Solar Powered Vapour Absorption Refrigeration (SPVAR) System as a rural microenterprise

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Abstract
The continuous increase in the cost and demand for energy has led to more research and development to utilize available and renewable energy resources efficiently. The absorption refrigeration system (ARS) is becoming more important because it can produce higher cooling capacity than vapor compression systems, and it can be powered by other sources of energy (like waste heat from gas and steam turbines, sun, geothermal, biomass) other than electricity. But as far as COP of these refrigeration systems is concerned, it is always a challenge to the researchers to significantly increase the COP for these systems. The most popular refrigeration and air conditioning systems at present are those based on the vapour absorption systems. These systems are popular because they are reliable, relatively inexpensive and their technology is well established. However, these systems require high grade energy for their operation. There are still problems to be solved in research field, especially small cooling capacity machine (about 1 to 10 kW) which are suitable for small farmers and residential uses. Apart from this, the recent discovery that the conventional working fluids of vapour absorption systems are causing the ozone layer depletion and greenhouse effects has forced the scientific researchers to look for alternative systems for cooling applications. The natural alternative is of course the absorption system, which mainly uses heat energy for its operation. Moreover, the working fluids of these systems are environment friendly. The present study elaborates feasibility of such systems using H_2O–$LiBr$ solution and exergy analysis.

Keywords: Absorption refrigeration system, renewable energy, greenhouse effect

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Introduction

It is a well known fact that in Asian sub continent especially India, agriculture is main occupation. More than 70% of the population still lives in villages and their wealth totally or partially depend on what they cultivate [1]. Another important fact that needs to be focused, is, that a seasonal crop cultivates abundantly like tomato, grapes, mangoes and most of the vegetables. For farmers it becomes a challenge to transport it to the market in a short time and to sell it at proper price. Rural areas of India also lack in transport network. It is very expensive and difficult to transfer material to market. Farmers then have no choice other than either to get it spoiled in the field itself or to sell it at low price. Expensive cold storages are out of reach for small farmers. Middle Traders buy it at nominal price and store it in cold storages and sell it on high price afterwards. This leads to steep fluctuation in price of vegetables and even though producer and consumer both suffer. This situation is deteriorating farmer's financial and economic strength day by day and this is when they are doing real and most important ground work. They are finally not receiving for what they deserve. And this is simply because they don't have tools to preserve their hard earned crop.

Objectives

Broad objectives of the proposal are

• To design and fabricate a modified small boiler unit with Water Pre Heater (WPH) based on bio mass that will be used to maintain steam flow when sun light is not adequate. Dr Mudgal has designed and used similar kind of boiler in his Multiple effect distillation unit [2].
• To design and fabricate a unique solar collector capable of producing steam at about 150° C with the flow rate of about 15 kg/ hr
• To design and fabricate an effective Solar Power Vapour Absorption Refrigeration (SPVAR) System having "Low maintenance cost"
• Exploring possibilities of automated hybridization of boiler steam and solar collector steam supply with SPVAR unit as per the requirement
• Parametric study of different size and capacity SPVAR system in actual environment
•   Field testing of the finally designed and developed SPVAR Unit

Novelty / uniqueness of the Proposal

In present work, a solar powered, steam and hot water driven, single stage, absorption cooling system, using a lithium bromide water solution, will be analyzed for determining the effect of various parameters on coefficient of performance (COP). Four basic stages in the absorption cycle are generation, condensation, evaporation and absorption with ideally no moving part. This small scale system is the ever first approach to be deployed in rural areas for decentralized applications. Vapour Absorption Systems offer many advantages like

•   It offers flexibility to utilize any sort of low grade, low cost heat energy available   to produce cooling and thus giving a high savings in operating costs.
•   It can operate on steam or any other waste heat source as the energy source instead of costly and unreliable electric power [3].

•   No moving parts ensure noiseless, vibration-less and trouble free operation.
•   Moreover maintenance costs are negligible as compared to power driven mechanical systems.
•   Refrigerating effect is produced using a clean refrigerant in place of ozone-depleting chlorine based compounds.

Methodology

A suitable working fluid is probably the single most important factor in any refrigeration system. The cycle efficiency and operation characteristics of an absorption refrigeration system depend on the properties of refrigerant, absorbent and their mixtures. The most important thermo-physical properties are: heat of vaporization of refrigerant, heat of solution, vapour pressure of refrigerant and absorbent, solubility of refrigerant in solvent, heat capacity of solution, viscosity of solution and surface tension and thermal conductivity of the solution. Apart from this, the other selection criteria for the working fluids are their toxicity, chemical stability and corrosivity [1].

The proposed system in Fig. 1 bears a cooling capacity of around 1TR. Thermodynamic analysis of the system involves finding important parameters like enthalpy, mass flow rates, flow ratio, Heat and Mass Transfers for the whole system to finally calculate the system Coefficient of Performance (COP). These values are to be then used for design of the system. First some set of thermodynamic equations have been derived in terms of mass flow rates and enthalpy by applying mass and energy balance for each component. Then the actual system conditions like temperature, pressures, and enthalpies are substituted in the equations to finally obtain the COP value for the system.

A steady flow analysis of the system is carried out with the following assumptions:

1.   Steady state and steady flow
2.   Changes in potential and kinetic energies across each component are negligible
3.   No pressure drops due to friction
4.   Only pure refrigerant boils in the generator.

Outline of the proposal

Vapour Absorption Refrigeration Systems belong to the class of vapour cycles similar to vapour absorption refrigeration systems. However, unlike vapour absorption refrigeration systems, the required input to absorption systems is in the form of heat. Hence these systems are also called as heat operated or thermal energy driven systems. Both vapour absorption and absorption refrigeration cycles accomplish the removal of heat through the evaporation of a refrigerant at a low pressure and the rejection of heat through the condensation of the refrigerant at a higher pressure.
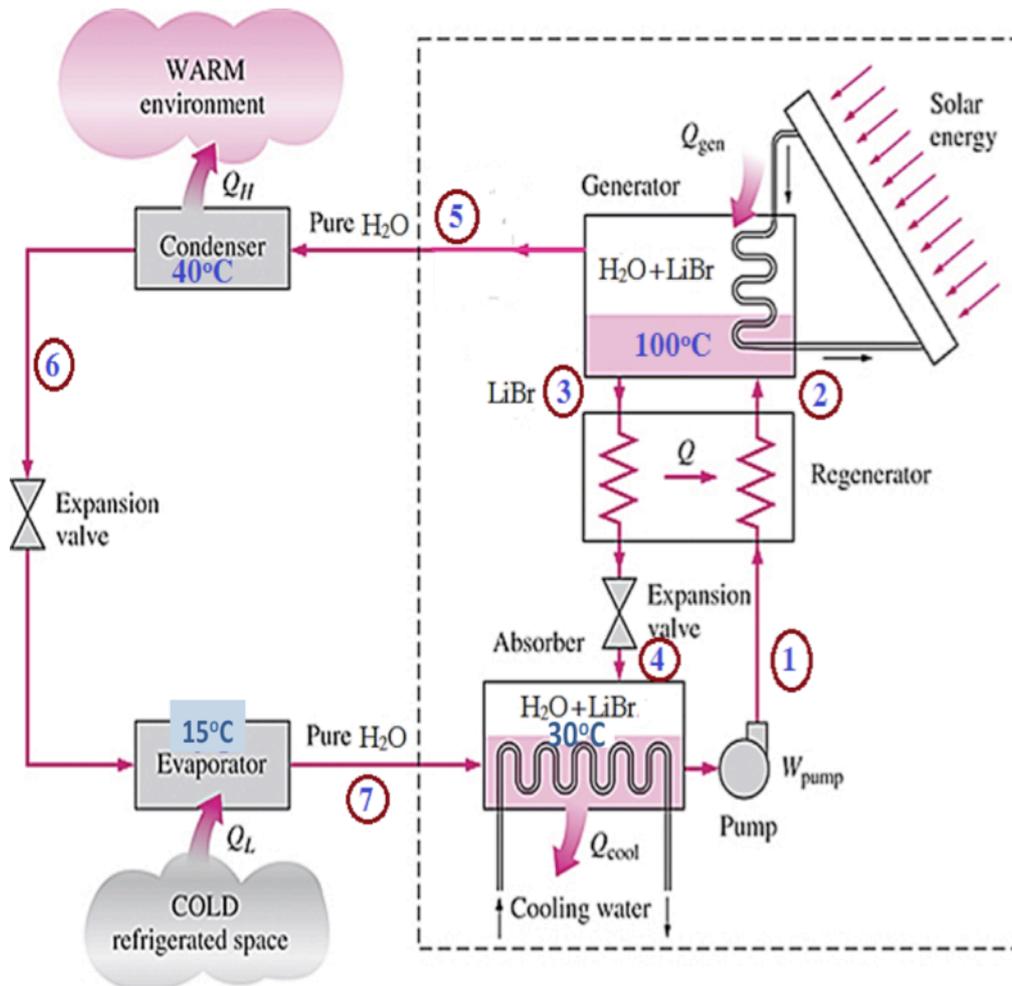
Figure 1: Schematic view of I TR Vapour Absorption Refrigeration Systems

The basic difference is that a vapour absorption system employs a mechanical compressor to create the pressure differences necessary to circulate the refrigerant whereas an absorption system uses heat source and the differences cause an absorption system to use little to no work input, but energy must be supplied in the form of heat. This makes the system very attractive when there is a cheap source of heat, such as solar heat or waste heat from electricity or heat generation.

Mathematical Calculations of Parameters:

Evaporator Capacity = 3.5KW = 1TR

Operating Temperatures and Pressures:

Most favorable conditions for optimum working of system with the utilization of waste heat source in environmental conditions are estimated as:

Operating Parameter	Calculated Value
Tg = Generator Temp	100^0C
Pg = Generator Pressure	7.38 kPa
Tc = Condenser Temp	40^0C
Pg = Condenser pressure	7.38 kPa

Ta = Absorber Temp.   30^{0}C
Pa = Pe= Absorber Pressure   1.70 kPa
Te = Evaporator Temp.   15^{0}C
Pe = Evaporator pressure   1.70 kPa

Conclusion

The proposed method of cooling will provide decentralized and affordable solutions for preservation of fruits and vegetables which otherwise, either get spoiled or farmer doesn't get reasonable price for it especially in summers when temperature is above 40-45°C. Solar Power Vapour Absorption Refrigeration (SPVAR) System will provide an affordable mechanism for preserving fruits and vegetables on site in the farmer's field itself for months even in typical summers.

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