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Solar Assisted Automobile A/C Based On A Water-Lithium Bromide Absorption Refrigeration System

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Abstract

This paper concerned about constructing an air conditioning system of automobiles using water-lithium bromide absorption system powered by solar energy. The main objective of this paper is to enhance the efficiency of the A/C. automobile system and reducing fuel consumptions. A simulation of the system is performed using Solidwoks to show the temperature distribution and flow trajectories during system operation.

Keywords: Automotive, A/C, Solar, Water-lithium Bromide, Absorption.

INTRODUCTION

Today, as we drive our automobiles, a great many of us can enjoy the same comfort levels that we are accustomed to at home and at work. With the push of a button or the slide of a lever, we make the seamless transition from heating to cooling and back again without ever wondering how this change occurs. That is, unless something goes awry. Since the advent of the automotive air conditioning system in the 1940's, many things have undergone extensive change. Improvements, such as computerized automatic temperature control (which allow you to set the desired temperature and have the system adjust automatically) and improvements to overall durability, have added complexity to today's modern air conditioning system. In general vehicle is used, on average, about 249 hours annually or about 41 minutes per day, 365 days a year [1]. Estimates of air-conditioning use range from 107 to 121 hours per year or 43% to 49% of vehicle usage. An air conditioner compressor can add up to 5-6 kW peak power draw on a vehicle's engine. This power draw is equivalent to a vehicle driving steady state down the road at 35 mph (56 km/h).

Unfortunately, the days of "do-it-yourself" repair to these systems, is almost a thing of the past. One of the newest developments on general air conditioning systems is the usage of the absorption refrigeration systems which gives a high efficiency and low operating cost and also a good solution for the older electrical air conditioning systems. These developments were used on automobile air conditioning system as on vaccine trucks. For passenger cars, in summer heat may make it uncomfortable for you to get in your car immediately, and its even not good for cars interior components, and here the idea of the project take a place to reduce these problems by turning the air conditioning system on while the car is turned off so you can enter your car while it is cooled and suitable to use, and another advantage of the system is to reduce the load on the engine created by the compressor.

AUTOMOTIVE ABSORPTION REFRIGERATION SYSTEM

Vehicles are found to have primarily three different types of air conditioning systems. While each of the three types differs, the concept and design are very similar to one another. The most common components which make up these automotive systems are the following: Compressor, Condenser, Evaporator, Orifice Tube, Thermal Expansion Valve , Receiver-Dryer And Accumulator(Fig.1).

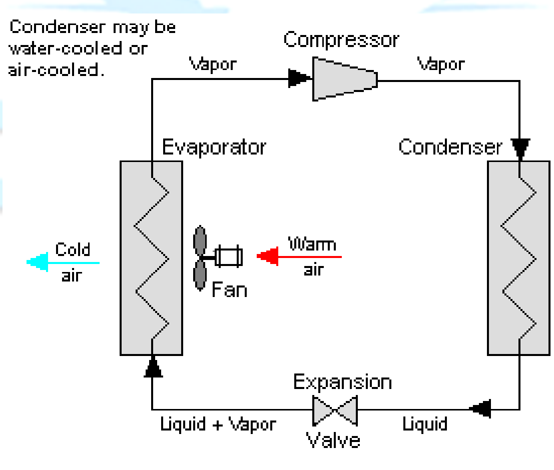

Fig. 1: Typical Single Stage Vapor Compression Refrigeration [2]

Another form of refrigeration that becomes economically attractive when there is a source of inexpensive thermal energy at a temperature of 100 to 200°C is absorption refrigeration. Some examples of inexpensive thermal energy sources include geothermal energy, solar energy, and waste heat from cogeneration or process steam plants, and even natural gas when it is available at a relatively low price. As the name implies, absorption refrigeration systems involve the absorption of a refrigerant by a transport medium. The most widely used absorption refrigeration system is the ammonia-water system, where ammonia (NH_3) serves as the refrigerant and water (H_2O) as the transport medium. Other absorption refrigeration systems include Water-Lithium Bromide and Water-Lithium Chloride systems, where water serves as the refrigerant. The latter two systems are limited to applications such as air-conditioning where the minimum temperature is above the freezing point of water. To understand the basic principles involved in absorption refrigeration, we examine the NH_3–H_2O system shown in Fig. 3. The ammonia–water refrigeration machine was patented by the Frenchman Ferdinand Carre in 1859. Within a few years, the machines based on this principle were being built in the United States primarily to make ice and store food. You will immediately notice from the figure that this system looks very much likes the vapor-compression system, except that the compressor has been replaced by a complex absorption mechanism consisting of: an absorber, a pump, a generator, a regenerator, a valve and a rectifier. Once the pressure of NH_3 is raised by the components in the box(this is the only thing they are set up to do), it is cooled and condensed in the condenser by rejecting heat to the surroundings , is throttled to the evaporator pressure , and absorbs heat from the refrigerated space as it flows through the evaporator. So there is nothing new there. Here is what happens in the box: Ammonia vapor leaves the evaporator and enters the absorber, where it dissolves and reacts with water to form $NH_3 \cdot H_2O$. This is an exothermic reaction; thus heat is released during this process. The amount of NH_3 that can be dissolved in H_2O is inversely proportional to the temperature. Therefore, it is necessary to cool the absorber to maintain its temperature as low as possible, hence to maximize the amount of NH3 dissolved in water. The liquid NH3.H2O solution, which is rich in NH3, is then pumped to the generator. Heat is transferred to the solution from a source to vaporize some of the solution. The vapor, which is rich in NH3, passes through a rectifier, which separates the water and returns it to the generator. The high-pressure pure NH3vapor then continues its journey through the rest of the cycle. [3]

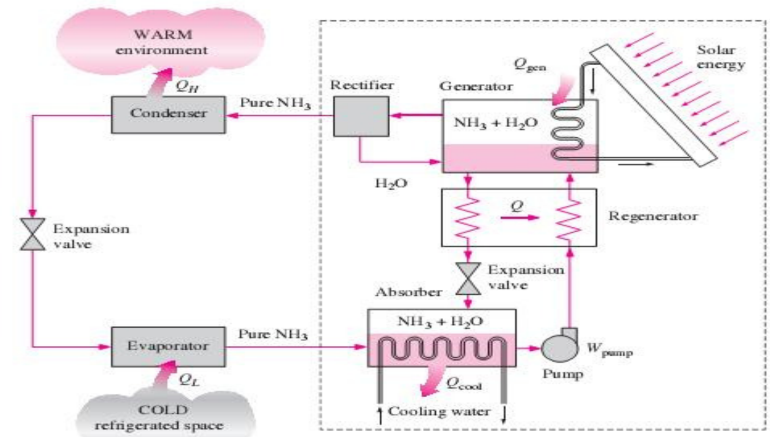

Fig.2: Absorption refrigeration cycle [3]

The hot NH_3 + H_2O solution , which is weak in NH_3, then passes through a regenerator , where it transfers some heat to the rich solution leaving the pump, and is throttled to the absorber pressure. Compared with vapor-compression systems, absorption refrigeration systems have one major advantage: **A liquid is compressed instead of a vapor.** The steady-flow work is proportional to the specific volume, and thus the work input for absorption refrigeration systems is very small (on the order of one percent of the heat supplied to the generator) and often neglected in the cycle analysis. The operation of these systems is based on heat transfer from an external source. Therefore, absorption refrigeration systems are often classified as *heat-driven systems*. Vapor compression refrigeration systems. They are more complex and occupy more space, they are much less efficient thus requiring much larger cooling towers to reject the waste heat, and they are more difficult to service since they are less common. Therefore, absorption refrigeration systems should be considered only when the unit cost of thermal energy is low and is projected to remain low relative to electricity. [3]

Refrigerant Lines or Hoses

Special flexible refrigerant lines are used in automobile air conditioning applications:

1- To carry liquid refrigerant from receiver \ dryer to evaporator expansion valve
2- (liquid line)
3- To carry vapor refrigerant from evaporator to compressor (suction line)
4- To carry hot compressed vapor from compressor to condenser
5- To carry liquid refrigerant from condenser to liquid receiver\dryer.

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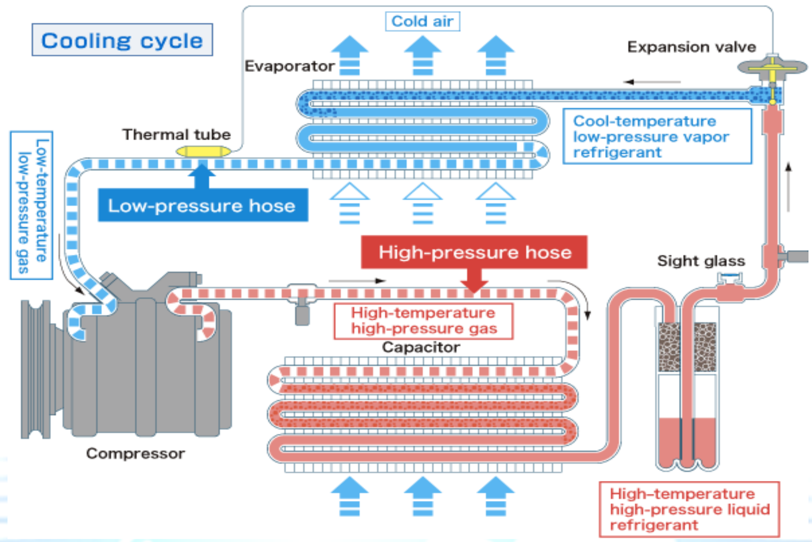

Fig. 3: Refrigerant lines [4].

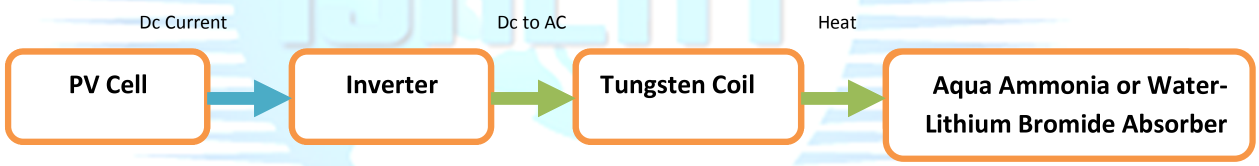

Fig. 4: Block Diagram for PV cells system

In a water-lithium bromide vapor absorption refrigeration system, water is used as the refrigerant while lithium bromide (Li- Br) is used as the absorbent. In the absorber, the lithium bromide absorbs the water refrigerant, creating a solution of water and lithium bromide. This solution is pumped by the pump to the generator where the solution is heated. The water refrigerant gets vaporized and moves to the condenser where it is cooled while the lithium bromide flows back to the absorber where it further absorbs water coming from the evaporator.

The water-lithium bromide vapor absorption system is used in a number of air conditioning applications. This system is useful for applications where the temperature required is more than 0 degree C.

Water-Lithium Bromide Solution has some special features in an absorption refrigeration system:

1) Lithium bromide has great affinity for water vapor, however, when the water-lithium bromide solution is formed, they are not completely soluble with each other under

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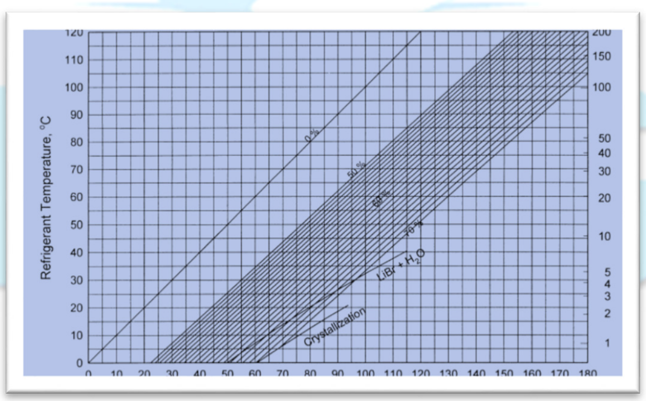
all the operating conditions of the absorption refrigeration system. Because of this, the designer must take care that such conditions would not be created where crystallization and precipitation of the lithium bromide would occur.

2) The water used as the refrigerant in the absorption refrigeration system means the operating pressures in the condenser and the evaporator must be very low. Even the difference of pressure between the condenser and the evaporator must be very low. This can be achieved even without installing the expansion valve in the system, since the drop in pressure occurs due to friction in the refrigeration piping and in the spray nozzles.

3) The capacity of any absorption refrigeration system depends on the ability of the absorbent to absorb the refrigerant, which in turn depends on the concentration of the absorbent. To increase the capacity of the system, the concentration of absorbent should be increased, which would enable absorption of more refrigerant. Some of the most common methods used to change the concentration of the absorbent are: controlling the flow of the steam or hot water to the generator, controlling the flow of water used for condensing in the condenser, and re-concentrating the absorbent leaving the generator and entering the absorber.

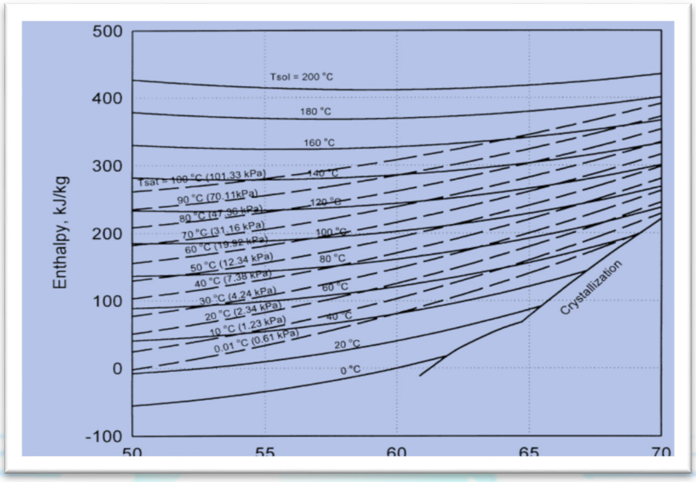
Aqueous lithium bromide (Li-Br) solutions and similar mixtures have long been used in absorption refrigeration. Thermo properties as thermal conductivity, density, kinematic viscosity, and liquid specific heat are needed for adequate design analysis and evaluations of absorption refrigeration systems.

Thermodynamic properties (figure 5&6), of Li-Br given in the literature were with typical equations for an effective calculation of the design data [5] .The enthalpy of solution was calculated by the procedure of McNeely's [6].



Solution Temperature, ºC

Figure 5: Duhring diagram of the H2O + LiBr



Concentration, wt % Absorbent

Figure 6: Enthalpy-concentration diagram of the H2O + LiBr

The following equation was used for the regression:

$Q = \dot{m} * C_P * (T_{out} - T_{in})$
Where,

Q: Heat rate (W),$\dot{m}$: Mass flow rate (kg/s), C_P :Specific heat at constant pressure(J/kg.°K),

T_{out}: Outlet temperature (°C.), T_{in}: Inlet temperature (°C).

The source of heat in a solar collector is solar energy and the input power is usually the irradiation, G, received on the surface of the collector, absorbed and then transferred to the working fluid. By dividing the net power output by the input power, an overall efficiency can be defined. Such efficiency is generally considered as instantaneous efficiency because it is a function of instantaneous operating conditions including local climatic parameters like the ambient temperature, the wind speed, etc.

Table1: Summary of properties of lithium bromide [7].

Properties of lithium bromide	
Chemical formula	LiBr
Molar mass	86.845(3) g/mol

Appearance	White solid hygroscopic
Density	3.464 g/cm^3
Melting point	552 °C (1,026 °F; 825 K)
Boiling point	1,265 °C (2,309 °F; 1,538 K)
Solubility in water	143 g/100 mL (0 °C) 166.7 g/100 mL (20 °C) 266 g/100 mL (100 °C)
Solubility	soluble in methanol, ethanol,ether, acetone slightly soluble in pyridine
Specific heat capacity (C)	51.88 J/mol K
Std molar entropy (S°_{298})	66.9 J/mol K
Std enthalpy of formation ($\Delta_f H^{\circ}_{298}$)	-350.3 kJ/mol
Gibbs free energy($\Delta_f G^{\circ}$)	-338.9 kJ/mol
Std enthalpy of combustion($\Delta_c H^{\circ}_{298}$)	-157 kJ/mol
Flash point	Not-flammable
Lethal dose or concentration (*LD*, *LC*):	
LD_{50} (Median dose)	1800 mg/kg (oral, rat)

Solar Cell

A solar cell, also called a photovoltaic cell, is used to convert solar energy into electrical energy. Solar cells are the basic elements of a solar module (also known as a solar panel). Silicon is by far the commonest of a variety of semiconductors from which solar cells are made. A typical modern solar cell is squared-shaped measuring 10 cm × 10 cm. It is covered by a clear anti-reflection coating (ARC) that reduces the amount of light lost to reflection at the cell surface. As shown in the Fig.4. [8]

Fig.7: Solar Cell [8]

Types of solar cells

There are three main types of solar cells (Table 2), which are distinguished by the type of crystal used in them. They are mono crystalline, polycrystalline, and amorphous.

1- Mono-crystalline silicon cell
2- Polycrystalline cells
3- Amorphous cells

Table 2: Construction of PV module [8]

Material	Efficiency in lab (%)	Efficiency of production cell (%)
Mono-crystalline silicon	about 24	14-17
polycrystalline silicon	about 18	13-15
amorphous silicon	about 13	5-7

Absorption Refrigeration Cycles:

Compression and absorption refrigeration systems differ in terms of the type of drive energy supplied and in the method they use to increase the pressure [9].

In an absorption refrigerator, the refrigerant is expelled from an aqueous solution by supplying heat energy. The refrigerant vapour is then condensed in a downstream condenser and releases heat. In a hydrogen atmosphere, the refrigerant evaporates and absorbs heat from the environment to be cooled (Fig.8).

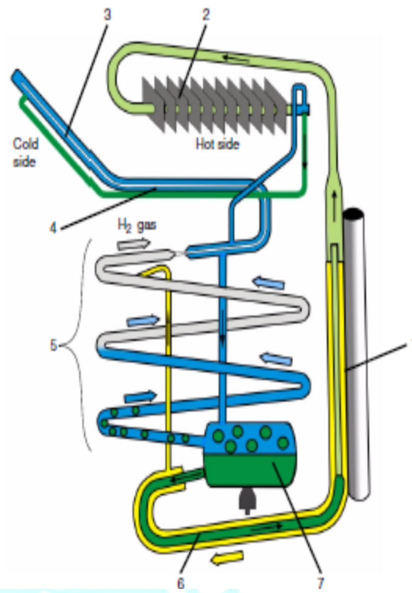


Figure 8: Function diagram of the absorption refrigeration cycle [10].

1- Boiler with vapour rich solution ,2- Condenser,3- Evaporator Weak solution,4- Gas heat exchanger,5- Absorber ,6- Liquid heat exchanger,7- Storage tank

- Rich solution
- Weak solution
- Gas mixture

The gaseous refrigerant then comes into contact with water again and goes into solution. This restores the initial condition and completes the process cycle.

The function of an absorption refrigerator without a mechanically powered compressor is based on two fundamental facts:

• Water has the property that it can absorb large quantities of gas when cold. This gas can be expelled again at a higher temperature.

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• Gas vapour can be condensed in an enclosed system under pressure and at room temperature. If it absorbs a large amount of heat, it can be condensed again at a lower temperature.

RESULTS AND DISCUSSION

By using the solid works we find these results: This is the direction that used in the heat exchanger, as the water – lithium bromide (Red) flows from left to right, the water (Blue) flows in opposite direction, to decrease its temperature (Fig.9).

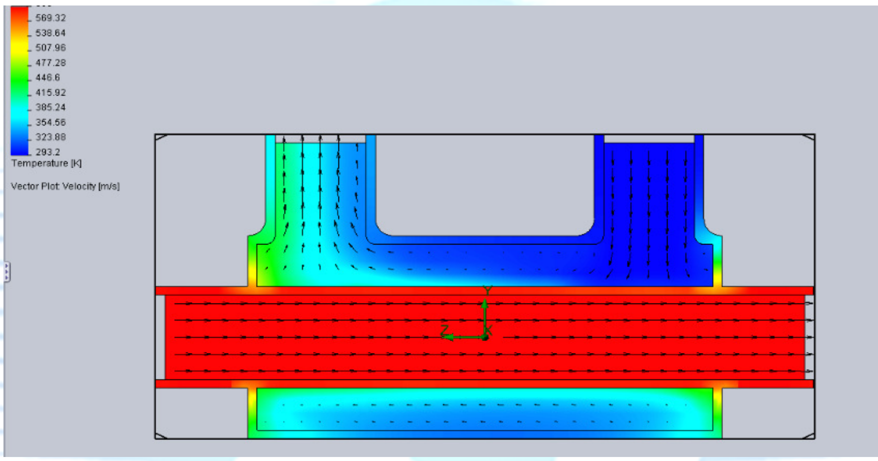

Fig.9: Cut Plot – Directions of Flows [11]

And this shows the differences in temperature as the water enters and exits as a Trajectory flow.

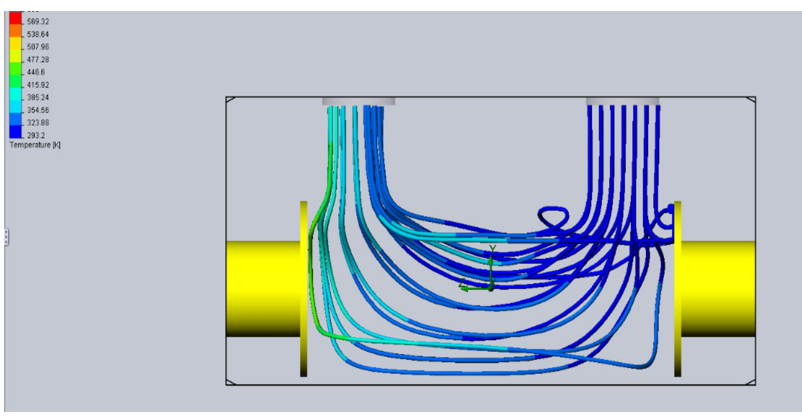

Fig.10: Flow trajectory – Temperature [11]

And this shows the differences in velocity as the water enters and exits as a Trajectory flow.

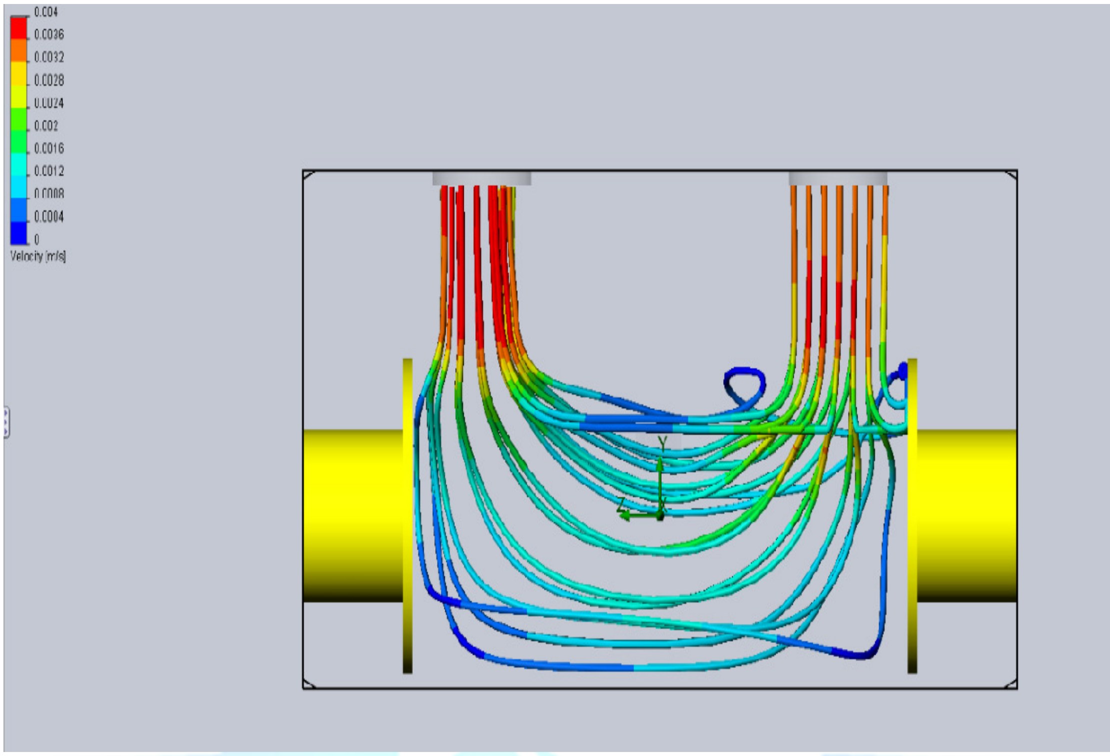

Fig.11: Flow trajectory – Velocity [11]

Conclusions

The system is simulated and analyzed using Solid woks application to find flow trajectories and temperature distribution. It is found that there is a considerable enhancement of the air conditioning performance using the suggested system.

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