Catalyst Research Volume 23, Issue 2, December 2023 Pp. 5146-5156

# DESIGN AND DEVELOPMENT OF ELECTROLUX VAPOUR ABSORPTION REFRIGERATION SYSTEM

**Dr. Abhijit A. Patil**
Assistant Professor, Department of Mechanical Engineering, Sanjay Ghodawat University, Atigre, Kolhapur, Maharashtra, 416118

**Abstract:**
Thermodynamic analysis of both the conventional and the modified cycles has been carried out. Here, the variation of performance parameters (circulation ratio, internal heat recovered and coefficient of performance) are compared with the operating temperatures (absorber, condenser, evaporator and generator temperatures), heat exchanger effectiveness and split factor (It is the ratio of the mass flow rate of the refrigerant to the absorber to the mass flow rate of the refrigerant in the cycle). The split factor has been selected in such a way that, to yield maximum coefficient of performance under different operating conditions. It is found that the maximum coefficient of performance could be obtained when the split factor is in the range of 0.8 to 0.9. Under ideal operating conditions, the maximum internal heat recovered in the modified cycle is 26.73 kW. For a fixed evaporator and sink (absorber and condenser) temperatures of -10°C and 45°C respectively, thermodynamic coefficient of performance of 0.52 to 0.61 has been obtained in the generator temperature range between 130°C and 160°C. At the optimum split factor range between 0.8 and 0.9, the coefficient of performance of the modified cycle shows an improvement of 20 to 67% higher than that of a conventional cycle, under different operating conditions.

Based on the outcome of thermodynamic simulation, an experimental set up of an air-cooled modified generator-absorber heat exchangebased vapour absorption refrigeration system of 10.5 kW cooling capacity, has been built with ammonia-water as the working fluid. The major components have been designed using standard procedure with relevant heat and mass transfer data.The system has been operated with under various operating conditions to obtain the effect of operating parameters on the system performance. The mass flow rate of the weak solution and the fuel flow rate are varied to study their influence on the system performance. The system reached the steady state in about 90 minutes and yielded a maximum cooling capacity of 9.5 kW and fuel coefficient of performance of 0.61, at a generator and evaporator temperatures of 120°C and 2°C, respectively. The amount of internal heat recovered is about 9 to 16 kW under various operating conditions. Under no load condition, the system achieved a low evaporator temperature of -5°C, at the generator, absorber and condenser temperatures of 135°C, 56°C and 46°C respectively.

The feasibility of operating a small capacity (10.5 kW) air-cooled modified generator-absorber heat exchange-based vapour absorption refrigeration system using ammonia-water as the working fluid has been established. The performance of the system tested is higher compared to the conventional single effect ammonia-water system. These systems could be employed for cold storage applications in the rural and semi urban areas.

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 5146-5156

## Introduction

### Domestic Electrolux Refrigerator:

The domestic absorption type refrigerator was developed from an invention by Carl Munters and BaltzerVon Platen. This system is often called "Munters Platen System".This type of refrigerator is also called "Three-fluids absorption system". The three fluids used in this system are ammonia, hydrogen and water.The "ammonia" is used as a refrigerant because it possesses most of the desirable properties. Though it is toxic, and not otherwise preferred in domestic appliances, it is very safe in this system due to absence of any moving parts in the system and, therefore, there is the least chance of any leakage.The "hydrogen" being the lightest gas, is used to increase the rate of evaporation (the lighter the gas, faster is the evaporation) of the liquid ammonia passing through the evaporator. The hydrogen is also non-corrosive and insoluble in water. This is used in the low-pressure side of the system.The "water" is used as a solvent because it has the ability to absorb ammonia readily.

### Principle and working of Electrolux Refrigerators:

Fig. 1 Shows a schematic diagram of an Electrolux refrigerator. It is a domestic refrigerator and is the best known absorption type of refrigerator. The small energy supply is by means of a heater which may be electric or gas.

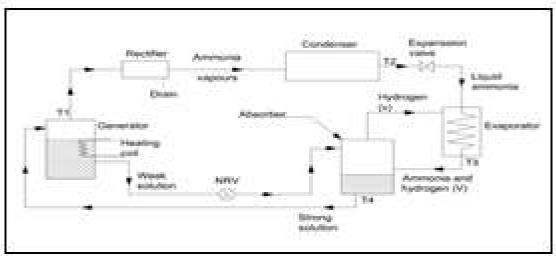


Fig1. Electrolux System

### Principle:

The principle involved makes use of the properties of gas-vapor mixtures. If a liquid is exposed to an inert atmosphere, it will evaporate until the atmosphere is saturated with the vapor of the liquid. This evaporation requires heat which is taken from the surroundings in which the evaporation takes place. A cooling effect is thus produced. The partial pressures of the refrigerant vapor (in this case ammonia) must be low in the evaporator, and higher in the condenser. The total pressure throughout the circuit must be constant so that the only movement of the working fluid is by convection currents. The partial pressure of ammonia is kept low in requisite parts of the circuit by concentrating hydrogen in those parts.

### Working:

This type of refrigeration system is called three-fluid absorption system. The main purpose of this system is to eliminate the pump so that in the absence of moving parts, the machine becomes noiseless. The three fluids used in this system are ammonia, hydrogen and water. The ammonia is used as a refrigerant because it possesses most of the desirable properties. The hydrogen, being the lightest gas, is used to increase the rate of evaporation of liquid ammonia passing through the evaporator. The hydrogen is also non-corrosive and insoluble in water. This is used in the low-

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 5146-5156

pressure side of the system. The water is used as solvent because it has ability to absorb ammonia readily.

The strong ammonia solution from the absorber through heat exchanger is heated in the generator by applying heat from an external source, usually a gas burner. During this heating process, ammonia vapours are removed from the solution and passed through the condenser. A rectifier or a water separator fitted before the condenser removes water vapour carried with the ammonia vapours, so that dry ammonia vapours are supplied to the condenser. The water vapours, if nor removed, will enter into the evaporator causing freezing and choking of the machine. The hot weak solution left behind in the generator flows to the absorber through the heat exchanger. This hot weak solution while passing through the exchanger is cooled. The removed by the weak solution is utilized in raising the temperature of strong solution passing through the heat exchanger. In this way, the absorption is accelerated and the improvement in the performance of a plant is achieved.

The ammonia vapours in the condenser are condensed by using external cooling source. The liquid refrigerant leaving the condenser flows under gravity to the evaporator where it meets the hydrogen gas. The hydrogen gas which is being fed to the evaporator permits the liquid ammonia to evaporate at low pressure and temperature according to Dalton's principle. During the process of evaporation, the ammonia latent heat from the refrigerated space and thus produces cooling effect.

The mixture of ammonia vapour and hydrogen is passed to the absorber where ammonia is absorbed in water while the hydrogen rises to the top and flows back to the evaporator. This completes the cycle. The coefficient of performance of this refrigerator is given by:

$$C.O.P.=\frac{\text{Heat absorbed in the evaporator}}{\text{Heat supplied in the generator}}$$

**LiteratureReview:**

In the paper of Dharmendra Patel and Tarun Gupta, titled 'Solar Based Vapour Absorption System' [1] shows that, the vapour absorption system uses heat energy, instead of mechanical energy as in vapour compression system, in order to change the condition of the refrigerant required for the operation of the refrigeration cycle.The paper discuss about the theoretical calculations are made of different components of the systems like evaporator, absorber, condenser and pump of vapour absorption system for a capacity of 0.25TR and experimentally developed and run system to validated for reducing the temperature for the free of cost of operation.

In the paper of K. Lingeswaran and C. Hemalatha, titled 'Experimental Studies on Solar Powered Diffusion Absorption Refrigerator' [2] shows that, an experimental investigation of solar powered diffusion absorption refrigeration system. It can be operated without any use of electrical or mechanical energy. The principle behind absorption refrigeration is that it uses three gases to accomplish its cooling effect namely ammonia (refrigerant) water (absorbent) and Helium. Ammonia is used as the refrigerant as it is easily available and can produce a better cooling effect. Helium is used to reduce the partial pressure of ammonia vapor in the evaporator chamber so that more ammonia evaporates yielding more cooling effect.In the paper, an experimental setup for absorption refrigeration is made using solar energy to supply input heat. A parabolic dish is used as the solar collector. Solar energy is concentrated to the generator pipes by the solar collector, heating the aqua ammonia solution. Circulation of the working fluid is achieved using a bubble-pump. The results show that the system performance is strongly dependent upon the input given by the solar collector, bubble-pump characteristics and the evaporator and absorber mass transfer performance. Cold is produced at temperatures between -5º C to -10º C for a driving temperature in the range of 80º C –150º C.

In the paper of V.D. Patel, A.J. Chaudhari et al.,'Theoretical and Experimental Evaluation of Vapour Absorption Refrigeration System' [3] shows that the theoretical calculations are made of different components of the systems like evaporator, absorber, condenser and pump of vapour absorption system for a capacity of 0.25TR and experimentally developed and run system to validated for reducing the temperature for the free of cost of operation.

In the paper of TarikShaikh and Prof.Yogesh J. Morabiya,'Review of Solar Absorption Refrigeration System using LiBr-Water and Simulate the performance of the system', [4] shows consistently increasing $CO_2$ emission and ozone depletion from CFC's are serious environmental issues challenging scientific community. In this aspect, vapour absorption system gives scope of utilizing low grade energy source i.e. solar panel for generating cooling effect which is dominated by high grade energy driven compression technology.Absorption refrigeration system provides large potential for reducing heat pollution of the environment. The paper describes simple absorption refrigeration system using Li-Br / $H_2O$ as a working pair. The simulation of the system was carried out using Engineering Equations Solver. Results of simulated performance of this system and the effects of the refrigeration load inlet temperature on the coefficient of performance, COP of the system are discussed. The performance of the system increased with increasing initial temperature of the cooling load. The effects of changing refrigeration load inlet temperature are investigated and shown.

**Construction:**

1. The first step of construction starts from rough design of table. The design of table is made by fabrication according to the size of the equipment. For fabrication of said table, the design is made in CAD software.The light weight material has chosen for the fabrication of table which is strong enough to sustain the weight of the entire assembly.
2. The cabinet chamber is designed according to the chosen dimensions and the chamber is insulated from surrounding by foam.
3. Panel is made up of sheet metal and slots are provided on panel for ammeter, voltmeter, energy meter, temperature indicator, power switch etc.
4. The outlet came from the generator is brazed with inlet of condenser. Similarly, the condenser outlet is brazed with the inlet of expansion valve, the expansion valve outlet is brazed with evaporator, the evaporator outlet tube is brazed with inlet of heat exchanger tube, outlet of heat exchanger is brazed with inlet of absorber and the outlet of absorber is joined to generator inlet tube by brazing.

**Setup diagram:**

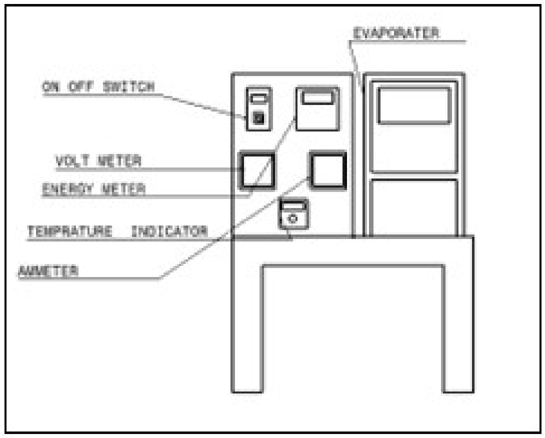


Fig. 2Setup diagram

**CAD modeling of setup:**

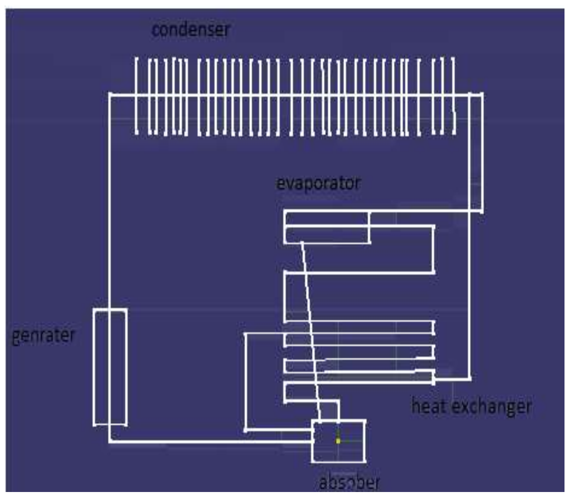


Fig. 3 CAD modeling of setup

**Actual photographs:**

**A) VARS Components pictures:**

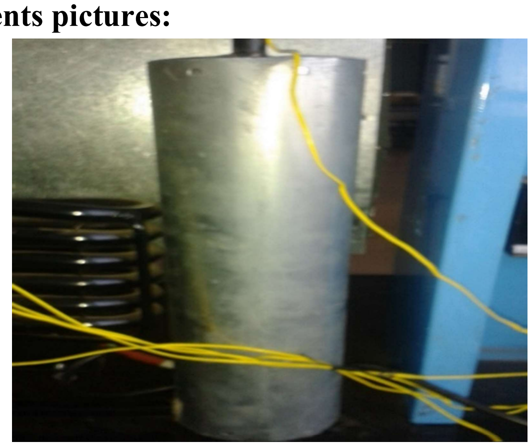

Fig. 4Evaporator

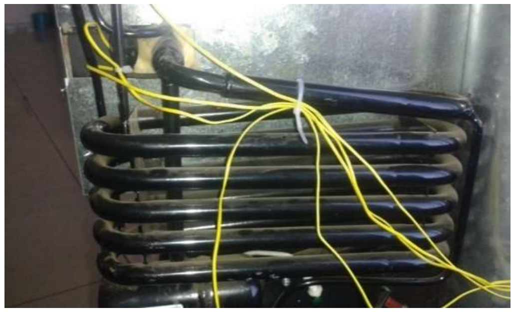

Fig. 5Heat Exchanger

Fig. 6 Natural Air Cooled Condenser

Fig. 7Generator

Fig. 8Evaporator Chamber

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 5146-5156

Fig. 9Evaporator

**Operating Procedure:**

**Technical Specifications:**

| | |
|---|---|
| Gross volume | 40 liters |
| Refrigerant | Water, ammonia, hydrogen |
| Generator | Electrically heated |
| Condenser | Natural convection type |
| Evaporator | Natural convection type |
| Material of | M.S. |
| Supply | 230 volts, 50 hz, 1 ph |

Table No.1 Technical Specifications

**Observations:**

In condenser pure $NH_3$ vapour pressure = Total pressure

In evaporator $NH_3$ vapour pressure = Total pressure - partial pressure of $H_2$

For example, consider the condenser temperature at 50ºC, and evaporator temperature as -15ºC. The corresponding vapour pressures of $NH_3$ are:

Condenser, $P_C$ = 20.33bar.

Evaporator outlet, $P_E$ = 2.6bar.

| Section | $NH_3$ | $H_2O$ | $H_2$ | Total |
|---|---|---|---|---|
| Condenser | 20.33 | 0 | 0 | 20.33 |
| Evaporator inlet | 1.516 | 0 | 18.814 | 20.33 |
| Evaporator outlet | 2.36 | 0 | 17.97 | 20.33 |
| Generator top | 15.54 | 4.79 | 0 | 20.33 |

Table No.2Pressures of $NH_3$, $H_2O$ and $H_2$ at specific temperature

It has been assumed that vapours leaving generator top are in equilibrium with entering rich solution at 40º C, at which temperature saturation pressure of $NH_3$is 15.45bar. It has also been

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 5146-5156

assumed that the temperature at evaporator inlet is -25º C at which temperature saturation pressure of $NH_3$ is 1.516bar.

**Sample Calculations:**

Applying 20-watt load in evaporator cabin.

Therefor assuming no loss condition

Refrigeration Effect=Load Applied = Output of evaporator

= 20 W

N = 20 W

From volt meter and ammeter

V=230 volts

I=350 mA

System Input (Generator) = V * I

= 230 * 350

Q= 80.50 W

$(COP)_{actual} = \frac{N}{Q}$

$= \frac{20}{80.50}$

= 0.24

**Design of Vapour Absorption Refrigeration System:**

Average Latent heat of evaporation of ammonia = 1400 kJ/kg

Designed Refrigeration Effect = 20 watt

Mass flow rate required$= \frac{\text{Designed refrigreation effect}}{\text{Average Latent heat of evaporation of AMMONIA}}$

$$= \frac{20}{1400}$$

= 0.014285 kg/s

Add losses through piping, insulation, heat transfer inefficiencies = 80 %

Mass flow rate required = $C + \frac{C*D}{100}$

$= 0.014285 + \frac{0.014285*80}{100}$

= 0.0257 kg/s

Add safety factor = 50 %

Designed mass flow rate = $E * \frac{150}{100}$

$$= 0.0257 * \frac{150}{100}$$

= 0.03857 kg/s

= 38.57 grams/sec

Solubility of $NH_3$ in water = 30% of strong solution

Water quantity required= $\frac{\text{Designed mass flow rate}}{30/100}$

$$= \frac{38.57}{30/100}$$

=128.5714286 grams

Volume occupied by water = 128.5714286 ml

Add extra space for separation = 128.5714286 ml

Volume of Generator = J+K

= 128.5714+ 128.5714

= 257.1428751 ml

**Conclusion:**

**Waste heat recovery**

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved.

Large quantity of hot flue gases is generated from Boilers, Kilns, Ovens and Furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered. Depending upon the type of process, waste heat can be rejected at virtually any temperature from that of chilled cooling water to high temperature waste gases from an industrial furnace or kiln. Usually higher the temperature, higher the quality and more cost effective is the heat recovery. In any study of waste heat recovery, it is absolutely necessary that there should be some use for the recovered heat. Typical examples of use would be preheating of combustion air, space heating, or pre-heating boiler feed water or process water. With high temperature heat recovery, a cascade system of waste heat recovery may be practiced to ensure that the maximum amount of heat is recovered at the highest potential. An example of this technique of waste heat recovery would be where the high temperature stage was used for air pre-heating and the low temperature stage used for process feed water heating or steam raising.

**Plant efficiency increasing factor:**

Chilled water-based cooling systems are frequently used to air condition large office buildings or campuses that encompass multiple buildings. They represent a large investment from the perspective of first cost, physical space they require within the building, as well as energy and maintenance cost. Yet despite these fiscal and spatial impacts, many chiller plants do not reach their potential from the standpoint of energy efficiency. In the past, California's Title 24 Energy Efficiency Standards for Non-

Residential Buildings did not have particularly aggressive efficiency standards for chillers. Larger buildings and multiple building campuses usually use a chiller plant to provide cooling. In such systems, chilled water is centrally generated and then piped throughout the building to air handling units serving individual tenant spaces, single floors, or several floors. Ductwork then runs from each air handler to the zones that are served. Chilled water-based systems result in far less ductwork than all-air systems because chilled water piping is used to convey thermal energy from the point of generation toeach point of use. Whereas the all-air systems used to cool smaller buildings usually contain all of their components packaged within a single cabinet (ergo the term "packaged cooling unit"), a chiller plant is acollection of individual components that have been selected to work together as a system. Though costlier to install and more complicated to operate, a chiller plant offers a number of benefits over simple packaged cooling units, including greater energy efficiency, better controllability, and longer life. Additionally, a chiller-based system can be much more efficient in terms of space utilization within the building because components need not be located within the same space.

**Lack of electricity:**

The electricity requirement in the rural areas is the very less but they cannot obtain this electricity. Due this reason they can operate the air conditioning system. So that we are designing this type of system in which the people which have to operate the ac system without any energy requirement.This study will give a clear understanding and insights of the primary factors that are responsible for utilization of electricity in rural and urban areas. The determinants of household expenditures on electricity consumption of both the rural and urban areas are identified and analyzed. The rural people's income is too low and they are not in a position of getting registration in Electrical Department. On the contrary, in urban areas people are paying subsidized electrical bill per month.

**References:**


1. Dharmendra Patel and Tarun Gupta, 'Solar Based Vapour Absorption System', Global Journal of Engineering Science and Researches, August 2015, Pages 509–515 Department of Mechanical Engineering, NGF College of Engineering & Technology, Palwal, India.
2. K. Lingeswaran and C. Hemalatha, 'Experimental Studies on Solar Powered Diffusion Absorption Refrigerator', Middle-East Journal of Scientific Research. Pages – ISSN 1990-9233, DOI: 10.5829/idosi.mejsr.2014.20.07.11374, 2014, Department of Electrical Engineering, Bharath University, Selaiyur, Chennai, India and Department of Electrical Engineering, Paavai Engineering College, Namakkal, India.
3. V.D.Patel, A.J.Chaudhari and R.D.Jilte, 'Theoretical and Experimental Evaluation of Vapour Absorption Refrigeration System',International Journal of Engineering Research and Applications. Pages ISSN: 2248-9622, 30 March 2012, Department of Mechanical

Engineering,Vidyavardhini's College of Engineering and Technology, Vasai (W), Dist: Thane, Pin: 401 202, (M.S.), India.

4. TarikShaikh and Prof. Yogesh J. Morabiya, 'Review of Solar Absorption Refrigeration System using Libr-Water and Simulate the performance of the system' International Journal of Advanced Engineering Research and Studies. Pages E-ISSN2249–8974,P.G. Student, Mechanical Department, Subject of Energy Engineering, Government Engineering College,Valsad and Assistant Professor, Chemical Department, Government Engineering College, Valsad.
5. Koyfman, A., M. Jelinek, A. Levy and I. Borde, 2003. An experimental investigation of bubble pumps performance for diffusion absorption refrigeration system with organic working fluids. Applied Thermal Engineering, 23:1881-94.
6. D.S.Kim, C.A.Infante, Ferreira, "solar refrigerationoption a state of the art review", International journal ofrefrigeration 3 I,(2008),3-15.
7. V.K.Bajpai, "design of solar powered vapourabsorption system", proceeding of the world congresson engineering, 2012 vol-3.
8. Park YM, Sonntag RE. Thermodynamic properties of ammonia-water mixtures: a generalized equation of state approach. ASHRAE Trans 1990; 96:150–9.
9. Dossat RJ. Principles of refrigeration. 2nd ed. New York: Jhon Wiley and sons: 1981.
10. Hasealer LE, et al. a design study for absorption cycle heat pumps for domestic heating. Report no. G1157 UK: Engg. Sci.div.,AERE Harwell:1978a.
11. Hortz I. An experimental study of the vapour absorption refrigeration in road transport vehicles. Ph.D thesis, Mech. Engg. Dept., Univ. of Strathclyde, Glasgow, UK 1994.
12. Alizadeh, S., Bahar, F., Geoola, F., Design and optimization of an absorption refrigeration system operated by solar energy, Solar Energy, Vol. 22, (1997),pp. 149-154.
13. Anand, D.K., Kumar, B., Absorption machine irreversibility using new entropycalculations, Solar Energy, Vol.39, (1987), pp. 243-256
14. Tyagi, K.P., Design parameters of an aqua-ammonia vapour absorptionrefrigeration system, Heat recovery systems & CHP, Vol. 8(4), (1988), pp. 375-377
15. Ercan Ataer. O, Gogus, Yalcin., Comparative study of irreversibilities in anaqua-ammonia absorption refrigeration system, International Journal of Refrigeration, Vol.14, (1991), pp. 86-92
16. Bell, I.A., Al-Daini, A.J., Al-Ali, Habib., Abdel-Gayed, R.G., and Duckers, l., Thedesign of an evaporator/absorber and thermodynamic analysis of a vapourabsorption chiller driven by solar energy, World Renewable Energy Congress, (1996), pp. 657-660.