Waste Heat Utilization in Vapour Absorption Refrigeration System

Abstract

In the recent decades the demand for electricity is increased tremendously in our country. Industries are routinely faces significant power cuts and forced to operate on diesel based captive generation. Any measure that may reduce electrical power consumption of a given industrial unit is very useful.

Vapor absorption refrigeration system (VARS) offers several advantages as compared to vapor compression refrigeration system as their heat input is low grade thermal energy such as waste heat available from the industries, solar energy and geothermal energy etc.

In the present scenario of high fuel cost, the utilization of low grade thermal energy in vapor absorption refrigeration is of great importance.

Gajanand Rathor
Lecturer,
Deptt. of Mechanical Engg.
Govt. Polytechnic College,
Kota

D.K. Jain
Lecturer,
Deptt. of Mechanical Engg.
Govt. Polytechnic College,
Kota

Gourav Goswami
Lecturer,
Deptt. of Mechanical Engg.
Govt. Polytechnic College,
Kota

Keywords: Waste Heat, Refrigeration, Vapor Absorption Refrigeration System (VARS)

Introduction

Vapor absorption refrigeration system has been in use from the start of the century.

The system should be based on some source of low grade thermal energy like waste steam or high temp. Exhaust gases and the end product is cooling effect.

The energy input is of the order of 5000 K cal/hr. per ton of refrigeration effect and power consumption is only 30-35% of the conventional vapor compression system.

There for VARS is a suitable option for those industries that have a source of waste thermal energy and that require either refrigeration or air conditioning.

The thermal energy requirement of the system is as follows:-

1. Waste heat available in the temp. range of 120-200°C
2. Biogas, solar energy or waste heat from industries
3. Geothermal energy

Vapor Absorption Refrigeration System :–The VAR system consists of four basic components a generator, an absorber, a pump and a throttle valve.

This Cycle is Shown in Fig 1.

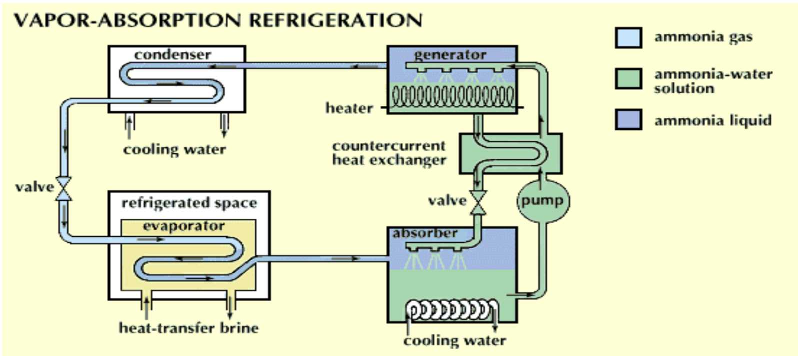
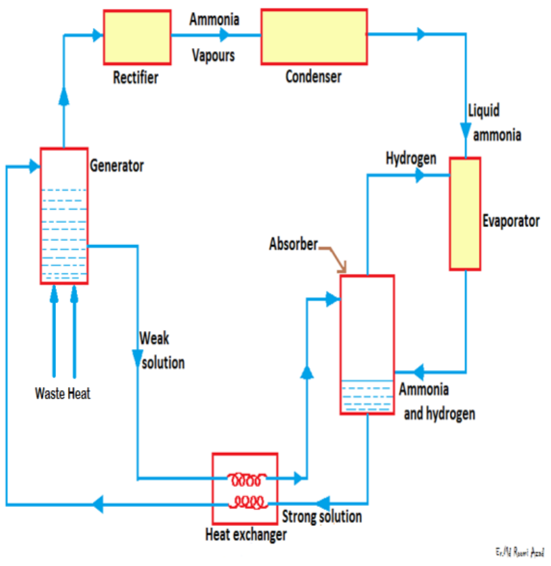


Fig.1

Heat is given to the generator as refrigerant vapor condenses at high pr. and afterwards heat is taken in at low temp. In the evaporator as the liquid refrigerant vaporizes at low pressure.

The vapor absorption cycle needs an input of heat to the generator and corresponding output of heat is obtained from the absorber as in fig.2



When ammonia is used, rectifier is needed which is positioned in the line taking vapor from the generator the condenser. It is necessary in cycles using an absorbent that is not completely nonvolatile. Vapor produced in the generator has an appreciable amount of absorbent vapor. This absorbent vapor is partially condensed by the rectifier.

Coefficient of Performance (COP)

COP is a measure of cycle ability to transfer heat between various temps.

$$COP = \frac{Heat\ taken\ in\ at\ low\ temp.(evaporator)}{Heat\ taken\ in\ at\ high\ temp.(generator)}$$

For any given operating temp. There is a upper limit for the amount of heat energy that can be transferred according to Carnot cycle.

In vapor compression cycle heat is raised from a lower temp.(T_E) to a high temp. (T_c)

For a carnot cycle

$$COP_C = \frac{Heat\ transfer\ at\ low\ temp.}{work\ input}$$

$$= \frac{T_E}{T_C - T_E}$$

In the absorption cycle heat energy being reduced in temp. From T_G (in the generator) to T_A (in the absorber) provides the driving force to lift heat from T_E to T_C for Carnot cycle which operator between these temps. Limits

$$COP_A = \frac{T_G - T_A}{T_G} = \frac{T_E}{T_G - T_E}$$

COP_A is always less than COP_C by an amount that depends on the temperature in the generator.

Because the COP is such a fundamental property of the VAR cycle it should be calculated under real test conditions. The most useful COP of an absorption cycle would be the COP actually obtained over the variety of conditions under which it operates. The temperature of generator, condenser, absorber and evaporator should be quoted along with the COP of the system. COP value can be improved by 10% to 20% by incorporating the improvements to the cycle components.

COP Decreases As the Temp. Lift of Cycle Increases.

Waste Heat as Input to Absorption System

Vapor absorption refrigeration system potentially offer several advantages as their heat input is low grade thermal energy such as waste heat available from industries, solar energy, geothermal energy etc.

Before using the waste heat to VAR following points should be considered

1. Availability of waste heat
2. Details of primary process producing the waste heat
3. Constraints on distance
4. Future expansion plans and modernization

Waste Heat Sources

Waste heat is a heat which is not used and exhausted as a waste product. From industries in the form of process steam and water, waste heat is available. The heat is discharged with the exhaust gases is energy type of industry. The discharged heat is in the form of sensible heat (hot gases and water) or in the form of latent heat (process steam).

Following are the waste heat sources

1. Waste steam available from processes
2. Diesel exhaust gases from diesel based power generatation sets at a temp. level of 350° C
3. Furnaces gases are available at high temp. In the case of forging units.

Waste Heat Sources and Temp. Range

Waste heat source	Temp. Range ° c
Process steam condensate	80 – 95
Flash steam	100 – 130
Waste steam	110 – 150
Boiler flue gases	180 – 350
Diesel engine exhausts	300-500
Furnace flue gases	450-800

The above table represents the distribution of industrial thermal discharges as a function of temp. Industrial thermal wastes are attractive for conservation into useful thermal, mechanical or electrical power due to the large volume of heat involved at individual location and temp. at which it is available.

Waste Heat Recovery

Waste heat recovery systems are designed to conserve energy by re-using available waste heat. They transfer heat from sources of waste heat to uses for recovered heat with various types of heat recovery equipments

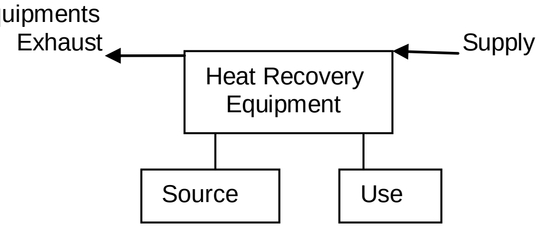


Fig. 3 Elements of Heat Recovery

The source produces waste heat as a result of process. The waste heat can be contained in a gas, liquid or vapor. The most economical utilization of waste heat is in vapor absorption refrigeration system.

Benefits of Heat Recovery

1. Reduction of energy cost
2. Reduction of equipment cost and size
3. Reduction of energy use

Amount of Heat Recovery

The heat loss from the exhaust must appear in the heat gained by the supply based upon the basic law of thermodynamics.

The amt. of heat contained by a material of weight W at temp. T with a sp. Heat Cp is defined as

H = CpWT , KJ,

H = Cp.V.d.T V – Vol. d – Density

Heat recovery from a gas

$Hg = 0.24 \times V \times .075 \times 60 \times \Delta T$

$= 1.08V \times \Delta T$ Btu/hr.

= 1.139 Kj/hr.

Heat recovery from a liquid (water)

$H_1 = 1 \times V \times 8.33 \times 60 \times \Delta T$

H1 = 500 V ΔT Btu/hr

= 527.5 KJ/hr

Heat recovery from a vapor

$Hv = Cp\ Vd\ \Delta T + Vd\ h_{cos}$

h_{cos} = heat of condensation of vaporization in application where hot exhaust gas is available such as with gas turbine diesel engine absorption chiller offer a significant advantage over single stage steam machine.

The high temp. Generator utilized hot and clean exhaust gases above 290° C to drive the absorption process.

Vapor Absorption Intermittent Cycle

Whatever the cooling cycle thermal energy must be discharged to the surroundings. In vapor absorption cycle both the condenser and the absorber must be cooled.

Let lithium bromide (LiBr) water sol. be the absorbent and water the refrigerant.

The concentration of Libra in the solution is maintained at 50° C by any suitable cooling method. A 60% Libr solution at 50° C maintains above it a water vapor pressure as low as 10 mm. of mercury.

The liquid which evaporates and thus removes thermal energy from the space to be cooled is always called the refrigerant. LiBr being a non-volatile solid does not exert any vapor pressure. So in LiBr-H_2O system, the total pressure above the absorbent solution is the same as the partial pressure of water vapor.

Selection of Working Fluid

The necessary for desirable characteristics of a refrigerant absorbent combination includes–

1. High heat of vaporization of refrigerant
2. High thermal conductivity
3. Low viscosity
4. Low viscosity of absorbent
5. Low heat capacity of absorbent
6. Low Sp.heats
7. Non-corrosive, non-toxic and non-flammable
8. Chemical stability
9. Easy availability at low cost

Conclusion

Absorption refrigeration is in principle an attractive method for using heat energy directly for cooling purpose. The chief advantage of the vapor absorption refrigeration system is that the former mainly requires heat energy at moderate temp. While is letter the energy input is shaft work which is high grade energy.

Today absorption heat recovery offers an excellent alternative to utilizing what previously amount of the wastage heat. Which at today's energy prices has become a valuable commodity? And the absorption process is actually very simple one. Absorption cycle is one that operates on several heat sources and thus ideal for heat recovery applications.
Because of its flexibility many sources of heat can be recovered to produce the desired cooling effect, as hot water, steam, solar and hot gases.

All nations must constantly strive to find ways to efficiently use energy at various temp. levels to accommodate the needs of industry.

References

1. M. Fallek absorption chillers for conservation application, ASHRAE transaction publication.
2. K.P. Tyagi, waste heat as potential input to VAR cycle, eight national symposiums on refrigeration and air conditioning, Feb. 26-27, 2007, IIT Kanpur.
3. Yardi, Rama Krishnan "VARS" based on waste heat "Jyoti News Ltd, Vol. 77, 2008
4. Satish K. maurya, a cooling system for an automobile based on VARS using waste heat of an engine.
5. K. Balaji, study of VARS using waste heat in sugar industry.
6. Shekhar D., cooling of a truck cabin by VARS using engine exhaust.