Design and Analysis of Biogas Powered Refrigerator for Dairy Farmers

Vijayendra Singh Sankhla, Deepak Sharma, Surendra Kothari, Sudhir Jain, Chitranjan Agarwal

Abstract: ***Biogas operated refrigeration system is being designed, fabricated and installed at Department of Renewable Energy Engineering, MPUAT, Udaipur for a 40 L capacity based on absorption principle. Developed biogas operated absorption refrigeration system has advantages of silent operation, no moving part. Developed system utilizes any heat source and therefore can operate anywhere, without electric utility infrastructure. In the presented research work analysis was done to identify the losses so that the performance of the developed refrigeration system can be evaluated & renewable energy resources can be used more efficiently to power refrigerators based on absorption principle.***

Keywords: ***Biogas, Refrigeration, Absorption system, Ammonia Water Refrigerant***

I. INTRODUCTION

Humans are highly dependent on RAC technologies for their cooling & heating requirements. This technology is widely used for controlling temperature in a confined region & to produce thermal comfort to occupants. Refrigeration has been used for several years & is not new for us but air conditioning technology is required to evolve in tune with the laws of thermodynamics & environment. Refrigeration systems are widely used for preserving perishable food items & several pharmaceuticals.

In the present scenario, with the increase in population the energy demand is also increasing exponentially. This drives the researchers to develop systems which can be powered by renewable energy resources. An estimation by IIF/IIR (Paris) revealed approximately 15% of the total power produced throughout the world is being consumed in refrigeration processes.

India being a tropical country, refrigeration is most broadly utilized , probably one of the most energy consuming field, characterized as any procedure of warmth expulsion from a place for saving sustenance and medications by improving their time span of usability.

Ranchers generally dairy agriculturists who pitch their items to send out to business sectors, refrigeration could assume an essential part to expand their yearly pay. Without cooling capacities the dairy items must be sold quickly in the wake of taking structure creatures.

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This decreases the possibility of arranging great costs, in light of the fact that the purchaser is in a superior dealing position. Especially in these segments, ranchers can possibly create a ton of biogas through accessible steers' excrement. Sun oriented Biogas Cross breed based refrigeration innovation would be a decent open door for such ranchers to take most extreme advantages.

II. VAPOUR ABSORPTION REFRIGERATION SYSTEM(VARS)

Vapour absorption refrigeration system (VARS) are powered by heat energy. These systems are generally utilized in industries and are most suitable for large capacities. Absorption refrigerators offers a scope of applying renewable energy sources, as the energy being used is low grade. One of the attractive effects pertaining to refrigerant-retentive blends for VARS are:

The refrigerant should show tremendous solvency accompanying arrangements of the system along with safety. This is to state that it should display pessimistic anomaly with Raoult's law at safeguard.

There must be substantial contrast in the breaking points of refrigerant and spongy (more prominent than 200°C), with the goal that exclusive refrigerant is bubbled off in the generator. This guarantees just unadulterated refrigerant courses wound up refrigerant circuit (condenser-extension valve-evaporator) prompting isothermal warmth move in evaporator and condenser.

It should show little warmth of blending with the goal that a high COP can be accomplished. Be that as it may, this prerequisite negates the primary necessity. Thus, practically speaking an exchange off is needed amongst solvency and warmth of blending.

The refrigerant-permeable blend ought to acquire tremendous warm conductivity and lower thickness for elite.

It ought not experience coagulation or cementing inward the framework.

The blend ought to be sheltered, synthetically steady, non-destructive, and modest and ought to be accessible effectively.

The most ordinarily utilized refrigerant-spongy combines in business frameworks are:

Water-Lithium Bromide for over 0 ^{0}C applications. Out of these two water act as refrigerant and lithium bromide acts as absorbent. Ammonia-Water (NH_3-H_2)) framework for regelation appositeness including alkali as refrigerant and H_2O as absorbent. .

2.1 Working of Biogas vapour absorption refrigeration system:

Refrigeration system based on absorption principle powered by biogas comprises of following components:

Biogas plant, biogas burner, refrigerator, cold storage cabinet, generator, evaporator, condenser ammonia + water refrigerant flow control unit, pressure relief valve, insulating material (PUF), piping and fittings, gaskets and a heat exchanger

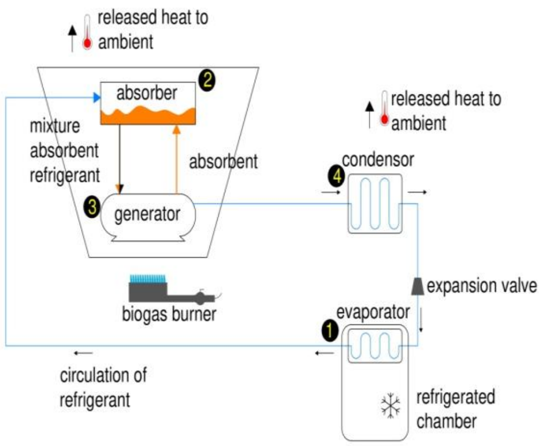

Figure 1: Layout of Biogas vapour absorption refrigeration system

Bio-thermal refrigeration plants are based on absorption principle and the required heat is obtained by combustion of biogas. In absorption system, a pair of substances having physical or chemical attraction between them is used for producing cooling effect. Conversion of thermal energy directly into cooling power is one of the unique capability of vapour absorption systems. The pair of substances being used, the substance having low boiling point is known as sorbate & the other having high boiling point is termed as sorbent. The sorbate plats the role of refrigerant & the biogas acts as the heating source for heating the refrigerant.

Performance of refrigeration system is defined as COP (coefficient of Performance). It shows how much heat can be rejected from cold body (Q_e) for each unit of heat(Q_g).

$$COP_{VARS} = \frac{Q_e}{Q_g + W_p} \approx \frac{Q_e}{Q_g} \quad \text{(Neglecting Pump work)}$$

III. METHODOLOGY

Vapour absorption refrigeration system(VARS) mainly consists of generator tube,absorber unit, and evaporator and condenser unit. In this case 40 L capacity absorption refrigerator of each part was designed and dimensions were determined.

For design of the VARS following parameters were calculated;

- Heat absorbed by the refrigerant in the evaporator.
- Capacity of refrigeration in TR (Tonne of refrigeration)
- Concentration of ammonia in eachstage.
- Enthalpies of ammonia at saturatedpoints.
- Enthalpies of strong and weak aqua-ammoniasolutions.
- Mass flow rate of ammonia in theevaporator.
- Mass flow rates of strong and weaksolution
- Absorber heatrejection.
- Heat added in the generator (heat given to the refrigerant in
- thegenerator).
- Heat rejection incondenser.

VARS mainly consists of generator tube, absorber unit, and evaporator and condenser unit. In this case 40 L capacity absorption refrigerator was modified for using heat energy. Heat energy was provided by the biogas flame. Absorption refrigerator of each part was designed and dimensions were calculated.

Table 1 Designed dimensions of the components of the VARS

<table>
<tr><th colspan="2" rowspan="2">Components</th><th colspan="5">Dimensions</th></tr>
<tr><th>Volume, m^3</th><th colspan="2">Diameter, m</th><th colspan="2">Length, m</th></tr>
<tr><td colspan="2" rowspan="2">Heat exchanger copper coil</td><td>4.24×10^{-5}</td><td colspan="2">0.006</td><td colspan="2">1.5</td></tr>
<tr><td colspan="5">No. of turns = 28</td></tr>
<tr><td colspan="2">Generator tube</td><td>7.85×10^{-5}</td><td colspan="2">0.02</td><td colspan="2">0.25</td></tr>
<tr><td rowspan="2">Absorber unit</td><td>Absorber vessel</td><td>3.30×10^{-4}</td><td colspan="2">0.06</td><td colspan="2">0.125</td></tr>
<tr><td>Absorber tube</td><td>2.5×10^{-3}</td><td colspan="2">0.03</td><td colspan="2">3.6</td></tr>
<tr><td colspan="2">Evaporator</td><td>4.6×10^{-5}</td><td colspan="2">0.014</td><td colspan="2">0.30</td></tr>
<tr><td rowspan="3">Condenser unit</td><td>Condenser tube</td><td>4.9×10^{-5}</td><td colspan="2">0.014</td><td colspan="2">0.32</td></tr>
<tr><td rowspan="2">Condenser fins</td><td rowspan="2">3.5×10^{-6}</td><td>Length,m</td><td>Width, m</td><td>Thickness, m</td><td>No. of fins</td></tr>
<tr><td>0.07</td><td>0.05</td><td>0.001</td><td>35</td></tr>
</table>

Figure 2: Fabricated Biogas Powered vapour absorption refrigeration system

IV. RESULTS & DISCUSSIONS

The biogas powered VARS was evaluated for its performance & results so obtained are discussed as follows: Figure 3 shows that Initially at the time of starting the generator was at 20°C. The generator was provided heat energy using biogas as a fuel. Due to this addition of heat the generator temperature increases rapidly and attains temperature of 140°C in one hour, with the increase in time, generator temperature falls to a minimum of 138°C & then increase gradually reaching a temperature of 140°C again. This fall and gradual rise of temperature takes place repeatedly over a time period of next 11 hours. Hence during the first 12 hours of operation the generator attains maximum temperature which lies between a range of 135°C - 140°C.

The variation of COP corresponding to above mentioned time period of operation is discussed as follows: During the first hour of operation the COP of the refrigerator seems to increase and reached a maximum of 0.45.Further during next 4 of operation the COP decreases gradually & there is a steep decrease in COP after 6th hour of operation. Further there is a continuous decrement in COP as observed, from the graph it is observed this pattern of gradual decreases in value of COP takes place during 24 hours of operation and the average COP of the refrigerator over a period of 24 hours is obtained as 0.12.

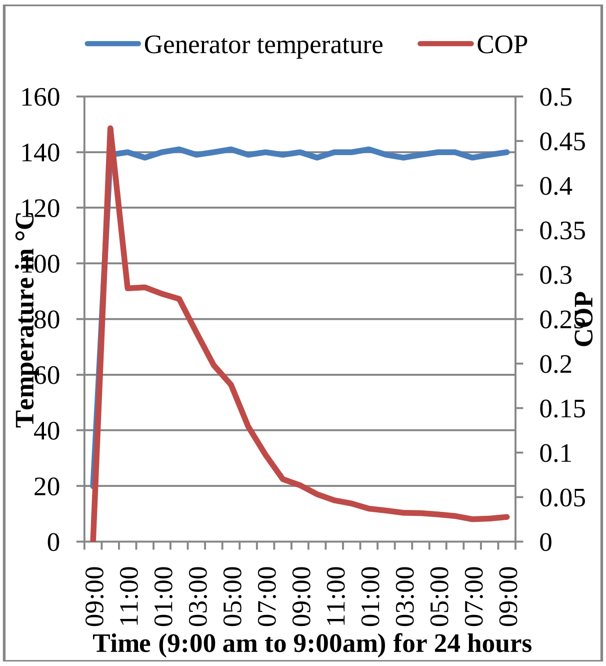

Fig. 3: variations of generator temperature and COP of the system with time

Figure 4 shows that over a time period of 24 hours, the following observations were made & are discussed as follows: The graph predicts that during first 11 hours of operation the refrigerator cabinet temperature is maintained at a constant value of 2°C. During the 12th hour of operation a steep decrease in evaporator temperature is observed and is found to be 1.5, which is the minimum temperature attained by the evaporator during 24 hours of operation. In next 12 hours of operation the evaporator temperature is maintained at 2°C approximately i.e.constant value, the average temperature is 2°Cduring 24 hours.

The variation of COP corresponding to above mentioned time period of operation is discussed as follows: During the first hour of operation the COP of the refrigerator seems to increases and reached a maximum of 0.45.Further during next 4 of operation the decreases gradually & there is a steep decrease in COP after 6th hour of operation. The further continuous decrement in COP is observed in operation. From the graph it is observed this pattern of gradual decrease in value of COP takes place during 24 hours of operation and the average COP of the refrigerator over a period of 24 hours is obtained as 0.12.

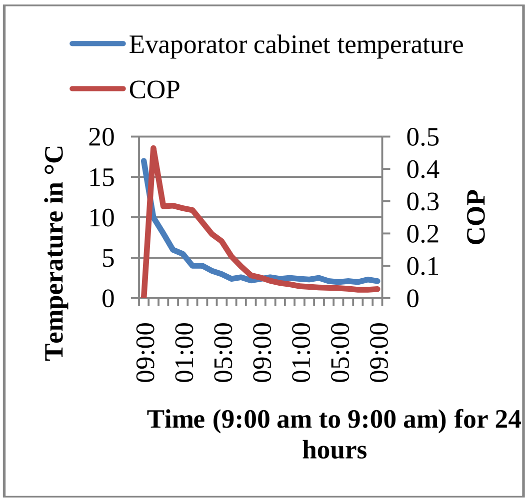

Fig. 4 : Variations of evaporator temperature and COP of the system with time

Figure 5 shows that over a time period of 24 hours, the following observations made are as follows: The graph predicts that during first 4 hours of operation the refrigerator cabinet temperature is maintained at a constant value of 2°C.At this time, heat extraction by water is reaches its maximum value of 3660 KJ and heat extraction is maintained around this value for 24 hours. With respect to variation in room temperature and cabinet temperature, the average heat extraction in 24 hours is 2630 KJ. For maintaining 2°C to 4°C cabinet temperature and heat extraction of 2630 KJ, supply ofheat is required continuously. Biogas consumption is found to be 130 liter per hour which produces approximately 2600 KJ energy per hour. Graph shows that around 2600 KJ heat energy is required per hour for maintaining the desired temperatures and heat extraction. After 24 hours of evaluation total biogas required is approximately 3000 liter. It produces 62500 KJ energy which is the actual energy required for biogas operated refrigeration systems.

In the graph, it is observed that COP of the system initially reaches 0.45 and after that COP is continuously decreased due to increased heat, supplied is increasing per hour and heat extraction is maintained with respect to cabinet temperature and room temperature. Over a time of 24 hours COP is gradually decreased. After the completion of 24 hours of operation it is observed that average COP of the system 0.12.

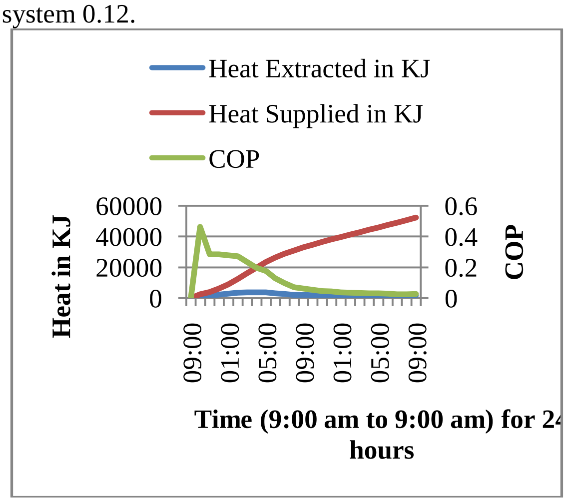

Fig.5 : Variations of heat extracted, heat supplied and COP of the system with time

V. CONCLUSION

Biogas flame from biogas burner which was produced by biogas energy. Its heat given to generator of vapour absorption refrigeration system and generator achieved its maximum temperature 140°C after one hour. Evaporator cabinet temperature achieved 4 °C. It was maintained in the range of 2°C to 4°C throughout 24 hours with respect to continuous supply of heat from biogas flame to generator. The average actual COP and average maximum COP of biogas powered vapour absorption refrigeration system 0.13 full load test of refrigerator. This experiment was repeated for three day in three days for Full load test

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