt} = \tau_{\alpha}$ optical efficiency of solar collector.

U_L is over all heat loss coefficient (W/m^2.° C).

$T_{abs,avg}$ is average temperature of heat transfer fluid in receiver (° C).

T_a is ambient temperature (° C).

I is solar radiation (W/m^2).

F_m is called the collector efficiency factor or a heat transfer factor. The value of F_m depends on the type of the collector and operating conditions. Typical values of F_m is in the range of 0.8-0.9 for non-evacuated air collectors, 0.9-0.95 for non-evacuated liquid collectors, and 0.95-1 for evacuated collectors.

In essence, it is easier to measure the temperature of the heat transfer fluid than to measure the temperature of the absorber surface temperature. Therefore, the solar collector efficiency is often written in terms of the temperature of the inlet (T_i) and outlet (T_o) temperature of the heat transfer fluid. The average temperature of the absorber surface can be assumed to be:

$$T_{abs.avg} = \frac{T_i + T_o}{2}$$

The efficiency of the solar collector can be defined as:

$$\eta = F_R\left(\eta_{opt} - \frac{U_L\left(T_i - T_a\right)}{I}\right) \qquad (2)$$

or

$$\eta = F_R\left(\tau_\alpha\right)_e - F_R U_L \frac{\left(T_i - T_a\right)}{I} \qquad (3)$$

F_R is the collector heat removal factor. The later equation is based on the 'Hottel-Whillier-Bliss' Equation. The value of factors $F_R(\tau_\alpha)$e and $F_R U_L$ depend on the type of the collectors, layer of the cover glass and selective material. Typical values of these factors are shown in Table (1):

Table (1): The Value of $F_R(\tau_\alpha)_e$ and $F_R U_L$ for Some Type of Solar Collector

Solar Collector Type	$F_R(\tau_\alpha)_e$	$F_R U_L$ (W m^{-2} K^{-1})
Flat-Plate, Selective-Surface, Single-Glass Cover	0.80	5.00
Flat-Plate, Selective-Surface, Double-Glass Cover	0.80	3.50
Evacuated Tubular Collectors	0.80	Range 1-2
Parabolic-Through Concentrating solar collector (PTC)	**0.70**	**2.5**

Concentrating Solar Collectors:

Two types of line-axis concentrating solar thermal collectors are commonly used today: a Compound Parabolic Concentrating (CPC) and Parabolic-through Concen- trating (PTC).

The concentration ratio (C) describes the characteristics of the concentrating solar collector. It is the ratio of the incident solar radiation area (Ain) to the absorber area (A_{abs}).

$$C = \frac{A_{in}}{A_{abs}} \qquad (5)$$

The concentrating optical solar collector is suitable for high temperature applications (e.g. temperatures >150°C). The large absorber area induces high heat losses. By concentrating the radiation incident of the aperture onto a smaller absorber, the heat losses per absorber area can be reduced. Tracking system is necessary to follow the movement of the sun in order to maintain concentration. The compound parabolic concentrator (CPC) is however not necessary for tracking since the concentration ratio is quite low. The CPC can, therefore, play an important role in solar cooling in the future. The main contribution is the direct (not the diffuse) solar radiation which differs somewhat from the flat-plate solar collector.

Concentrators can be divided into two categories: non-imaging and imaging concentrators. The non-imaging concentrator does not produce a clearly defined image of the sun on the absorber; but distributes radiation from all parts of the solar disc onto all parts of the absorber. The values of the concentration ratio of linear non-imaging collectors are quite low, generally below ten. The imaging concentrator is similar to a simple camera lens, which can form images on the absorber.

For a concentrating collector with a reflectivity (ρ), the optical efficiency can be written as,

$$\eta = \rho\tau_{\alpha} \tag{6}$$

Present Solar Driven Absorption System

Present design study is adapt gas fired diffusion-absorption heat pump 150 liter (5ft) refrigerator which available in the market and modify it by removing the original heat input source (kerosene flam, chimney and the jacket of electrical heater) and substitute it with solar heat input source.

Two attempt were done, first with pipe of height 90 cm, the bottom section, 40 cm height with diameter of 5cm, and upper section, 50cm height with diameter of 4 cm, around the original generator pipe of refrigerator, using as heat Input generator, fill with hot water maintaining at temperature of 97°C ,but the refrigerator is not operate because the temperature of water is not enough to allow the ammonia–water mixture to boil and no temperature gradient along the pipe height where the heat pump occurs, and second attempt with a pipe 30 cm height and diameter of 5 cm around the bottom section of original generator pipe of refrigerator, using a fluid with high boiling point to reach the temperature at which ammonia vapor generation, this was observed when working fluid temperature inlet the external generator(pipe added) reach 140°C where the rectifier pipe becomes hot . In this work glycerin was used as a working fluid (boiling point 290°C).Figure(1) show the pipe added and all the parts of the cooling system.

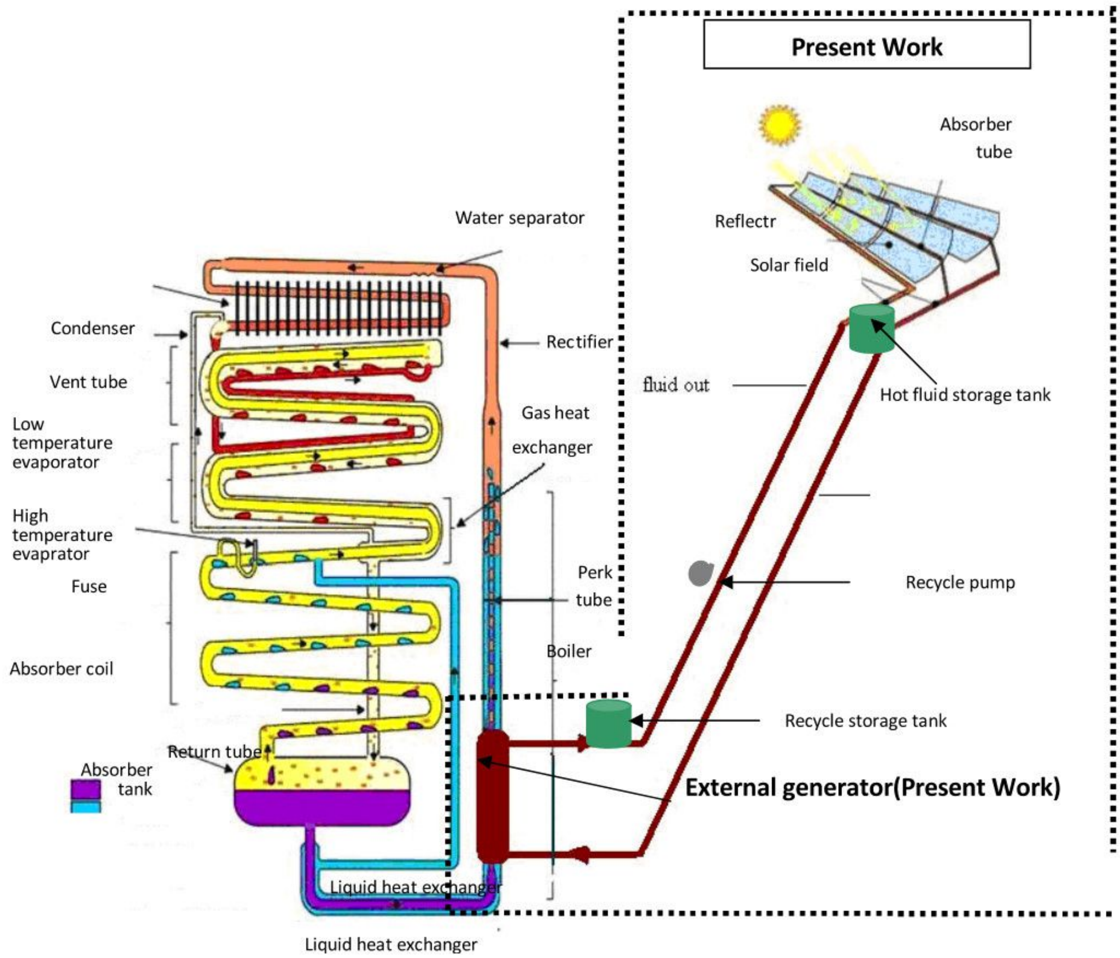

Figure (1) Solar Driven Platen-Munter Diffusion Absorption Refrigetator

The operating pressure of the cooling unit (150 liter (5ft)) is 23bar, concentration of rich solution is 33%, concentration of weak solution is 12%, and 1kg of ammonia vapor leave the generator toward the condenser need 649kcal [12].

From the T\Log diagram the boiling point of rich ammonia-water mixture (33%) is 130°C and the weak mixture (12%) temperature at 23bar is about 190°C .To operate the cooling unit with above condition, inlet generator temperature about 200°C, and outlet temperature about 140°C must be supplied from solar concentrator, then the flow rate of the working fluid required to achieve this operation is calculate as follow:

In this study 2.52hr was measured to generate 1kg of ammonia with 649kcal, the energy demand of the generator is:

$$Q_g = \frac{649}{2.52} = 257.5\ kcal\ hr^{-1}$$

$$= 257.5 \times 1.166667 = 300\,\mathrm{W}$$

$$Q_g = \dot{m} C_p \Delta T \qquad (7)$$

The specific heat C_p of glycerin is 2.4J/g °C, which is define:

$$\dot{m} = \frac{Q_g}{C_p \Delta T}$$

then the mass flow rate of heat exchange fluid required (glycerin) can be calculated based on the proposed entrance and exit temperatures of the oil in the generator:

$$\dot{m} = \frac{300}{2.4 \times (200 - 140)} = 2.1\ g\ s^{-1}$$

$$= 7.56\ \mathrm{kg\ hr^{-1}}$$

The density of glycerin is 1.26 g/cm^3 then:

The volumetric flow rate is:

$$\frac{7.56}{1.26} = 6\ \text{liter hr}^{-1}$$

The required hot fluid volume for 24hr is:

$6 \times 24 = 144$ liter perday

Parabolic-through Concentrating (PTC) collector, shown in figure(1), was used in this study. The area of the solar collector required by the system was determined based on the quantity of energy demanded and the mass flow of required heat exchange fluid. The energy demand of the generator is 300W (considering a safety factor of 15%, i.e Q_g=345W).

To determine the efficiency of the solar collector it is necessary to know the temperature difference and the solar radiation. The absorber inlet and outlet temperatures were obtained to be 130°C and 200°C, respectively, and the ambient temperature is 30°C.For an average of six hours of effective solar radiation, the value of 1000W/m^2 , then from Equation(3),and table(1) the efficiency of the solar collector is:

$$\eta = 0.7 - 2.5\frac{130 - 30}{1000} = 0.45$$

Then the energy absorbed is:

$$Q_{abs} = 0.45 \times 1000 = 450 \text{ W/m}^2$$

This result in a total absorption (receiver) area of:

$$A_{abs} = \frac{345}{450} = 0.77 \text{m}^2$$

The required outside wall temperature of the absorber is calculated from following equation:

$$Q_{abs} = U_a(T - T_{abs,ave})$$

$$T_{abs,ave} = \frac{T_i + T_o}{2} = \frac{130 + 200}{2} = 135°C$$

Where T_i and T_o are inlet and outlet temperatures of absorber, respectively, and U_a is the heat conduction coefficient =8W/m^{2o}C.Then:

$$T = \frac{450}{8} + 165 = 221.25°C$$

The thermal output Q_{out} of concentrating collector operating at temperature T is given by:

$$Q_{out} = Q_g = F_m(\tau\tau\alpha_e A_{in} q_{in} - F_m U_a A_{abs}(T - T_a) \qquad (9)$$

Dividing equation (9) by A_{abs} yield:

$$\frac{Q_g}{A_{abs}} = Q_{abs} = F_m(\tau\tau\alpha_e \frac{A_{in}}{A_{abs}} q_{in} - F_m U_a(T - T_a)$$

$F_m = 0.9, (\tau\alpha)_e = 0.8, \text{and } q_{in} = 1000 W/m^2$ then:

$$\frac{A_{in}}{A_{abs}} = \frac{0.9 \times 8(221.25 - 30)}{720} + 450 = 2.54$$

Then:

$A_{in}=0.77\times2.54=2m^2$

Heat storage

Heat storage tank was shown in figure(1), allows a solar thermal plant to produce power at night and on overcast days. This allows the use of solar power for base load generation as well as peak power generation, with the potential of displacing both coal and natural gas fired power plants. Additionally, the utilization of the generator is higher which reduces cost.

Heat is transferred to a thermal storage medium in an insulated reservoir during the day, and withdrawn for power generation at night. Thermal storage media include pressurized steam, concrete, a variety of phase change materials, and molten salts such as sodium and potassium nitrate.

Heat transport refers to the activity in which heat from a solar collector is transported to the heat storage vault. Heat insulation is vital in both heat transport tubing as well as the storage vault. It prevents heat loss, which in turn relates to energy loss, or decrease in the efficiency of the system.

Results & Discussion

Solar cooling systems strongly depend on local conditions e.g. solar radiation, ambient temperature, or cooling load. Systems should therefore be specifically designed for each location, thereby obtaining the best performance. For thermally-driven systems, a solar cooling system requires less solar collector area per cooling demand (kWh. One severe restriction for solar cooling in general is the heat rejection temperature. Heat sink temperatures must be kept as low as possible in order to maintain a stable operation and high performance.

A good local heat sink such as a lake, a river or the sea or even a cooling tower can be used with additional parasitic energy consumption for the latter. The best solar cooling locations are therefore located near sufficient solar radiation and a good heat sink.

Solar driven absorption refrigerator need less initial operating time than gas fired refrigerator, when increase the working fluid flow rate at initial time. This refrigerator is expensive compare with gas fired and electrical refrigerators but it is active when the house is complete work with solar energy(heating, washing, cooking, …etc) and in the remote areas (out of electrical grid).The refrigerator is not operate when the working fluid from collector pass along the whole boiler tube because no temperature gradient occurs.

The disadvantages of using solar instead of gas fired refrigerator:

- The efficiency of solar refrigerator will be approaches to minimum value with the presence of cloud, or at night.
- There are some difficults for the multi-components that connected with the solar refrigerator system.

References

1. Kapar, J. C., Areport on Utitization of Solar Energy for refrigeration and air conditioning applications, Solar Energy, 4, (1960).
2. Development Trends in the Production of Energy Electrowatt Engineering Services Ltd. Zurich, (1979).
3. International Symposium Workshop Solar Energy, (16-22), June, Cairo, Egypt, (1978).
4. Transactions of the conference on the use of Solar Energy, the Scientific Basis Tuscan, University of Arizona Press, (1958).
5. Christopher Carroll, Lucas Growth model, 29, pp. 1-5 (2009).
6. Simth M. C. Geothermal Energy, Loss Alamos Report La-5289- Ms. 1973.
7. Solar Energy Research, Univ. of Wisconsin Press (1955).
8. Lucas, Rebert E., on the mechanics of Economic Development, J. Monetary Economics, 22, pp. 3-42, (1988).
9. Eisenstadt. M., Flanigan, M, & Farber, A., Solar Air conditioning with an Ammonia- water Absorption Refrigeration system, AM. SOC. Mec. Eng., (1959).
10. Key Issues for Renewable Heat in Europe (K4RES-H), Solar Assisted Cooling-WP3, Task, 3.5, European Solar thermal Idustry Federation (2006).
11. R. H. B. Exel, Principles of Solar thermal conversion, King Mongkut's University of Technology Thonburi (2000).
12. Carl G. Alimen Chapter 3 (The gas circulation), pp. 3-13, (2007).