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# Design and Analysis of Solar Refrigeration System Impaired by Chloro-Fluoro Refrigerants

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***Abstract---*** *Solar energy is a periodic unsteady heat source. In the utilization of solar energy, direct recovery at about 100°C is feasible and economical. In the solar driven ejector-absorption refrigeration cycle with re-absorption of the strong solution and pressure boost of the weak solution. High COP is obtained by increasing the efficiency of the absorber with the help of Ejectors (liquid - gas) Low pressure refrigerant vapour is injected and pressurized high pressure solution. Flow resistance is minimized. A small solution pump is used, in this system No moving parts, No Lubrication, Low maintenance and simple in operation. Working fluids is based on salt absorbent, low evaporation temperature and reduce the problem of crystallization. Working pairs used in the system is NH3 - H20 (or) NH3 - Lithium Nitrate.*

***Keywords---*** *Chloro-Fluoro Refrigerants, Design and Analysis, Solar Refrigeration.*

## MOTIVATION FOR THE PRESENT WORK

- Elimination of dependence on high-grade energy
- Achievement of cooling with low-grade thermal energy with is cheaper and abundant.
- Operation of the cooling system at a source temperature as low as 65°C.
- Protection of the stratospheric ozone umbrella which is impaired by chloro-fluoro refrigerants

## I. INTRODUCTION

This paper deals with solar- driven ejection absorption refrigeration (EAR) cycle with reabsorption of the strong solution and pressure boost of the weak solution. The physical model is described and the corresponding thermodynamic calculation is performed with the working pair $NH_3$-$LiNO_3$. It is demonstrated that the EAR cycle has obvious advantages as compared with the conventional absorption refrigeration cycle 1) the controllable high absorption pressure allows for substantially high COP by the action of a liquid-gas ejector in which the low pressure refrigerant vapour is injected and pressurized as a result of the ejection of high-pressure solution 2) internal steady operation can be realized for refrigeration cycles driven by unsteady heat sources, especially for solar energy, by adjusting the power input consumed by solution pumps under the condition of economical and reasonable utilization of electric energy.

Refrigeration is defined as the science of providing and maintaining temperature below surrounding atmosphere. Refrigeration is a method to achieve and maintain low temperature by supplying work input continuously.

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Refrigeration may also be defined as the process by which the temperature of a given space or a substance is lowered below that of the atmosphere or surroundings. In simple, refrigeration means the cooling of or removal of heat from a system. The equipment employed to maintain the system at a low temperature is termed as refrigerating system and the system which is kept at lower temperature is called refrigerated system.

Ironically, refrigerators keep things cold because of the nature of heat. The Second Law of Thermodynamics essentially states that if a cold object is placed next to a hot object, the cold object will become warmer and the hot object will become cooler. A refrigerator does not cool items by lowering their original temperatures; instead, an evaporating gas called a refrigerant draws heat away, leaving the surrounding area much colder. Refrigerators and air conditioners both work on the principle of cooling through evaporation.

The refrigeration cycle is a heat engine operating in reverse, known as a phase change heat pump. Using a refrigerant which boils at a low temperature produces a relative coldness, lowering the temperature of the refrigerator to a level which prevents bacteria from multiplying and ruining food. A refrigeration cycle works on essentially the same principle that makes your hand feel cold when water is evaporating off of it. Other liquids, including some known as refrigerants, produce even lower temperatures when they evaporate.

Solar energy is a periodic unsteady heat source. In the utilization of solar energy, direct heat recovery at about 100° C is feasible and economical, but there are shortcomings when solar energy is used for refrigeration.

1) Fluctuation of the temperature of heat source makes the efficiency and capacity of refrigeration vary greatly;
2) Conventional refrigeration cycles have poor adaptability to variable operating conditions, and are unable to overcome the effect of temperature fluctuation of heat sources;
3) The coefficient of performance is very low.

## II. Importance Of Refrigeration

Refrigeration has a wide application in one’s daily life such as

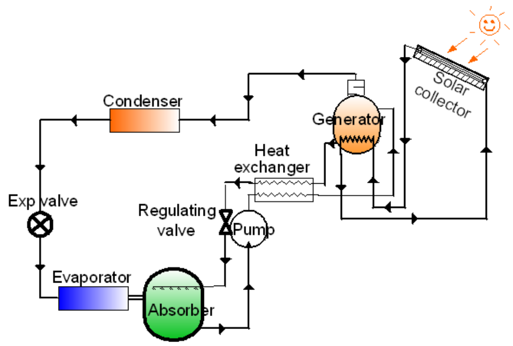
- For comfort purpose
- For industrial purpose
- For medicine purpose
- For preservation of food products
- For research work
- For computer functioning

## III. Refrigeration Is Generally Achieved By Executing A Following Refrigeration Cycle

- Vapour compression refrigeration cycle
- Vapour absorption refrigeration cycle
- Vapour ejector refrigeration cycle
- Vapour adsorption refrigeration cycle.

## IV. SOLAR VAPOUR ABSORPTION REFRIGERATION CYCLE

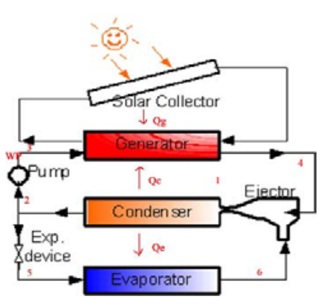
A simple vapour absorption system is shown in fig below. If a compressor in a vapour compression system were replaced with a generator absorber assembly, the result would be a simple vapour absorption system. A low pressure refrigerant vapour (Ammonia) coming from the evaporator is absorbed in the absorber by the weak solution of refrigerant in water. Absorption of ammonia lowers the pressure in the absorber, which in turn draws more ammonia vapour from the evaporator. Cooling arrangement evolved in absorber.




This increase ammonia absorption capacity of water. The pump draws strong solution from the absorber, built up a pressure up to 10 bar and forces the strong solution in the generator. In the generator, strong solution of ammonia is heated by some external sources such as a gas or steam. In the heating process, the ammonia vapour is driven out of the solution as a high pressure vapour leaving behind in the generator a weak solution. The weak solution flow back to the absorber through a restriction which maintains the pressure difference between the high and the low sides of the system. From the generator the refrigerant vapour is conducted to the condenser where it is condensed. Then the high pressure liquid ammonia is passed through a throttle valve to the evaporator where it absorbs its latent heat thus producing cooling effect.

## V. SOLAR EJECTOR REFRIGERATION CYCLE

Waste energy is available and its cost is negligible in many industrial cases. At the same time these industrial process may have refrigeration needs, which may be satisfied by means of a refrigerated system based on ejector technology. This latter may more attractive than the conventional refrigeration technology because its overall cost is generally lower. An ejector refrigeration cycle uses industrial waste heat as a thermal driver at temperature level ranging from + 60° C to + 150 °C in order to produce cooling at levels ranging from 0 °C to + 20° C. Combine with this solar collector is attached so that more heat is generated.

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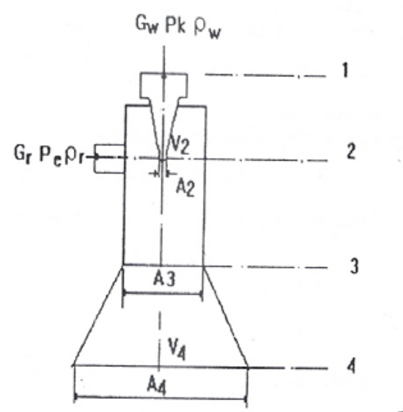
Referring to fig, the ejector refrigeration combines two loops. The first loop 1-2-3-4-1 is that of power cycle and second one 1-2-5-6-1 is that of a refrigeration cycle.

In the power loop, low grade heat $Q_{G\ is}$ delivered to the generator, where liquid refrigerant at point 3 is vaporized at high pressure. This vapour (called the primary fluid) flows through the ejector and induces the vapour from the evaporator (called the secondary fluid) at point 4. In the diffuser section of an ejector the primary and secondary fluids are mixed and undergo a pressure recovery process. The mixed steam at 1 flows to the condenser and leaves it at the point 2 where the heat of condensation is rejected to the environment. Finally the flow of condensate is pumped back to the generator to complete the power cycle.

In the refrigeration cycle the condensate from the condenser is expanded through a expansion valve to a low pressure state 5 and enters the evaporator, where it is evaporated to produce the necessary cooling effect $Q_E$. The refrigerant vapour at 6 is then drawn and mixed with the primary fluid before it is compressed in state 1. Finally it is condensed in state 2 thus completing the refrigeration cycle.



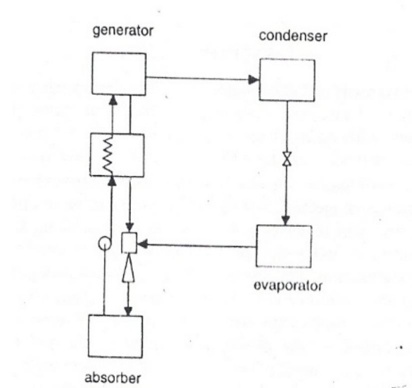

The liquid gas flow processes in the ejector include 4 stages as follows.

- Ejection
- Injection
- Mixing
- Diffusion

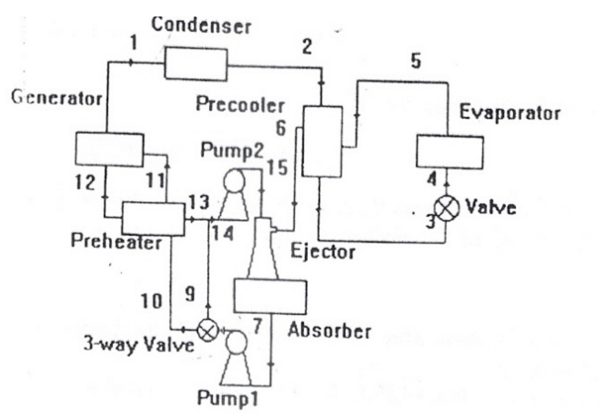
## VI. EAR SYSTEM

Systems with different cycle configuration have been developed. However, system complexities were increased over that of the conventional cycle, and none seems to provide a better COP than a double effect absorption system. The ejector using high-temperature concentrated solution returning from the generator as a primary fluid, and a refrigerant vapour from the evaporator as a secondary fluid. The ejector exhaust was discharged to the absorber. The increase in absorber pressure results in the circulation rate of the solution being reduced than that for a conventional cycle operated for the same condition. It can be noted that for the two cycles previously described, an ejector was used to raise the absorber pressure in order to reduce the solution concentration.

The combined ejector-absorption refrigerator discussed here was developed to operate with a high-temperature heat source (for the generator) and low-temperature cooling fluid (for the condenser and absorber), and provide a significant improvement performance without greatly increasing the complexity of the system. In this case, ejector is positioned between the generator and the condenser to increase cooling capacity without significantly increasing the generator and absorber capacities. In fact, for the same cooling effect the capacity of the absorber is reduced by about one-third of the design.




The new cycle solar-driven ejection absorption refrigeration (EAR) cycle with reabsorption of the strong solution and pressure of the weak solution as shown in fig. below




***Description***

1. A portion of high-pressure strong solution comes back to the absorber to augment absorption efficiency by using a three -way valve.
2. By using the second solution pump, the high pressure solution is further pressurized and comes into the ejector to inject the low –pressure refrigerant vapour thus the absorption pressure increases. The absorption efficiency will further increase with the increases of the absorption pressure.
3. By regulating the reabsorption ratio of the strong solution or/and boosting the pressure difference of the second solution pump, the steady operation of the refrigeration cycle driven by unsteady heat sources it realized.

Compared with the conventional cycle, the improved cycle can work under varying operating conditions by adjusting the flow rate and pressure difference of the solution pumps, e.g.,

In the early morning and late afternoon, the collected solar heat decreases and the cooling capacity correspondingly decrease. Increasing $K_s$ or/and $D_p$ in the improved cycle can make the operating condition steady. This is especially fit for the utilization of unsteady heat sources.

When the heat flux and the temperature of heat sources are constant, increasing $K_s$ or/and $D_p$ can meet the urgent or temporary need of added cooling capacity.

In the improved cycle, as the absorption pressure increases, refrigeration efficiency increases. This means that at the same generation temperature, the improved cycle can work at a lower refrigeration temperature than the conventional cycle.

***Refrigerants***

The refrigerant used must have following characteristics:

a) physical and thermodynamic characteristics
b) Environmental impact
c) Safety
d) Economic and availability

$NH_3$-$LiNO_3$ is the best among the three working pairs $NH_3$-$LiNO_3$, $NH_3$-NaSCN and $NH_3$-$H_2O$.

***Result***

COP of ejector : 0.85

COP of absorption : 0.98

COP of combined

Ejector and absorption : 1.89

***Advantages***

- Liquid gas flow processes in the ejector include three stages as Ejection, Injection, and Mixing.
- Flow resistance are minimized
- Fluid is incompressible and potential energy is zero.
- To adjusting the power input to the solution pump under condition of economical and reasonable utilization of electrical energy.
- Reabsorption of the strong solution and pressure boost of the weak solution can be obtained.

## VII. CONCLUSION

The newly improved ejection absorption refrigeration cycle with reabsorption of strong solution and pressure boost of the weak solution is adaptable to varying operating, especially in utilization of the low-grate unsteady heat source- solar energy.

Apart from a small liquid pump, the cycle has no moving parts and hence no requirement for lubrication. Also it has low capital cost, simplicity of operation reliability, low maintenances. The two-phase model in the ejector proposed here is very important for the refrigeration system design.

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