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Utilizing Solar Energy for Room Airconditioning System

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***Abstract*— In this research work, the working of solar air-conditioning system has been considered. This paper includes construction wise and parameter wise analysis of this complete system specially designed for Indian climate. The power consumption is a very major issue in India and the paper solves the problem of power consumption especially in the case of air-conditioning. Construction and working of air conditioning system has been explained and all the parameters related to the system have been considered. It will also have a small energy storage capacity. Variation in operating conditions of the system has been taken into account, while designing the system.**

Keywords— Solar Air-Conditioning; Optical Air-conditionin; Thermal Conditioning;

I. Introduction

India due to its locational advantage in the equatorial sun- belt is blessed to receive plentiful of solar energy which in future will play a major role when it comes to energy availability on our planet. India receives sunshine and has clear sky conditions for approximately 300 days in a year. Hence, we are ideally located to receive solar energy and harness the same to supplement our energy demand. Solar energy is a clean energy and can be utilized to operate our household appliances including the air conditioners. In the last couple of decades considerable work has been done in using the solar energy for cooling of buildings and also in water and room heating. In-spite of tremendous work carried out in this direction, practical use due to the problems related with storing of the energy, use at night and cost effectiveness, is limited and major breakthrough is still awaited. Various researchers [1] [2] and [3] have come out with some practical solution which utilizes some supplementary source of energy in conjunction with solar energy for refrigeration and air conditioning purposes. The major difficulty experienced is in making cost effective and efficient hybrid solar air conditioners, which is capable of harnessing solar energy thorough solar collectors, store it and then power the air conditioner for its use when mostly required.

II. General Discussion

A. Solar Energy Availability

The estimation of solar energy can be done from the meteorological data [4] and the empirical relation [5]. The information given in them will help us in choosing the type of collectors, angle of tilt and the direction which the collectors should face to receive maximum solar radiation.

B. Solar Collectors Types

Solar Collectors are either focusing (concentrating) or flat plate collectors. The focusing collectors are more efficient and give higher temperatures. However, they require direct sunlight and are not operative in the cloudy or partly cloudy sky. The limiting factors in their practical use are high initial capital cost and maneuverability. In comparison, flat plate collectors are simple in design and cheaper and hence widely used, even though they are high on energy losses.

C. Flat-Plate Collectors

Flat plate collectors of various designs- tube in plate type, spiral wound types are in existence and their designs have been studied. The collector sheets are of conducting material. The absorptivity is increased by painting them black. Heat transfer losses are reduced by provision of air gaps. Non-exposed sides are insulated. The complete assembly is put and fixed in an air tight wooden box and erected to ensure desired direction of inclination. The direct and diffused solar energy absorbed by the collector is transferred to fluid flowing in the collectors. The output of the collector is boosted by the help of flat mirrors [6]. The mirrors may be reversible or irreversible type. Use of flat mirrors improves output and ensures higher operation temperature. Side mirrors can also be used on the edges. A lot of research work and experimentation has been done on collectors with an aim to evolve an effective, reliable and cost effective flat plate collector.

D. Solar Cooling System

A cooling system based on solar energy collects solar energy through solar collectors. In the system under consideration flat plate collectors of lower temperature range have been keeping in view the cost factor. The solar energy has its own shortcoming relates to its control, low concentration and intermittency. The flat plate collectors more or less ensure obtainable temperature for its application in the solar absorption refrigeration systems.

The solar absorption cooling systems have been the focus of study and many researchers have explored this field to achieve a break through. Many refrigerant –absorbent combinations are available. The deciding factors are pressure, temperature and the overall performance represented by the co-efficient of performance. In the system under study Ammonia-water combination has been used due its overall coefficient of performance and other associated advantages. It gives almost equal performance to other combination under the assumption that no water is transferred to the condenser. The generator temperature inlet range required in between 85^o-180^oC. The energy storage which may be considered is for hot side, cold side arrangement for liquid refrigerant and cooling space.

E. Solar Air-Conditioning System

In this investigation, ammonia water pair has been used. The storage arrangement has been made for the hot side and for the liquid refrigerant: Flat plate collectors. Because the hot side storage and the receiver is the liquid refrigerant storage. The schematic diagram showing the entire process is shown in fig.1. Other arrangements are liquid cooler, an evaporator and an absorber, a safety tank and heat exchanger. Other small but significant equipment is various control values, pump, blower and pipes which connect the complete equipment. In order to achieve efficiency and compactness, the collectors, storage and generator are made to function in one unit with the purpose of raising the temperature.

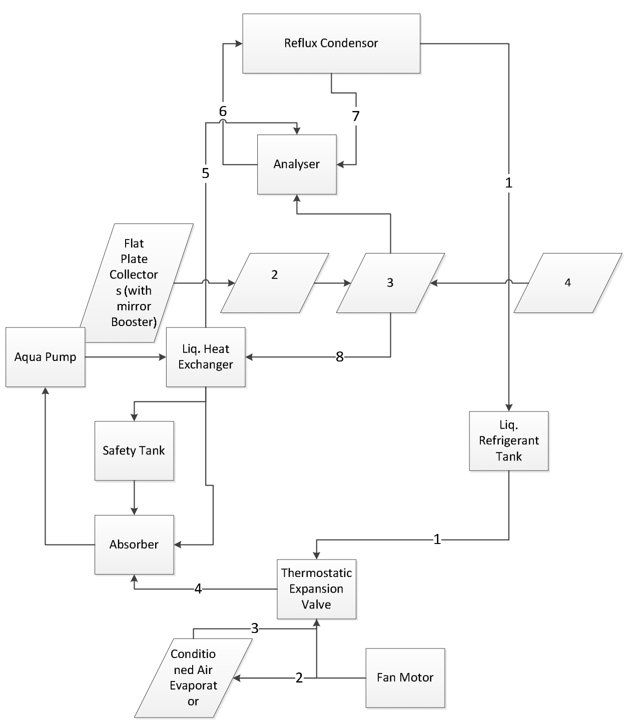


Fig.1. Solar Air-Conditioning System

The weak solution which is pumped from the absorber and through the heat exchanger is heated from the solar energy collected by the flat plate collectors which are filled with aqua ammonia solution. There is no change in the ammonia concentration in the ammonia solution.

As the heating takes places, water vapor from the weak solution is made and concentration of ammonia is improved. On the top of the collectors, analysis is placed. The ammonia passes through the analyzer to the reflux condenser. At these places, last trances of water are removed. The strong liquid ammonia is stored in the receiver which is provided with a constant flow valve non return value.

The strong liquid ammonia passes through the expansion value and reaches the evaporator whose performing of ammonia vapor takes place by the process of absorption of heat. The ammonia vapor is reabsorbed in the absorber and pumped to the compact unit of collector, storage and generator to repeat the cycle.

Colling of absorber and reflux condenser is achieved with the help of water circulation. Adequate mixing of solution and ammonia is provided in the absorber. The system starts working after initial warming up as the sun rises. Generator of ammonia depends upon the temperature and concentration of ammonia solution. Generation of ammonia in excess of the system requirement is stored in the receiver. As the sun sets and availability of solar energy goes down, the evaporator draws the ammonia supply from receiver. It increases the concentration of aqua ammonia in the generator. The ammonia generator commences till the minimum operating temperature is achieved. Due to power failure or otherwise, the aqua ammonia solution passes to safety tank to avoid any built up of pressure. Tanks are insulated to avoid loss of heat and quick starting up. The design consideration has taken come of the operating range of 85^o to 180^o C of ammonia water has been chosen accordingly. The components can with stand the operating range. The liquid heat exchanger incorporated gives strong aqua solution at saturation / near saturation condition.

III. Analysis

We have carried out analysis for

Outside conditions	37.5^o to 43.5^oC
	26.5^o to 29.5^oC
Design Condition	DBT 25^oC, RH 55%

The temperature and pressure obtained are tabulated in Table I.

TABLE I. TEMPERATUR & PRESSURE TABLE

Sr. No.	Item	T (Degree/centigrade)	Pressure (Kg/sq. cm)	Remarks
1	Cooling Water	32	-	
2	Evaporator	10	6.30	
3	Absorber	38	6.23	It is 0.07 Kg/sq. cm lower than evaporator pressure
4	Reflux Condenser	38	15	
5	Generator	85/125	15.10	It is 0.10 Kg/sq. cm higher than condenser pressure
6	Pre- cooler water	32	-	
7	Strong aqua ammonia solution entering the generator	72	-	
8	Ammonia Vapor leaving Analyzer	78	-	It is 6 degrees higher than ser No 7
9	Ammonia Vapor leaving Pre-cooler	32	-	It is 6 degrees lower than ser No 4

Equilibrium conditions have been taken at points 1, 7 and 8. Designing of components have been done at 85°C and 125°C. For the thermodynamic analysis, the method suggested by Jordan and Priester have been chosen [7]. Table II and Table III are the thermodynamic analysis at 85°C and 125°C.

TABLE II. GENERATOR TEMPERATURE DATA

Location	Pressure P kg/cm^{-2}	Temp TOC	Flow Weight W kg/unit time	Concentration X	Specific Enthalpy h (KJ.kg-1)	Total Enthalpy H (KJ)	For one Ton H (KJ/min)	Mass Flow (For One Ton kg/min)
1	15.22	38.0	1.0	1.00	176.14	176.14	31.752	0.20
2	14.90	-	1.0	1.00	110.04	110.04	19.908	0.20
3	6.37	10.0	1.0	1.00	1277.64	1277.64	231.84	0.20
4	6.20	32.0	1.0	1.00	1344	1344	247.59	0.20
5	15.35	72.0	7.64	0.58	95.76	709.80	128.73	1.25
6	15.35	78.0	1.05	0.99	1428	1445.22	260.40	0.183
7	15.35	38.0	0.05	0.02	158.76	1.932	0.3486	0.0033
8	15.35	85.0	6.53	0.50	147	942.90	171.36	1.21

TABLE III. THERMAL ANALYSIS DATA

Ser. No.	Pressure p kg/cm-2	Temperature TOC	Flow Weight W kg/unit time	Concentration X	Specific Enthalpy h KJ.kg-1	Total Enthalpy H KJ	For one ton H KJ/min	Mass Flow For one ton kg/min
1	15.22	38.0	1	1.00	175.14	175.14	31.75	0.20
2	14.90	-	1	1.00	110.04	110.04	19.90	0.20
3	6.37	10.0	1	1.00	1277.64	1277.64	231.84	0.20
4	6.20	66.0	7.9	0.40	58.33	446.04	81.06	1.20
5	15.35	102.0	7.9	0.40	244.86	1892.1	340.62	1.20
6	15.35	112	1.08	0.98	1572.06	1297.8	301.14	0.20
7	15.35	38.0	0.08	0.02	158.76	10.08	1.84	0.02
8	15.35	125.0	6.80	0.32	380.1	2557.8	459.90	1.20

IV. Components

A. Flat Plate Collectors

The flat plate collectors basically advocated by Hottel and Whillier serves the purposes [8]. A total of four such collectors have been used.

$$Heat\ load\ for\ one\ ton\ =\ 12660\ KJ/Hr.$$

If the system has to operate for 8Hours/day then

$$Heat\ load/day\ =\ 12660 \times 8$$
$$=\ 101280\ KJ/day$$

Assume collector capacity as 1055 KJ/ft^2

$$Then\ collector\ area\ =\ 101280/1055$$
$$=\ 96\ ft2$$
$$=\ 8.85\ m2$$
$$Let\ us\ select\ size\ of\ collector\ =\ 1.85m2x1.25m2$$
$$=\ 2.3125\ m2$$
$$No. of\ collectors\ =\ 8.8/\ 2.3125$$
$$=\ 4\ collectors$$

The absorbing surface is 3 cm dia. pipe with center distance of 10 cm to 5 cm diameter. header pipes. The pipes have weak ammonia liquid flowing with them. The exposed surfaces are painted black and are insulate to present heat less. The absorber faces SSW with a tilt of 15^o to 18^o to achieve best performance.

B. Analyzer

This analyzer along with reflux value removes water vapor from ammonia. A three plate analyzer with feed at the top of the middle plate has been considered. One bubble cap on each tray is provided is a pipe size of 10 cm.

C. Reflux Condenser

A shell and a tube type condenser have been considered. Shell is one with two tube passes. The diameter of the shell is 10 cm with 6 to 8 baffles. The cooling water passes through 6 tubes of 2 cm outside diameter. The overall heat transfer coefficient of 3600 KJ/hr. m^2 ^{o}C has be designed considered.

D. Absorber

The construction is same as reflux condenser. It contains the weak ammonia solution. It is also connect to the safety as absorbent. Ammonia vapor from evaporates is absorbed readily here. The liberation of heat is neutralized by circulation of cold water as in the case of reflux condenser. The ammonia vapor enters the absorber from evaporator with 2 cm dia. pipe. Nozzles are located at top to spray aqua ammonia solution from generator. The aqua pump is of 50 Watt rating.

E. Liquid Heat Exchanger

It is of dual pipe construction having nine sections. Each section is 200 cm long. The outer pipe in which strong solution flows is of 1.5 cm dia. and the inner pipe in which weak solution flows is of 0.5 cm. an overall heat transfer co-efficient of 3500 KJ/hr. m^2 ^{o}C has been taken into account.

F. Pipes

Since, we are working to achieve one ton of refrigeration, the pipes selected for inter connection of components are 0.5 cm, 1 cm and 2 cm. the material is CVPC pipes.

G. Pumps

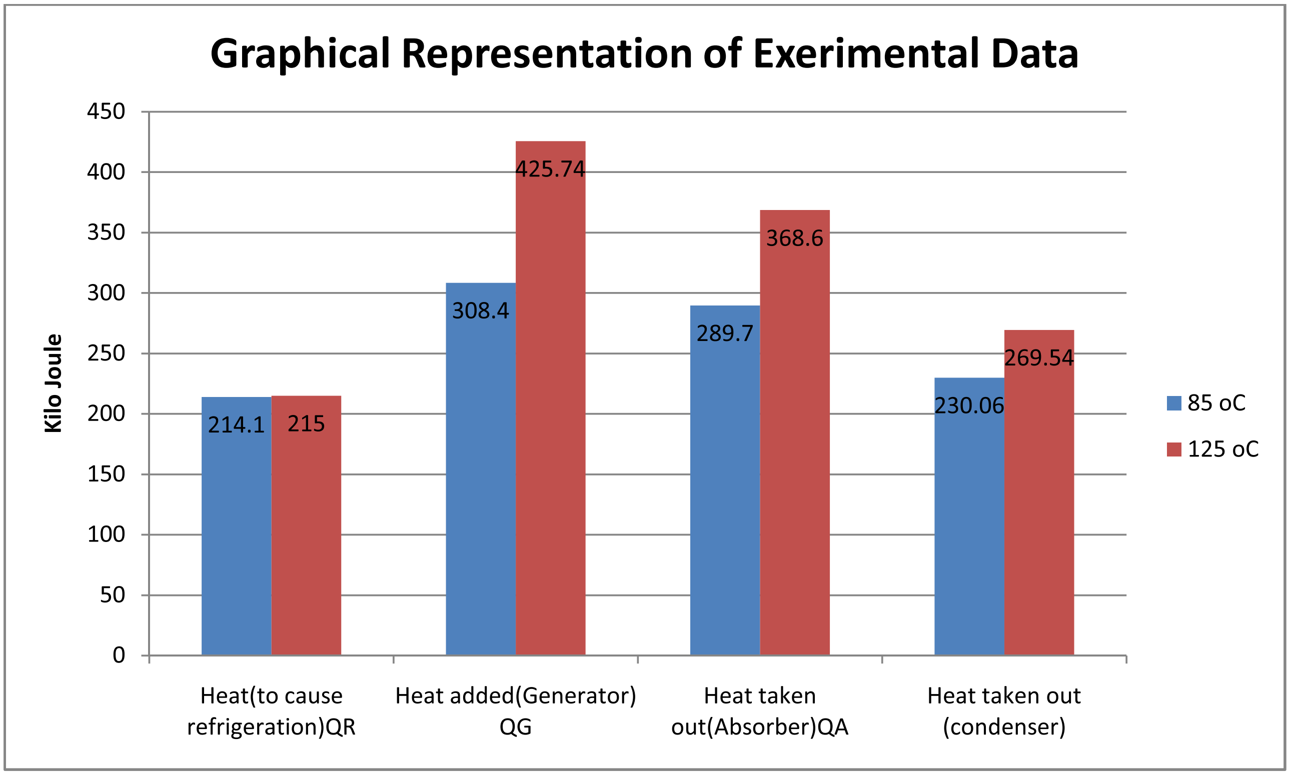
The ratings of pumps are; aqua pump 50 watts, water pump 100 watts and the fan are also of 50 watts.

V. Result

The above research gives the result in two different atmospheric conditions. Table IV and Table V has two temperatures 85^{o}C and 125^{o}C. In Table IV we are calculating Heat Q_R, Heat added Q_G, Heat Taken out Q_A, Heat Taken Out (Condenser) and Energy added by Aqua Pump. These are the parameters which are calculated from the experiment demonstration.

TABLE IV. Experimental Calculations

Ser. No.	ITEM	UNIT	TEMPERATURE		REMARKS
			85^{o}C	125^{o}C	
1	Heat(to cause refrigeration)QR	KJ.m^{-1}	214.10	215.00	The mass flow rate through condenser is 0.20kg/min
2	Heat added(Generator) QG	KJ.m^{-1}	308.40	425.74	
3	Heat taken out(Absorber)QA	KJ.m^{-1}	289.70	368.60	
4	Heat taken out (condenser)	KJ.m^{-1}	230.06	269.54	
5	Energy added by Aqua Pump	KJ.m^{-1}	2.30	2.30	Assuming pump efficiency of 70%



From the above table we are calculating coefficient of performance which is shown in Table V. This Coefficient of Performance evaluates the capacity of air-conditioner. The Coefficient of Performance for 85°C is approximate 0.69 and for 125°C, it is 0.51. This data is very less for an efficient system so for improving this system we are working on another mechanism of air-conditioner and that is also completely based upon solar energy.

$$COP = \frac{Q_R}{Q_G}$$

TABLE V. COEFFICIENT OF PERFORMANCE

Ser. No.	FORMULA	TEMPERATURE		REMARKS
		85°C	**125°C**	
1.	Q_R/Q_G	0.69	0.51	For Q_R and Q_G (refer Table IV)

VI. CONCLUSION

The air-conditioner system by using solar energy has been articulated. Variations in operating conditions have been taken into account. The design will be fully tried and after fabrication result analyzed. However, it has been seen from the various research/experimentation done that the use of ammonia is dangerous if proper safety precautions are not accounted for in the system and the COP of ammonia-water pair is low as compared to ammonia with other combinations. While doing the research, another method of cooling by using Low Pressure Thermocouple Mist Chamber was experimented side by side. This field of research seems to be more promising.

VII. REFERENCE

[1] L. Fatiha and E. Abdelmoussehel, "Experimentation of a solar adsorption refrigerator in Morocco," Renewable Energy, vol. 32, pp.2629-2641, December 2007.

[2] Khalil, Essam E.,"Efficient energy utilization in air conditioned buildings in Egypt: New directive", Thermal Issues in Emerging Technologies, 2008. ThETA '08. Second International Conference on Digital Object Identifier: 10.1109/THETA.2008.5167194 Publication Year: 2008 , Page(s): 443 – 448.

[3] Technical and economic analysis of a solar — Assisted air-conditioning system Sayadi, Z. ; May, S.E. ; Bourouis, M. ; Bellagi, A. Thermal Issues in Emerging Technologies Theory and Applications (ThETA), 2010 3rd International Conference on Digital Object Identifier: 10.1109/THETA.2010.5766415 Publication Year: 2010 , Page(s): 331 - 338.

[4] "Impact investigation of rooftop Solar PV system: A case study in India" Joshi, K.A. ; Pindoriya, N.M. Innovative Smart Grid Technologies (ISGT Europe), 2012 3rd IEEE PES International Conference and Exhibition on Digital Object Identifier: 10.1109/ISGTEurope.2012.6465813 Publication Year: 2012 , Page(s): 1 - 8.

[5] "The development of multifunctional solar assisted airsource air conditioner with hot water machine and its operation analysis" Ji Chaoyang ; Chen Jianbo ; Zhou Cong ; Zhong Jiaxian Electric Technology and Civil Engineering (ICETCE), 2011 International Conference on Digital Object Identifier: 10.1109/ICETCE.2011.5775920 Publication Year: 2011 , Page(s): 1680 – 1683.

[6] A physical model based approach to distributedcollector solar field control Silva, R.N. ; Rato, L.M. ; Barao, L.M. ; Lemos, J.M. American Control Conference, 2002. Proceedings of the 2002 Volume: 5 Digital Object Identifier: 10.1109/ACC.2002.1024523 Publication Year: 2002, Page(s): 3817 - 3822 vol.5.

[7] Jordan, Richard Charles & Priester, Gayle B 1956,Refrigeration and air conditioning, 2nd ed, Prentice-Hall, Englewood Cliffs, N.J

[8] L.W. Florschuetz, Extension of the Hottel-Whillier model to the analysis of combined photovoltaic/thermal flat plate collectors, Solar Energy, Volume 22, Issue 4, 1979, Pages 361-366, ISSN 0038-092X, http://dx.doi.org/10.1016/0038-092X(79)90190-7