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## DESIGN AND FABRICATION OF VAPOUR ABSORPTION GENERATOR TO INCREASE THE EFFECTIVENESS

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## ABSTRACT

Experimental analysis on vapor absorption generator was conducted. The system uses helical coil type heat exchanger, absorber tank, steam generator. From different refrigerants working pairs Ammonia was used because it costs less, readily available and is environmental friendly. Design of generator was done and the volume chosen is 5 lt. Fabrication of generator was done on a refrigerant canister. Effectiveness of the generator at different inlet temperatures is presented. Inlet temperature of the generator was taken at 80°C and effectiveness was calculated to be 0.725. It is observed that effectiveness of the generator increases with increase in temperature. Corresponding graphs have also been depicted for different inlet temperatures and volume of generator.

## INTRODUCTION

Refrigeration is the process of moving heat from one location to another under controlled conditions. The work of warmth transport is driven by mechanical work, however can also be driven by different means that like optical maser, electricity, magnetism. There are a unit 2 strategies of refrigeration: 1-Non cyclic refrigeration 2-Cyclic refrigeration. On cyclic refrigeration, the higher than refrigeration methodology cools a contained space by melting ice, or by subliming ice. This method is like dropping comestibles within a instrumentation and running ice on top of it. Usually normal ice is used for this type of refrigeration.

#### **Cyclic Refrigeration**

This consists of a refrigeration cycle, where heat is removed from a low-temperature space or source and rejected to a high-temperature sink with the help of external work, and its inverse, the thermodynamic power cycle. In the power cycle, heat is supplied from a high-temperature source to the engine, part of the heat being used to produce work and the rest being rejected to a low-temperature sink. This satisfies the second law of thermodynamics Cyclic refrigeration is classified as: 1. Vapour compression cycle 2. Vapour absorption cycle.

## Vapour Compression Cycle

This cycle is used in most households for preserving foods for a long time. The cycle works as follows:

**Compression:** The circulating refrigerant enters the compressor as vapour and the vapour is compressed at high pressure and temperature, but below vapour pressure of that temperature. The vapour exits the compressor.

**Condensation:** The high temperature and pressured vapour enters the condenser where the vapour is condensed and converted into liquid by removing additional heat at constant pressure.

**Expansion:** The liquid refrigerant still under quite pressurized enters the expansion coil where the pressure of the refrigerant drastically drops causing flash evaporation.

**Evaporation:** The low pressure liquid passes through

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the evaporator coils where the evaporator fan blows and produces cooling effect. The heat from the contents kept inside the fridge is used to heat up the refrigerant back to vapour phase.

In the current age of modern machinery industries all over the world thrive to invent new technologies resulting in new machineries leading to utilization of different sources of energy. Thereby releasing unwanted components or emissions at the back end of the process. There are lot of manufacturing industries and refineries produce gases like carbon dioxide, ammonia and many more.

#### Vapour Absorption

These gases are released into atmosphere causing adverse effects on environment. But, utilizing these flue gases as heat sources and using for instance ammonia - water as working pair these gases can be contained. This corresponds to vapour absorption refrigeration system thereby displacing costly and electricity driven vapour compression refrigeration system. Hence there is a positive impact on industrial economy and environment. There is one such instance below (Eyringer, et al., 2005) Maritime transport is a huge energy-consuming sector globally. Typically onboard energy is produced using diesel engine combustion. This power is used for propulsion and to generate electricity that is needed onboard. However, environmental and economic concerns have caused the maritime sector to explore alternative solutions in order to improve the efficiency of the energy usage system and to reduce their emissions. Diesel engine combustion produces pollutants like SOx and NOx. Approximately 3.3% of global CO, emissions are caused by shipping. The International Maritime Organization is the major global regulator for emissions maritime transport. Moreover, the European Union has implemented a directive for sulphur emissions in specific control areas. These factors and the fact that the prices of fossil fuels are rising continuously have motivated the marine sector to reduce its fuel consumption. At present, some effort has been devoted to the utilization of the vast amount of waste energy from diesel engines used aboard ships for refrigeration. There are several types of refrigeration technology being used for marine applications, including compression refrigeration, sorption refrigeration, and injection refrigeration. It needs extra energy to drive the compression and injection refrigeration systems, which leads to the increase of fuel consumption of ships. (Cao, et al., 2015) conducted a transient simulation of the engine waste heat powered absorption cooling system for cargo ship application on a TRNSYS platform.

The absorption cooling model was developed and validated against the literature. The engine waste heat model was based on experimental data.

Challenges to the absorption cooling system on shipboard applications were also addressed by suggesting potential solutions. (Fernandez-Seara, et al., 1998) designed, modelled and analyzed a gasto-thermal fluid WHR system for a trawler chillers fishing vessel. An ammonia-water absorption refrigeration plant was used for onboard cooling. Synthetic oil was used as a heat transfer fluid. The influence of geometric design parameters and thermal operating conditions were studied on heat exchangers and system thermal performance. The high and constant engine load maintained during the fishing period allowed the recovery of heat from engine exhaust at a thermal level that exceeds that power required by the absorption system. (Ezgi, 2014). conducted a thermodynamic analysis of a HVAC system consisting of a water-lithium bromide (H<sub>2</sub>O-LiBr) absorption heat pump for application on a naval surface ship. A comparison was made between an absorption heat pump and a vapour compression heat pump system. The case ship used a vapour compression heat pump system for both heating and cooling. The heat pump had coefficient of performance (COPs) between two to four. The electric motor of the compressor in a vapour compression heat pump was fed by a diesel generator set on board the ship. The electrical load of compression directly influenced the overall fuel economy and emissions. Fuel consumption and CO<sub>2</sub> emissions decreased while maintaining the same cooling power when the absorption heat pump system was used. (Ebrahimi, et al., 2015) studied a two-phase cooling system and an absorption refrigeration system as associated with WHR in data centres. They simulated both water-LiBr and Ammonia-water absorption cooling systems. They replaced the condenser in the cooling circuit with the generator of an absorption refrigeration cycle. The verification indicated the superiority of the water-LiBr absorption system for data centre/server operating conditions. (Behrooz and Ziapour, 2011) presented an experimental study of an ammonia-water absorption refrigeration system using the exhaust gas of an internal combustion engine as an energy source. The exhaust gas energy availableness and also the impact of the absorption refrigeration cycle engine performance, exhaust emissions, and power (Mathur and Mehta, 2007) presented refrigerants and psychometric properties and charts for different refrigerants. (Gomri, 2009) observed that for better performance of absorption chillier, first priority must be given to optimization

evaporation while absorber should be considered as second. Although, it is also found that absorber, generator and evaporator are the three components having highest Exergy loss rate. (Gutiérrez-urueta, et al., 2014) observed that absorber has lowest value of exegetic efficiency among all the components of the system. Therefore, better performance of the system absorber needs to be optimized. It is also found that for both single and double effect LiBr-H<sub>2</sub>O VARS, highest irreversibility takes place in absorber followed by condenser, evaporator and solution heat exchanger. (Henry, 1920) presented specific heats of ammonia at different temperatures. (Sathiya, 2016) presented to increase the efficiency and the power output of the Energy recovery system. A nozzle of suitable material is installed above a cooling tower of a certain height. The nozzle is employed to boost the speed of the exhaust air taking off of the cooling system exhaust. A horizontal axis turbine is placed over the highest of the nozzle such it's parallel to the cooling system. The wind turbine selected is of a size slightly less than the outlet of the nozzle.

## EXPERIMENTAL PROCEDURE

(Fig. 1) shows the vapour absorption system model. Heat generator is highlighted in blue, in this component the helical coil is seen through which hot steam is passed. The steam generator shown in metallic colour produces steam at high temperature and pressure. When flow valve is released the steam passes through these coils and heats the generator and the pipe inside. The absorber tank which is shown in red is where the refrigerant (Ammonia-water) is stored. A submersible pump pushes the refrigerant inside through pipes into the heat exchanger where the ammonia turns into vapour and exits from the top of the generator. The pipe travels back to the absorber carrying condensed refrigerant with it.



Fig. 1 Vapour absorption system.

#### **Generator Fabrication**

The Generator is taken as a storage cylinder of 5 lt volume according to design calculations. The cylinder is cut from the top and the bottom using a cutting tool to allow the helical coil setup to be installed in the cylinder. The number of turns in the coil is assumed to be 15 considering the coil diameter, height of the cylinder, design calculations. Inner and outer diameters of the cylinder are measured and analyzed to allow the installation of cold fluid inlet tubing. The copper coil is used is 3/8 which is wound around a metal tubing. The copper is carefully welded to the metal tube using gas welding to properly fix the copper tube on the pipe and the movement of the tube is arrested. The coil is wound in such a way that the inlet flow is one the top and the outlet flow is at the bottom of the opposite end. Two holes are drilled using drilling machine to match the diameter of the copper tube such that the tubes come out of the holes. The pipe with copper coil is inserted into the cylinder such that the excess copper lengths from two ends are pulled out through the holes drilled on the surface of the cylinder and the ends are sealed to avoid leakage. The pipe is welded shut to from top and bottom of the tank. (Fig. 2) shows fabricated heat exchanger where the refrigerant vaporizes and is send back into the absorber tank in condensed state.

#### **Steam Generator Fabrication**

The steam generator is fabricated using a pressurized container such as a pressure cooker. The safety valve is replaced by copper coil arrangement attached with pressure gauge and thermocouple. The 3/8 valves are attached for flow control and pressure build up inside the cooker. When the cooker is heated the closed valves blocks the steam from passing through the copper coils and pressure is further increased along with the pressure build inside the closed vessel. When the required pressure is indicated the valves are opened and the steam is released out at high pressure. For experimental analysis pressure gauge and thermocouples are attached. The nut and bolt are employed for easy dismantle and white Teflon tapes are provided for leakage prevention. Inside the steam generator the water is filled up to 2.5 lt and is heated on a stove. When the temperature rises and when the vapour pressure of the liquid is equal to pressure exerted by the surroundings, boiling occurs. The closed vessel increases the atmospheric pressure and hence the boiling point increases up to 120°C (Fig. 3) shows a steam generator where hot steam is generated inside the pressure vessel while the flow control valves are closed. Once the valves are opened the steam is released at high pressure.



Fig. 2 Heat exchanger.



Fig. 3 Steam generator.

#### **Absorber Tank Fabrication**

The absorber tank is a 10 lt stainless steel vessel which is used in commercial households. The top cover is drilled and a hollow shaft is welded on it to support piping for the system. One hole is for inlet of the generator and other is for outlet of the generator and back to the tank. The pipes connected are held in position with the help of metal clamps. The refrigerant filled inside the tank is strong because of the percentage of ammonia is more than that of water. A submersible pump is placed inside the liquid to allow pumping action. The pumped liquid passes through the inlet pipe and into the generator where the steam from the steam generator heats up the inside pipe. The heated pipe comes in contact with the refrigerant and vaporizes it. The ammonia vapour which comes out of the generator is directed back into the tank. The gaseous ammonia becomes liquid when losing temperature. Water which acts as absorbent absorbs the vapour and the cycle repeats again. (Fig. 4) represents a absorber tank which contains Ammonia-Water refrigerant absorbent pair.

#### **Final Process Description**

The components are attached as the block diagram, Firstly the absorber inlet is attached to the bottom of the generator and tightened with clamp. The outlet of the generator is attached back to the absorber known as absorber outlet. Steam generator inlet is attached to the to the steam inlet of the coil. The outlet of the coil is extended and a canister is placed below it. The pressure cooker is filled with water for steam generation. The temperature inside the cooker is higher since the pressure is directly proportional to boiling point and the atmospheric pressure is also increased. When the required pressure is built, the valves are released and steam is taken out at the other end of the helical coil. After some time the generator gets hot due the conduction and convection heat transfer. Now when the required temperature is obtained, the ammonia water mixture is introduced by pumping action using submersible pump. The ammonia in the mixture gets evaporated due to the heat inside the heat exchanger. While returning back to the absorber the temperature is reduced and slight condensation occurs. Now the water in the absorber absorbs the ammonia and it becomes liquid. The process starts again as long as the pumping power is supplied shown in (Fig. 5).



Fig. 4 Absorber tank.



Fig. 5 Vapour absorption generator.

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		0		0							
Tg	h <sub>1</sub>	h <sub>2</sub> =h <sub>3</sub>	h <sub>4</sub>	Qe	Mr	Density	volume in liters for working duration t (min)				
(°c)	(Kj/kg)	(kj/kg)	(Kj/kg)	(KJ/min)	(Kg/min)	(Kg/m³)	t=15	t=30	t=60	t=120	t=240
20	1508	293	1534	21	0.01692184	0.73	0.347709	0.695418	1.390836	2.781672	5.563344
30	1532	341	1556	21	0.01728395	0.73	0.35515	0.710299	1.420599	2.841197	5.682395
40	1556	390	1578	21	0.01767677	0.73	0.363221	0.726443	1.452885	2.90577	5.81154
50	1580	440	1602	21	0.01807229	0.73	0.371348	0.742697	1.485394	2.970787	5.941575
60	1604	490	1622	21	0.01855124	0.73	0.38119	0.76238	1.524759	3.049518	6.099037
70	1630	540	1644	21	0.01902174	0.73	0.390858	0.781715	1.563431	3.126861	6.253722
20	1508	293	1534	42	0.03384367	0.73	0.695418	1.390836	2.781672	5.563344	11.12669
30	1532	341	1556	42	0.0345679	0.73	0.710299	1.420599	2.841197	5.682395	11.36479
40	1556	390	1578	42	0.03535354	0.73	0.726443	1.452885	2.90577	5.81154	11.62308
50	1580	440	1602	42	0.03614458	0.73	0.742697	1.485394	2.970787	5.941575	11.88315
60	1604	490	1622	42	0.03710247	0.73	0.76238	1.524759	3.049518	6.099037	12.19807
70	1630	540	1644	42	0.03804348	0.73	0.781715	1.563431	3.126861	6.253722	12.50744
20	1508	293	1534	63	0.05076551	0.73	1.043127	2.086254	4.172508	8.345016	16.69003
30	1532	341	1556	63	0.05185185	0.73	1.065449	2.130898	4.261796	8.523592	17.04718
40	1556	390	1578	63	0.0530303	0.73	1.089664	2.179328	4.358655	8.71731	17.43462
50	1580	440	1602	63	0.05421687	0.73	1.114045	2.22809	4.456181	8.912362	17.82472
60	1604	490	1622	63	0.05565371	0.73	1.143569	2.287139	4.574278	9.148555	18.29711
70	1630	540	1644	63	0.05706522	0.73	1.172573	2.345146	4.690292	9.380584	18.76117
20	1508	293	1534	84	0.06768735	0.73	1.390836	2.781672	5.563344	11.12669	22.25337
30	1532	341	1556	84	0.0691358	0.73	1.420599	2.841197	5.682395	11.36479	22.72958
40	1556	390	1578	84	0.07070707	0.73	1.452885	2.90577	5.81154	11.62308	23.24616
50	1580	440	1602	84	0.07228916	0.73	1.485394	2.970787	5.941575	11.88315	23.7663
60	1604	490	1622	84	0.07420495	0.73	1.524759	3.049518	6.099037	12.19807	24.39615
70	1630	540	1644	84	0.07608696	0.73	1.563431	3.126861	6.253722	12.50744	25.01489
20	1508	293	1534	105	0.08460919	0.73	1.738545	3.47709	6.95418	13.90836	27.81672
30	1532	341	1556	105	0.08641975	0.73	1.775748	3.551497	7.102993	14.20599	28.41197
40	1556	390	1578	105	0.08838384	0.73	1.816106	3.632213	7.264425	14.52885	29.0577
50	1580	440	1602	105	0.09036145	0.73	1.856742	3.713484	7.426968	14.85394	29.70787
60	1604	490	1622	105	0.09275618	0.73	1.905949	3.811898	7.623796	15.24759	30.49518
70	1630	540	1644	105	0.0951087	0.73	1.954288	3.908577	7.817153	15.63431	31.26861
20	1508	293	1534	210	0.16921837	0.73	3.47709	6.95418	13.90836	27.81672	55.63344
30	1532	341	1556	210	0.17283951	0.73	3.551497	7.102993	14.20599	28.41197	56.82395
40	1556	390	1578	210	0.17676768	0.73	3.632213	7.264425	14.52885	29.0577	58.1154
50	1580	440	1602	210	0.18072289	0.73	3.713484	7.426968	14.85394	29.70787	59.41575
60	1604	490	1622	210	0.18551237	0.73	3.811898	7.623796	15.24759	30.49518	60.99037

**Table 1.** Volume of generator/heat exchanger.

TR

0.1

0.2

0.3

0.4

0.5

1

70

## **RESULT AND DISCUSSION**

540

1630

Vapour absorption generator volume was calculated using design procedure. Final system was designed and fabricated by above said procedure. Analysis was conducted on the generator and the effectiveness of the generator was calculated. Effectiveness was observed and compared at different inlet temperature  $(T_{o})$  Tables 1 and 2, (Fig. 6).

1644

210

0.19021739

0.73

- 1. Heat lost by hot fluid =Heat gained by cold fluid (Energy balance equation)
- 2. Heat carried by hot water= $Q_h = Mr_h \times C_{ph} \times (T_{hi} T_{ho})$
- 3.  $Mr_h$  is calculated experimentally which is equal to

Table 2. Inlet generator temperature- effectiveness.

0	
Inlet generator temperature (Tg°c)	Effectiveness (ε)
50	0.67
60	0.69
70	0.718
80	0.725

3.908577 7.817153 15.63431 31.26861 62.53722

(1.5/60)=0.025 Kg/min

4. From the table below temperature and specific heat is taken

Q<sub>b</sub>=0.025 × 4179.2 × (80-35)=4701.6 W

5. Heat carried by cold fluid (water + ammonia)= $Q_c=Mr_c \times C_{pc} \times (T_{ci}-T_{co})$ 

1730

- 6. Mr<sub>c</sub> is taken from the design tables.
- 7. Specific heat is calculated to be the average of both the fluids=
- (4178+4600)/2=4388KJ/Kg-K
- 8. Q<sub>c</sub>=0.016 × 4388 × (36-20)=1123.32 W
- 9.  $Q_{averag} = (Q_h + Q_c)/2 = (4701.6 + 1123.32)/2 = 2912.464 \text{ W}$
- 10.  $Q_{max} = Q_c \times C_{min} \times (T_{hi} T_{co}) = 0.016 \times 4179.2 \times (80-20) = 4012.623 \text{ W}$
- 11. Effectiveness (ε)=(Q<sub>average</sub>/ Q<sub>max</sub>)=(2912.464/4012.623)=0.725

From the (Fig. 6) depicts the Effectiveness-inlet temperature of generator, if the inlet temperature of generator increases corresponds the effectiveness also increases. From the (Fig. 7) says Volume of Generator-Mass flow rate Mass flow rate increases corresponds the volume of generator increases, from that effectiveness is increases.

## CONCLUSION

The design calculations for generator fabrication were done. The concentration of ammonia water, driving pressure (5 bar) and driving temperature (80°C) was studied. It is observed from design calculation table that increase in tone of refrigeration requires higher volume of the generator. Analysis on the generator was carried out and the effectiveness of the generator was calculated. The Effectiveness was found to be 0.725. This shows that with increase in inlet temperature of generator the effectiveness of the generator can be increased.

#### **FUTURE ENHANCEMENTS**

A novel GAX absorption refrigeration cycle is proposed. Part of the solution out from water cooled absorber flows to a refrigerant cooled absorber to absorb part of the vapour out from evaporator. The refrigerant cooled absorber is cooled by refrigerant which evaporates at an intermediate pressure. The vapour at intermediate pressure is absorbed by the solution out from refrigerant cooled absorber in a high pressure absorber. The proposed cycle can make use of the absorption heat that cannot be utilized by standard GAX cycle to make additional refrigeration. Therefore, the COP of the proposed cycle is much higher than that of the standard GAX (SGAX) cycle. Automobiles parts or inside cabins can be cooled with engine an exhaust gas which has very high temperatures. The gas can be filtered and passed at high pressure as a heat source for absorption refrigeration cycle. To include analyzer, rectifier and working fluid hydrogen to convert the strong solution into weak solution and to facilitate the faster rate of evaporation in the evaporator in vapour absorption system.

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