DESIGN AND ANALYSIS OF THERMOSYPHON SOLAR AIR-CONDITIONING AND REFRIGERATION SYSTEM

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Abstract - *This paper presents a detailed survey and description of a new solar based air-conditioning technique. The use of solar powered air conditioning systems for heating and cooling requirements in the buildings would be more economical. Aim of this project is to review the literature on emerging technologies for solar air conditioner and provide knowledge which will be helpful to initiate the study in order to investigate the influence of various parameters on the overall system performance. Solar cooling is a clean and cost-effective technology, solar cooling offer environmental benefits including reducing main grid demand and shift the load during peak usage and reduced greenhouse gas emissions. The aim of the project is to study thermo-siphon solar absorption cooling systems with the absorption pair of lithium-bromide and water. Thermo-siphoning principle is used for circulation of liquids and volatile gases in heating and cooling applications. Natural convection of the liquid starts when heat transferred to the liquid gives rise in temperature differences which will have a corresponding pressure difference, due to this pressure difference natural convection takes place. In this project solar energy is being used as the main power source, as a result the overall efficiency of the system could be improved.*

Key Words: **Thermo-siphon system, Heat Transfer, solar air-conditioning, Creo element pro, Ansys, Transient thermal analysis, Thermal Heat Load, Thermodynamic properties.**

1. INTRODUCTION

Solar air-conditioning system is an innovation made to reduce the application of electricity for people or companies who installs such a system inside their offices or homes. Instead of using ordinary electricity to power up those conventional air conditioners which can be very expensive, this innovation allows you to save up on costs because it is powered largely by solar technology. It's always best to use in places where there's an abundance of sunlight. This system will certainly become the most cost-effective solution in reducing the temperature in one place.The main consumption factors in the residential field is: heating and air-conditioning, sanitary hot water, lighting and electric devices. Air-conditioning and heating consumes the largest part of the invoice then comes the sanitary hot water and then the lighting. This consumption can reach 75% of the total electric energy production.

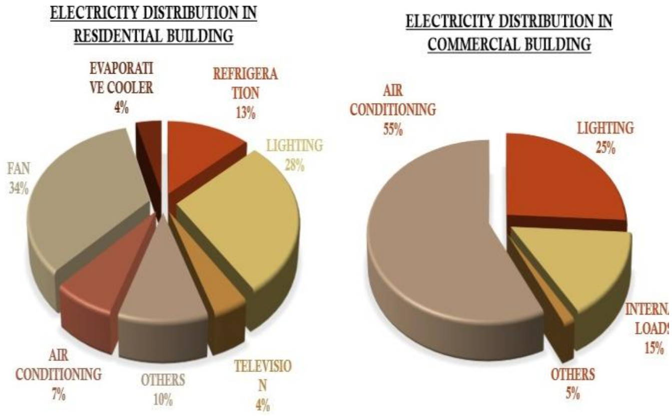


Figure No. 1 Power consumption

1.1 Solar Air-conditioning

Process of converting solar thermal energy into conditioned air. Eco-friendly as well as Energy-efficient. Solar air conditioning refers to any air conditioning system that uses solar power. Solar air conditioning units come in two basic types, mainly hybrids and chillers. Solar-powered absorption chillers, also known as evaporative coolers, work by heating and cooling water through evaporation and condensation respectively.

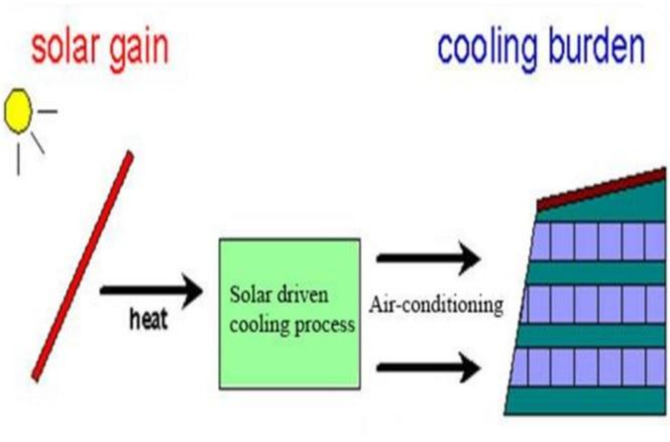


Figure No. 2 Solar Air-conditioning Layout

1.2 Solar powered vapor absorption cooling system

The solar collector converts the solar energy from sunlight to thermal energy, The Thermal energy is then passed through high temperature energy storage tank then to the absorption system.

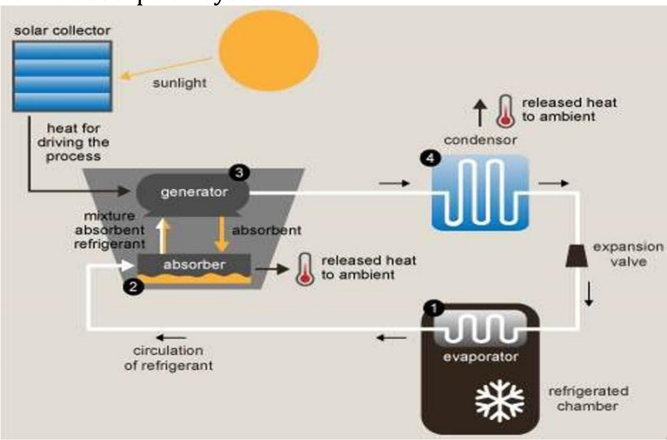


Fig No. 3 Solar powered vapor absorption system

2. Solar powered vapor absorption cooling system

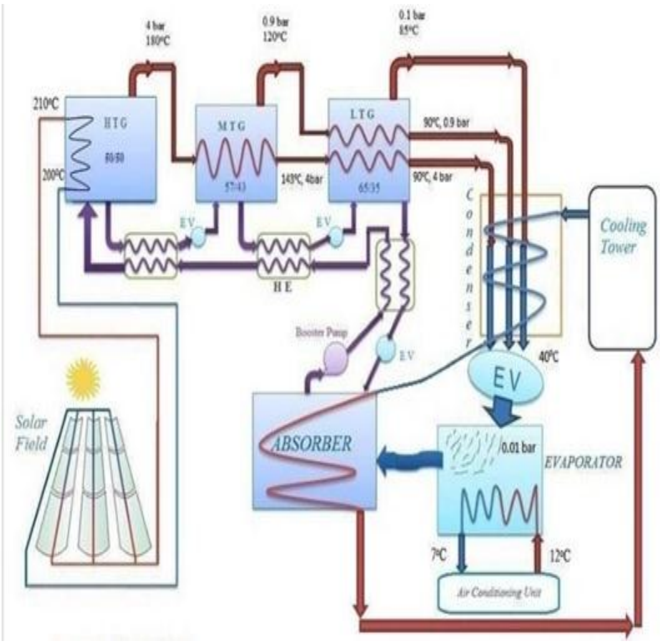


Figure No. 4 Advanced solar absorption Air-conditioning system

2.1 Parts of a vapor absorption cooling system

Evaporator

The building load is taken in the evaporator, as the water evaporates and the water vapor will pass to absorber. Inside the evaporator, relatively warm return water from the chilled-water system flows through the tubes. An evaporator pump draws the liquid refrigerant from the bottom of the evaporator and continuously circulates it to be sprayed over the tube surfaces. This maximizes heat transfer. As heat transfers from the water to the cooler liquid refrigerant, the refrigerant boils (vaporizes) and the resulting refrigerant vapor is drawn into the lower pressure absorber. Physically, the evaporator and absorber are contained inside the same shell. The vacuum is created by hygroscopic action due to the strong affinity lithium bromide has for water makes the refrigerant to move to absorber.

Absorber

The Lithium bromide absorbs the water and form weak solution then it is passed to the generator through intermediate heat exchanger. Absorber types used for Lithium bromide-water system is absorption of vapor refrigerant into a falling film of solution over cooled horizontal tubes

Generator

The hot water used to separate the weak solution form water vapor and form strong lithium bromide solution, and then the water vapor is passed to the condenser. The hot water provided from Low-grade heat source can be upgraded by using **solar energy.** At this part we use a thermo-syphon based system instead of using a motor to circulate the water. Cu tubes would be present in the solar collector setup water do flows though the tubes, and in this way temperature would increase and hence the pressure. The cold water tank would be located at a certain altitude when compared to the solar collector, this let cold water to come down due to gravity and the hot water is lighter and it would move up and in this manner natural convection takes place.

Heat exchanger

The strong solution of lithium bromide is passed to the absorber through heat exchanger after the separation in the generator. The weak solution from the absorber is pumped through the same heat exchanger to the generator, so the temperature of weak solution increased while as the strong solution temperature decreased.

Condenser

The cold water from cooling tower used to remove the heat and condensate the water vapor, and then the liquid water will enter the expansion valve.

Cooling water from cooling tower

Cold water supplied from cooling tower used to remove the heat from condenser and absorber then the heat is dissipated in the cooling tower to outside.

Auxiliary heat source

The auxiliary heat source is needed when sun is not shining or solar energy source is not enough to main continuous operation.

Medium (Refrigerant- absorbent pair)

Water-Lithium Bromide (H2O-LiBr) system for moderate temperatures (above 50C) applications specifically air conditioning and water chiller. Here water as refrigerant and solution of lithium bromide as absorbent is being used.

Lithium bromide is a salt which has high affinity towards water hence help in absorption.

3. LITERATURE SURVEY

Sustainable Solutions for Energy and Environment Ayman Jamal Alazazmeh [1] The study presents a global evaluation of the potential to use solar radiation in the air conditioning with application to an office building located in Cluj-Napoca, Romania. The study was realized for a one year period, based on multiannual average values for solar radiation and ambient temperature. It were compared the performances of two types of solar cooling systems, one based on absorption chiller and one of photovoltaic type

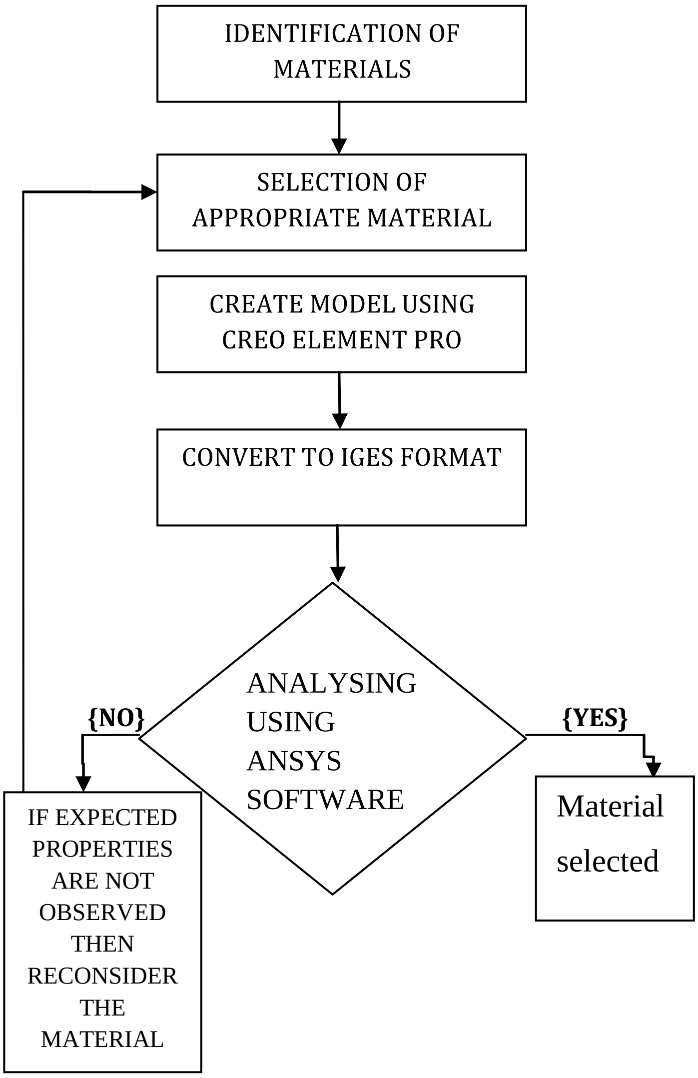
Aref Y. Maalej, and Hamed [2] This paper presents a detailed survey and description of a new solar -based air-conditioning technique using a solid adsorption system. This technique uses solar energy to produce cold or hot air and does not pollute the environment. The key component of the system is a rotary desiccant wheel used for dehumidification. The design procedure suggested is simple and does not require high technology. This type of unit can be used widely in the regions with abundant solar resources due to such advantages as environmental protection, energy saving and low operation costs.

Esmail M Mokheimer King Fahd University of Petroleum and Minerals[3] Solar cooling is a clean and cost-effective technology, solar cooling offer environmental benefits including reducing main grid demand and shift the load during peak usage and reduced greenhouse gas emissions. The main objective of this paper is to review and analyze different solar cooling technologies that can be used to provide the required cooling and refrigeration effect from solar energy.

Christopher Baldwina, Colonel By Drive, Ottawa, Ontario[4] The implementation of solar cooling systems could assist in reducing this energy consumption, and consequently, reduce greenhouse gas emissions released into the atmosphere as a result of the generation of the required electricity to power typical air conditioners. Related work conducted under the International Energy Agency is also described and a review of cooling installations both worldwide and Canada are discussed.

K. Sopian, M.M.S. Dezfouli, S. Mat and M.H. Ruslan Solar Energy Research Institute[5] Solar assisted desiccant cooling system is an attractive and cost effective application for air conditioning system. To find effect of dehumidification capacity on the performance of cooling system, four configurations of desiccant cooling system have been investigated. . It was achieved that by increasing the dehumidification capacity of desiccant cooling system the COP of system will be increased. Therefore, due to high dehumidification capacity, the two-stage ventilation mode with 1.06 of COP was considered as the best model amongst the other configurations.

4. METHODOLOGY



5. MATERIALS

5.1 EXISTING MATERIALS

5.1.1 Water based cooling systems

The thermo-syphon cooling system operates on the principle of natural convection caused by variation in density of water, and hence does not use a pump. Initially we were using water as a medium for heat exchange, the process was like water flows through the heat exchanger tubes and water absorbs heat when it enters the evaporator coil and emit heats when it passes through the condenser coil The heated water expands, due to which the density decreases. When it cools down, its volume decreases and hence density increases. These variations in density set up convection currents so that circulation of water takes place.

All components of water-cooling systems except the circulating pump are being used.

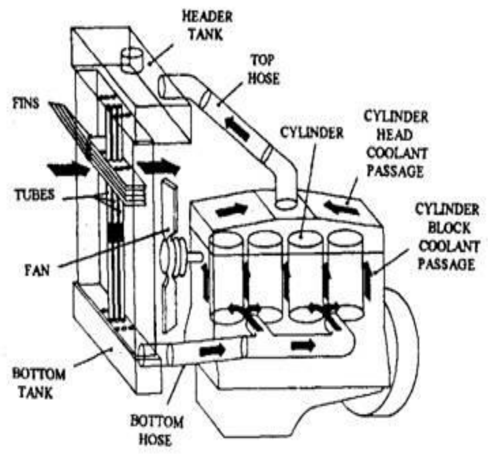


Figure No.5 Thermo-syphon based cooling system in automobiles

5.1.2 Thermo-syphon based cooling system using solar power

As the sun shines on the collector, the water inside the collector flow-tubes is heated. When it gets heated, this water expands slightly and becomes lighter than the cold water in the solar storage tank mounted above the collector. Gravity then pulls heavier, cold water down from the tank and into the collector inlet. The cold water pushes the heated water through the collector outlet and into the top of the tank, thus heating the water in tank and this cycle repeats. Valves are being used to control the flow.

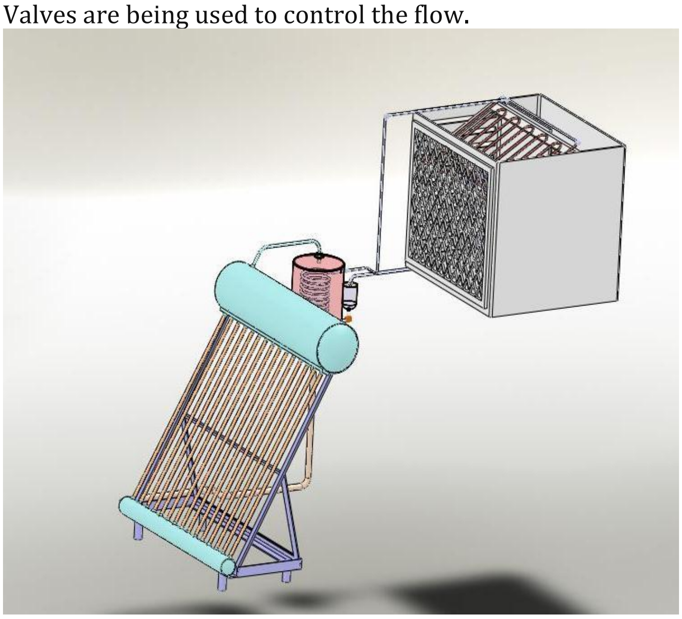


Fig No. 6 Thermo-syphon solar-air-conditioning setup

A thermos-syphon system requires neither pump nor controller. Cold water from the city water line flows directly to the tank on the roof. Heated water flows from the rooftop tank to the auxiliary tank installed at ground level whenever water is used within the residence. This system features a thermally operated valve that protects the collector from freezing. It also includes isolation valves, which allow the solar system to be manually drained in case of freezing conditions, or to be bypassed completely.

5.1.3 Advantages of thermo-syphon cooling systems

- Cheap as no water pump is required.
- Reliable as there are no moving parts. Circulation of water depends solely on engine temperature. The hotter the engine, the greater is the circulation.
- Simple and rugged construction.
- Lower maintenance cost

5.2 NEW MATERIAL

LITHIUM BROMIDE

LiBr is prepared by treatment of lithium carbonate with hydro bromic acid. The salt forms several crystalline hydrates, unlike the other alkali metal bromides. The anhydrous salt forms cubic crystals similar to common salt (sodium chloride). Lithium hydroxide and hydro bromic acid (aqueous solution of hydrogen bromide) will precipitate lithium bromide in the presence of water.

LiOH + HBr → LiBr + H2O

Lithium bromide is used in air-conditioning systems as desiccant. Lithium bromide is used as a salt in absorption chilling along with water (see absorption refrigerator). Otherwise the salt is useful as a reagent in organic synthesis. For example, it reversibly forms adducts with some pharmaceuticals. Using water and lithium bromide which are natural as refrigerant medium, no CFCs, few moving parts enable quiet and vibration-free operation.

Mechanical properties

Density

Density is defined as an object mass per unit volume. Mass is a property.

The density can be expressed as

$\rho = m / V = 1 / v_g$, where,

ρ = density (kg/m^3)

m = mass (kg)

V = volume (m^3) and v_g = specific volume (m^3/kg)

Density of lithium bromide substance at 20 °C is 3.46 g/ccm

Molecular weight: 86.85kg/kmol

Pressure

Pressure is a measure of the force exerted per unit area on the boundaries of a substance (or system). It is caused by the collisions of the molecules of the substance with the boundaries of the system. As molecules hit the walls, they exert forces that try to push the walls outward. The forces resulting from all of these collisions cause the pressure exerted by a system on its surroundings. Pressure is frequently measured in units of N/m^2 ($kg/m.s^2$).

Table No.1 Temperature pressure relation chart

Temperature (°C)	(°F)	psia
25	77	0.0765
38	100	0.01689
66	150	0.7551
93	200	2.640

Absolute pressure

It is the actual pressure at a given position and it is measured relative to absolute vacuum (i.e., absolute zero pressure).The eddy viscosity is also commonly called the turbulent viscosity and it is normally written as μ_t.

Solubility

Amount of a substance (called the solute) that dissolves in a unit volume of a liquid substance (called the solvent) to form a saturated solution under specified conditions of temperature and pressure. Solubility is expressed usually as moles of solute per 100 grams of solvent.

Table No.2 Temperature vs. solubility chart

APPEARANCE	white, crystalline powder
FORMULA	LiBr
PHYSICAL PROPERTIES	Molecular weight: 86.85
	Density: 3.46 g/ccm (at 20 °C)
	Boiling Point: 1,265 °C
	Solubility:

Temp. °C	g / 100 g H_2O
-20	111
0	130
20	149
50	191
100	232

Solution enthalpy in water
2.7 kJ/Mo

Thermal conductivity

Temperature is a measure of the molecular activity of a substance. The greater the movement of molecules, the higher the temperature. It is a relative measure of how "hot" or "cold" a substance is and can be used to predict the direction of heat transfer. The heat transfer characteristics of a solid material are measured by a property called the thermal conductivity(k) measured in W/m-K. It is a measure of a substance's ability to transfer heat through a solid by conduction. The thermal conductivity of most liquids and solids varies with temperature. For vapors, it depends upon pressure. Crystallization temperature -16°C (3°F) Boiling point @ 760 mm Hg 141°C (285°F)

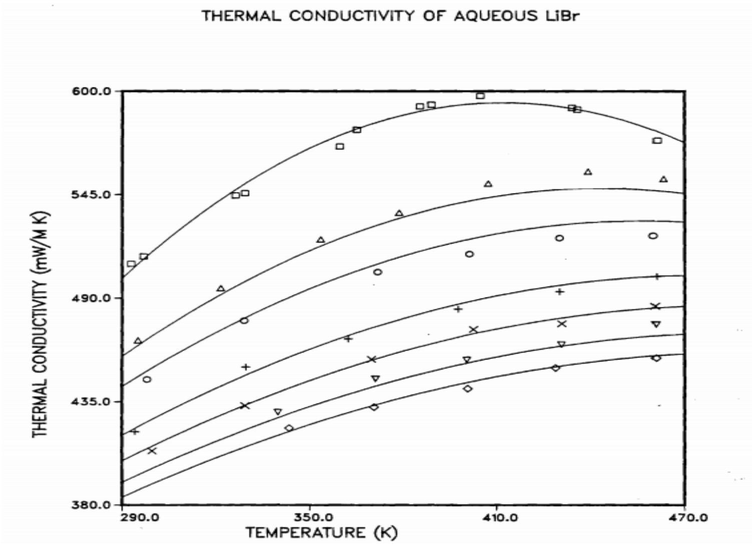


Fig No. 7 Thermal conductivity vs. Temperature graph

6. DESIGN AND ANALYSIS USING ANSYS

ANSYS Mechanical technology incorporates both structural and material non-linearity. ANSYS Metaphysics software includes solvers for thermal, structural, CFD, electromagnetic, and acoustics and can Sometimes couple these separate physics together in order to address multidisciplinary applications.

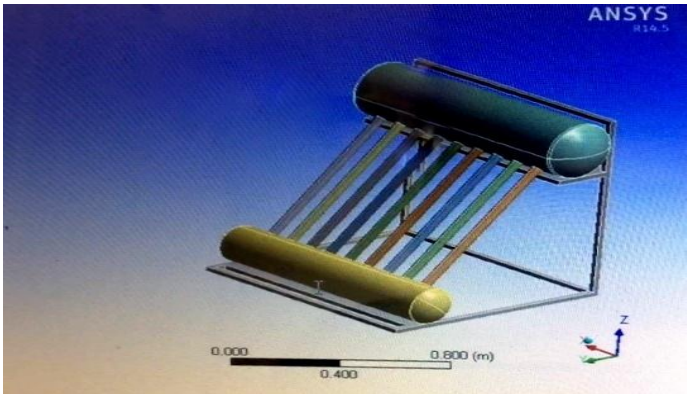


Fig No. 8 Geometric view of Thermo-siphon cooling system (Ansys work-bench)

PRESSURE ANALYSIS

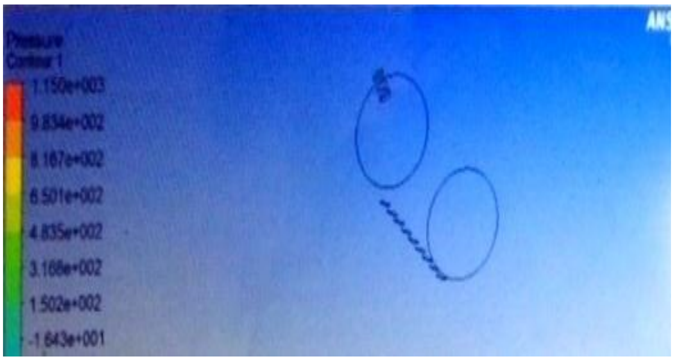


Fig No. 9 Pressure variation with respect to Temperature

Pressure is a measure of the force exerted per unit area on the boundaries of a substance (or system). It is caused by the collisions of the molecules of the substance with the boundaries of the system. As molecules hit the walls, they exert forces that try to push the walls outward. The forces resulting from all of these collisions cause the pressure exerted by a system on its surroundings. Here by observing the Results we could observe that with the increase in the Temperature there is a considerable amount of changes in the Pressure of the medium which is actually required property for the working of a Thermo-siphon based working system. Here when Temperature increases pressure also increases. Red colored region indicates the highest temperature (outlet) and green colored region indicates the lowest temperature regions (inlet).

TEMPERATURE ANALYSIS

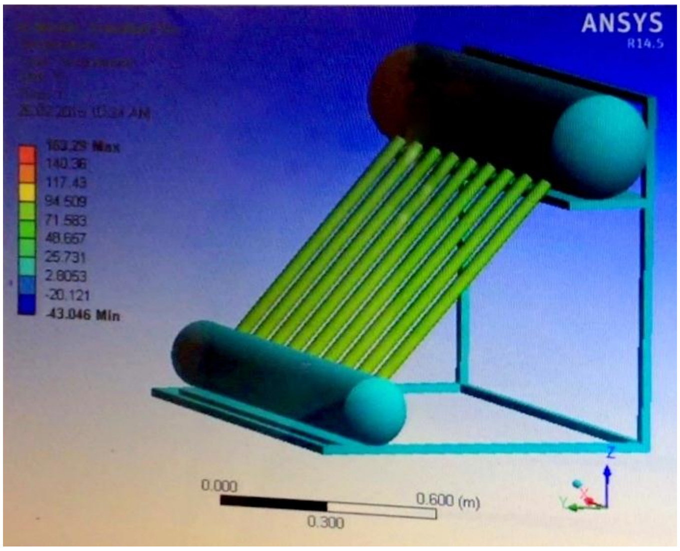


Figure No. 10 Temperature Range.

Transient thermal analyses determine temperatures and other thermal quantities that vary over time. The variation of temperature distribution over time is of interest in many applications such as with cooling of electronic packages or a quenching analysis for heat treatment. Here we analysis the temperature in various areas and we found that the design is comparatively good because it helps for the function of a thermo-siphon system effectively. The minimum temperature recorded was -43 degree Celsius and max 163 degree Celsius which shows the lithium-bromide medium do have a operational properties for a wide range of temperatures.

TOTAL HEAT FLUX

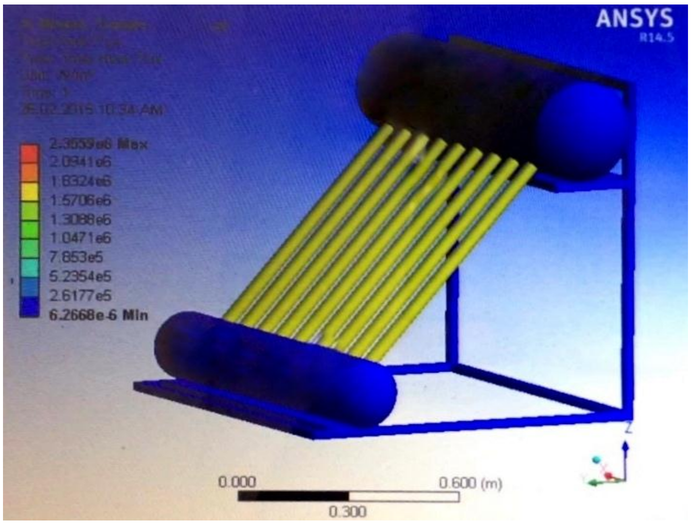


Figure No. 11 Total Heat Flux.

Heat flux or thermal flux, sometimes also referred to as heat flux density or heat flow rate intensity is a flow of energy per unit of area per unit of time. A thermo chemical BTU per second per square inch (BTU/s·in^2) is a US Customary and British Imperial unit of heat flux density. By definition, a thermo chemical BTU per second per square inch is the rate of heat energy of one thermo chemical BTU per second transferred through the area of one square inch, which is normal to the direction of the heat flux. Here the results are obtained in BTU/in^2/s units and the minimum value of the solar heat flux obtained is 6.2668 e-6 (The value is negative) and the maximum value of the solar heat flux obtained is 2.3559 e6.

7. RESULTS AND CONCLUSION

The analysis had been done and the results had been shown above, so from the above analysis we find that Lithium-Bromide solution do show better Thermal properties and we observed that the temperature could be applied in the range from a minimum temperature of negative 43 to a maximum temperature range of 163 degree Celsius, normally the working range of temperature that could come across in the practical usage of the system is in the range of 100-22 degree Celsius. According to ASHRAE, the amount of concentration of lithium bromide in solution must be less than 70% to avoid formation of salt crystals and more than 40% to absorb water in the absorber. The probability of dropping the concentration below 40% is at the strong of refrigerant solution line and above 70% is at the weak solution line .The concentration of Li-Br in strong solution is dependent on the absorber temperature and the evaporative temperature. Because the evaporative temperature is constant, the absorber temperature, which is equal to the ambient temperature, affects the strong solution concentration.

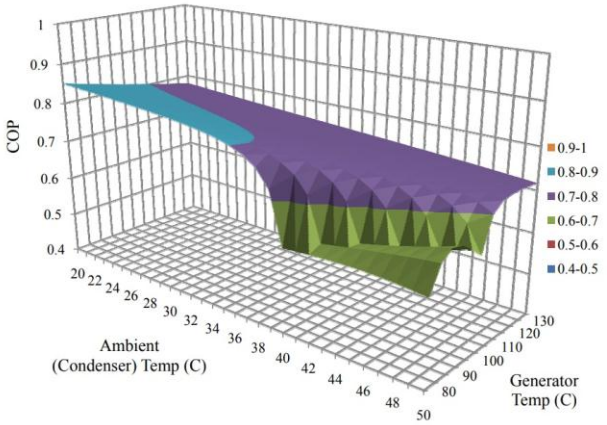


Figure No. 12 cop vs ambient temperature for different generator temperatures.

The coefficient of performance (COP) for the absorption cooling system is dependent on the generator energy and the cooling load (the pump work is small and can be neglected, if the flow is low only then the pump could be used). The cooling load is constant so the COP becomes related to the generator heat usage, which is related to the ambient and the generator temperatures, as shown in Figure above.

S. NO.	PARTICULARS	MINIMUM	MAXIMUM
1	TEMPERATURE (°C)	-43.046	163.29
2	TOTAL HEAT FLUX (W/m^2)	6.2668e-6	2.3559e6

Figure No. 13 Final Result.

Different approaches need to be considered to size the collector area in the solar absorption cooling system: for instance, the maximum energy required in the generator, the maximum ambient temperature, the maximum hourly solar radiation, the minimum collector efficiency, etc. For this simulation, the maximum ambient temperature is selected as the design point, which means the solar radiation and energy required in generator are related to the hottest hour during the cooling season. In view of shortage of energy production and fast increasing energy consumption, there is a need to minimize the overall energy consumption. COP of the system is depending upon the system temperatures. So as we introduce new material like lithium bromide into the air-conditioning industry as a refrigerant we could improve the overall efficiency of the system. lithium bromide solution have a greater boiling point and greater pressure factors when compared to water, helps to improve the process of natural convention of medium through the tubes. Due to its special properties we could incorporate solar energy to increase the temperature of the solution and hence due to the temperature being increased the pressure also increases and a pressure difference could be easily created which helps in the natural circulation of the medium through the tubes (Thermo-syphon system). In this project structural analysis of the structure had been studied deeply using creo parametric 2.0 software then after converting the file into IGES format the Pressure and temperature analysis had been analyzed with the help of Ansys software and we had found that the new medium is too good as far for the pressure and temperature range that it could withstand and hence it helps for the working of a Thermo-siphon system effectively. Finally, the system shows a COP of 0.8 and the strong solution flow rate ranges between 15 to 50 kg/hr.

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