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ANALYSES OF HALF-CYCLE WINDOW AIR CONDITIONING SYSTEM USING LPG

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ABSTRACT

Liquified petroleum gas (LPG) is one of the most important and potentially refrigerants for half-cycle air conditioning systems. Half cycle air conditioning system eliminates the compressor and condenser in providing air conditioning because working fluid in such cycles is already liquified at high pressure before passing through the system. When high pressure LPG is passed through an expansion device or a capillary tube of small internal diameter to the evaporator, refrigerant pressure drops down suddenly as a result LPG vaporizes in the evaporator and provides cooling. In this project, we have analyzed of half-cycle window air conditioning system using LPG. Liquefied petroleum gas (LPG) is an easily available gas stored in the cylinder for household purposes which consists of 24.4% propane, 56.4% butane, and 17.2% isobutene, which is varied from company to company and is used as a Refrigerant. The LPG is cheaper and possesses an environmentally friendly nature with no Ozone Depletion Potential (ODP) and no Global Warming Potential (GDP). The application of Air-Conditioner increased day to day as home appliances and in the industry over the last decade. We obtained the COP for the solar-powered and half-cycle air conditioning system as 6.3. Therefore, the half-cycle window air conditioning system using LPG and solar energy has enough potential field for air conditioning, but very few works have been done so far on its application in restaurants and residential properties facility and that makes the scope of the present research.

Keywords: LPG refrigerant; ½ cycle refrigeration; Evaporator; Capillary Tube; Solar Power.

1. INTRODUCTION

The crisis of energy demands an environmental friendly system for air conditioning purposes with less investment. The climatic change and global warming also demand accessible, affordable and environmentally-friendly cooling systems for refrigerators and air conditioners [1,2,3]. The household LPG cylinder and renewable solar energy systems are high energy efficiency and environmental friendly. Liquefied petroleum gas (LPG) is easily available gas stored in the cylinder for household purposes which consists of 24.4% propane, 56.4% butane and 17.2% isobutene [1,4,5]. Depending on the climate conditions and Government policy the composition of LPG may vary use as a Refrigerant [6]. Setiyo et al. Experimented by simulation that cooling effect is produced by LPG depends on the composition of LPG and invented that cooling effect generated by a mixture of LPG composition with 70% pro-pane and 30% butane is higher than other mixtures [7]. Since, half cycle air conditioning system eliminates the compressor and condenser in providing air conditioning because working fluid in such cycles is already liquified at high pressure before passing through the system [8]. Petroleum gas is stored in liquefied state before its utilization as fuel. The energy spent for pressurizing and liquefying is not recovered afterwards. If it is expanded in an evaporator, it will get vaporized and absorb latent heat to produce cooling [9]. The cooling effect depends on the LPG flow rate and evaporative pressure in the evaporator [10]. Setiyo et al. Showed the actual cooling effect of the half- cycle air conditioning system produced is as high as 1.2 kW for a LPG flow rate of more than 3 g/s and an air mass flow rate of 16 g/s [9]. However, the liquefied form of LPG can be used for cooling and the expanded gas (LPG) can be further used for combustion as a fuel. The main advantages are, the cooling is free of cost as no electricity is needed for operating the air conditioner, LPG is not consumed during the cooling process, only expanded and further used for cooking or any purposes, and finally the product is a green technology and is eco- friendly, as if eliminates the use of ozone-depleting refrigerants. Worldwide 17500 metric tons of conventional refrigerants is used by domestic refrigeration like CFC, HFC which causes high Ozone Depletion Layer (ODP) and Global Warming Potential (GWP). The use of LPG instead of CFC 22 has made a better progress since it has an environment friendly orientation with no ODP. LPG provided better cooling efficiency because of its characteristics [2]. For the use of

certain compositions and pressures of LPG in a closed-loop vapor compression refrigeration cycle as a refrigerant has been discussed widely with outcomes comparable to or better than R-134a [11,12,13].

For the last decade, day to day the application of air conditioner increases at home appliances and in industrial sector. In recent years, the utilization of solar-powered air conditioning has increased [14]. It has been observed that the energy requirements of people in the rural areas of developing countries like India, solar refrigeration can play a major role for refrigeration or air conditioning purpose. Lots of solar technologies proved, that's are technically compatible and feasible in our daily life and also have further scopes for development [15]. Solar power converts sunlight energy into electrical energy by using photovoltaic (PV), or using intense or concentrated solar power (CSP). Concentrated solar power systems is act by using lenses or mirrors [16] and a large area of sunlight is tracking to center by a small ray of light [17]. Patricio G. Cabading et al. [18] Studied energy conservation for window type air conditioner. They found that the Coefficient of Performance (COP) and Energy Efficiency Ratio (EER) of the solar-powered air conditioning system is 4.77 & the EER is 16.25 for the whole system during the test period. Gangadhar V. Amratwar et al [19] reviewed the solar PV panel-based vaccine refrigerator and performance evaluation in different part of the world. In techno –economic assessment study, they observed that DC refrigerator has relatively low-power consumption in comparison with AC refrigerator.

1.1 Objectives

The Objectives with specific aims of this project "analyses of half-cycle window air conditioning system using LPG" are as follows:

i. To design and develop half-cycle window air conditioning system for human comfort air conditioning using LPG and solar energy.
ii. To compare the important characteristics between LPG refrigeration system and traditional refrigeration system.
iii. To distinguish between the current existing refrigerator cost and estimated cost of LPG refrigerator.
iv. To develop a model for green energy application solar air conditioning system may operate whole year.

1.2 Possible Outcomes Of Work

i. LPG and solar powered half-cycle window air conditioning system can be useful in remote parts where electricity is not available.
ii. It can play an important role in restaurants, residential properties where continuously cooling required.
iii. The adoption of LPG and solar powered half-cycle window air conditioning system can save energy significantly and reduce the corresponding greenhouse gas emission.

2. EXPERIMENTAL FEATURE

2.1 Working Principle

LPG is extracted at high pressure in liquefied state from the storage device. Its pressure and flow rate is controlled by a valve connects it to the evaporator at requisite pressure in requisite quantity. An evaporator is housed through which LPG flows. It gets converted from a liquefied state to a gaseous state and expands. So it absorbs heat in the form of latent heat. Due to this process, heat from surrounding is absorbed so cooling effect is produced. This effect is magnified by an evaporator. A network of pipes containing gas is covered by thin and closely spaced fins which help in effective and fast cooling. The insulating material helps in storing the cooling effect for a longer period of time. The LPG leaves the evaporator in gaseous form; it is then directed towards the burner, engine, or any other application where it is to be used. Thus, no LPG is consumed for cooling purpose. On the other hand, solar panels absorbed heat energy by the PV cells when sunlight falls on to them and the silicon semiconductors in the cells convert the solar energy into electric energy through the PV effect. This electric energy is in the form of DC power which can directly charge the battery. The DC power in the battery is sent to an inverter which converts it into AC power. This AC power is now sent to the mains into the home, which in turn can power all necessary applications. The basic flow diagram of the proposed system is shown below:

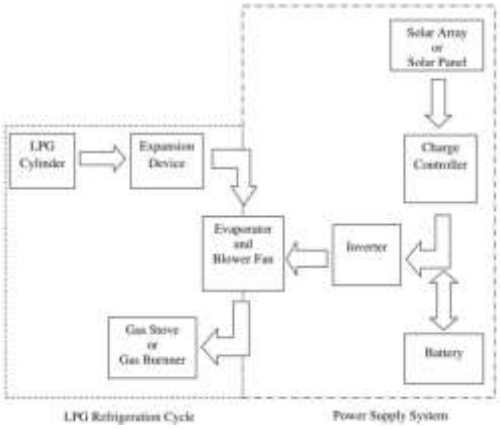

Fig. 1: Designed diagram of half cycle LPG air conditioner.

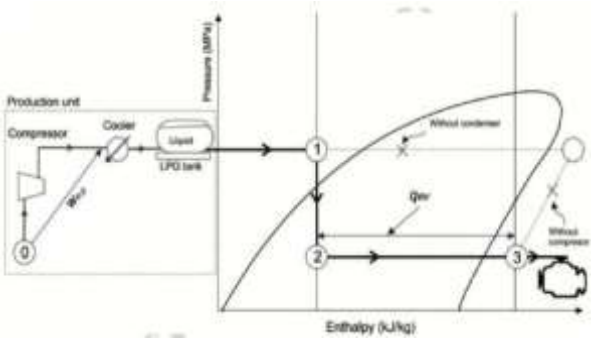

Fig. 2: Schematic diagram of half cycle LPG air conditioner with specific state points.

2.2 Construction Features

2.2.1 LPG gas cylinder

LPG is Liquefied Petroleum Gas which contains mainly Propane (0C3H8) and Butane (C4H10).These two either stored separately or together as a mix. LPG can be used as a fuel for domestic, industrial, agricultural, cooking, heating and drying processes. It can also used as an automotive fuel or as propellant for aerosol.The LPG is stored in the cylinder at about 12.5 bars. The use of LPG Cylinder eliminates the compressor and condenser from the system.

Fig. 3: LPG Gas cylinder

2.2.2 Capillary tube

Capillary tubes are tubes with small internal diameter. This diameter varies from 0.5 to 2.28 mm. Commonly used capillary tubes are made up of copper. When the refrigerant enters in the capillary tube, due to very small diameter its pressure drops down suddenly. The decrease in pressure of the refrigerant through the capillary depends on the diameter of capillary tube and the length of capillary tube.

Fig. 4: Capillary tube

2.2.3 Evaporator

The evaporator is also an important component of the refrigeration system. The cooling effect is produced by passing the refrigerant through the evaporator coil. The cooling effect is produced by passing the refrigerant through the evaporator coil. The evaporator removes heat from the substance and transfers it to the refrigerant. It means the evaporator act as heat exchangers. The refrigerant is passed through the capillary tube at very low temperature and pressure to the evaporators. The heat is absorbed by this refrigerant from the substance that is to be cooled and thus the refrigerant gets heated while the substance is cooled.

Fig. 5: Evaporator

2.2.4 High pressure pipes

The high pressure pipes are needed to be used as the LPG is delivered from cylinder at very high pressure. It consists of a steel pipe with steel spheres fixed at both the terminals. These spheres are pressed against the seating of connecting hole with the help of two swiveling nipple and thus the gas leakage is prevented. High pressure pipes are used to transfer high pressure gas from cylinder to capillary tube. These pipes are tested to 100Mp over recommended working pressure.

Fig. 6: High pressure pipe

2.2.5 Pressure gauge

This is an instrument used to measure pressure of the gas. There are two types of gauge use in this project viz. high pressure gauge and low pressure gauge.

Fig. 7: Pressure gauge

2.2.6 Gas burner

A gas burner is a device that produces a controlled flame by mixing a fuel gas such as acetylene, natural gas, or propane with an oxidizer such as the ambient air or supplied oxygen, and allowing for ignition and combustion.

Fig. 8: Gas burner or gas stove

2.2.7 Solar panel or array

A photovoltaic cell is also called a solar cell. It is a semiconductor device which converts sunlight into DC power using the photoelectric effect. Practically, all solar cells are photodiodes made of semiconductor material like silicon. A large number of solar cells are interconnected to form a solar module, combination of solar modules is called panel and combination of panels is called solar array. It is done to get the required power output from a PV system.

A solar cell works in three steps:

- Photons in the sunlight hit the solar cell and are absorbed by the semiconductor material.
- Negatively-charged electrons are knocked off from their atoms and start flowing in the same direction to produce electric current.
- A typical silicon solar cell can produce up to 0.5 V and current up to 6 A. Thus, its maximum power is 3 W.

Fig. 9: Solar panel or array

2.2.8 Solar charge controller

These are devices to ensure that the charging of batteries is done in a proper way. A solar charge controller is used to keep the battery from overcharging by regulating the voltage and current coming from the solar panel to the battery. This is done by constantly monitoring the battery current, voltage, and temperature.

Fig. 10: Solar charge controller

2.2.9 Inverter

The direct current (DC) electricity created by the panels is then connected by electrical cable to a Solar Inverter which is usually installed somewhere near the switchboard. Regular appliances in a home or business use alternating current (AC) electricity, so the solar inverter's job is to convert the DC energy to AC energy.

Fig. 11: Inverter

2.2.10 Blower fan

Also known as the air conditioner fan, the blower serves as one of the key components of a fully functioning air conditioning system. An air conditioner uses blowers to transfer the warm air away from any space and replace it with cold air. It also maximizes airflow for better circulation and machine function.

Fig. 12: Blower fan

2.2.11 Storage battery

These are used storage of solar energy. They are the most vital components of the Solar PV system. The success of a Solar PV system depends upon the battery storage system very much.

Fig. 13: Storage Battery

3. EXPERIMENTAL ANALYSIS

3.1 Specifications Of Components

a) **Copper Tubes:** According to the pressure 100 psi the outside diameter of tube = 100 mm and the thickness of the tube are = 1.5 mm.

b) **Capillary tube:** By considering the pressure and flow rate, we select the capillary tube with internal diameter = 1mm and length = 1m.

c) **Evaporator:** We select an evaporator of the air conditioner which is fins and tube type evaporator. The evaporator has the following dimensions: Length = 350 mm, Breadth = 250 mm and Height = 150 mm.

3.2 Operational Parameters

The experiment of this project was done on May 12, 2022 at 12:30 p.m. and readings were taken under fifteen minute intervals which are under as follow:

1. By considering the size of Room: 2m X 1.5m X 1.5m.
2. Initial temperature of air at the time of experiment: 32OC
3. Initial temperature of evaporator at the time of experiment: 30.5OC

Table 1: Experimental Readings

S. No.	Time (min)	Inlet Pressure (Bar)	Outlet Pressure (Bar)	Evaporator Temp. (◦C)	Air Temp. (◦C)
1	15	5.52	1.21	29.9	31.7

2	30	5.52	1.15	26.7	29.4
3	45	5.52	1.15	23.9	25.9
4	60	5.52	1.15	20.2	22.6
5	75	5.52	1.15	17.7	19.1
6	90	5.52	1.12	15.3	17.5

Chart

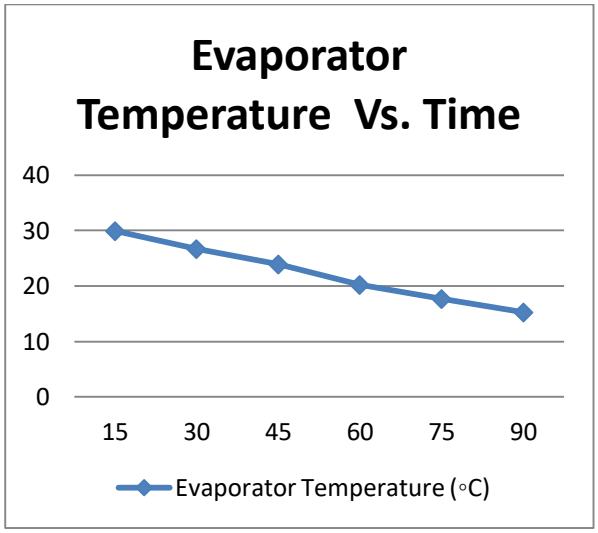

Chart-1: Evaporator Temperature (◦C) Vs. Time (min).

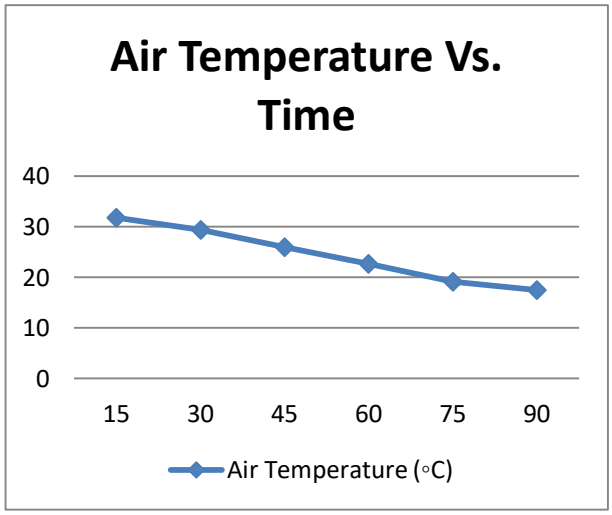

Chart-2: Air Temperature (◦C) Vs. Time (min).

3.3 Refrigerating Effect

We obtain from the LPG psychometric chart,
The properties of LPG at 5.525 bars are
Enthalpy h1 = 430.3 kJ/Kg
The properties of LPG at 1.22 bars are
Enthalpy hf = 107.3 kJ/Kg
Temp. tsat= -30 ^{0}C

XLPG = Dryness fraction of LPG from graph =0.5

So that,
Heat extracted from evaporator in 1.5 hour (Qeva) = Heat absorbed by LPG (QLPG)
Heat absorbed by LPG (QLPG) = Latent heat absorbed (QL)LPG +Sensible heat gain(QSen)LPG
We have the volume flow rate of LPG is 0.1 liter per min. and the specific volume of LPG at 1.22 bar pressure is 1.763×10-3 m3/Kg.

Therefore mass flow rate of LPG is = 0.0001/1.763×10-3
= 0.0567 Kg/min
m = 9.448×10-4 Kg/sec
(QLPG) = mLPG .xLPG .hfg + mLPG .cpLPG . (Tsup-Tsat)
=9.448×10-
4×0.5×375×10^3×5400+
9.448×10-4×1.67×(17.5+30)
= 0.956812
MJ/Hr.

h2 = hf+X.hfg
= (107.3 + 0.5 x 375)
= 294.8 KJ/Kg

hg = hf+ hfg
= (107.3 + 375)
= 482.3
KJ/Kg.

h3 = hg + Cp.
ΔT
= (482.3 + 1.67 x 47.5)
= 561.62 KJ/Kg

So the refrigerating effect is,
RE = h3 – h2
= (561.62 – 294.8)
= 266.82 KJ/Kg

For calculating the COP of the system, we required the work input. For work input we have a 14.5 Kg. LPG cylinder. Hence, input work is the amount of power required for filling 1 cylinder. From the PCRA energy audit report power required to refill 1 cylinder is 3.1354kWh.

Therefore, for filling 1 kg of LPG power required is,
= 3.1354/14.5
= 0.2162 kWh
We run the setup for 1.5 hr. for that power is
= 0.2162×1000/ (9.45/10000) ×5400
= 42.39W

3.4 COP of the LPG Refrigeration

System COP = (h3-h2)/W
= 266.82/42.39
= 6.3

4. COMPARE WITH CONVENTIONAL AIR CONDITIONER

Cop of a conventional air conditioner is normally up to 2.95 which is lesser than the LPG air conditioner. Conventional air conditioner required high input power than LPG air conditioner. Also, there are more moving parts in conventional air conditioner and not eco-friendly. Domestic air conditioner requires more maintenance and operation is noisy.

5. CONCLUSION

The basic goal of the half-cycle LPG window air conditioning system was to use high pressure of the LPG gas stored in cylinder for producing a cooling effect. In the process of refrigeration, adiabatic expansion of LPG takes place 100 psi to 10 psi. And due to this thermodynamically it absorbs heat from surrounding and cooling effect can be achieved. This cooling effect can be in the range 15 to 50 degrees. In an LPG refrigeration system capillary tube is more adjustable and better device. The initial and running cost of this LPG refrigeration system is really less. No outside energy source is required to run the system. As well as no moving components are present in the system which further reduces the maintenance cost as well. This LPG refrigeration system has wide scale application in hotel industries, chemical industries where the LPG consumption is at a higher level.

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