SOLAR COLD STORAGE & PERFORMANCE CHRACTERSTICS OF VCR CYCLE

Aditya Kr Verma[1*], Amit Kr Singh[1], Anas Siddique[1], Aryendra Kr Gautam[1], Prof. D N Srivastva[2]

[1]*Department of Mechanical Engineering*
Buddha Institute of Technology Gorakhpur, Uttar Pradesh, India
[2]*Dean, Department of Mechanical Engineering*
Buddha Institute of Technology Gorakhpur, Uttar Pradesh, India

Abstract

India stands as one of the major food producers in the world. The green revolution and white revolution refer to the drastic increase in food grain and milk productivity respectively and changed India's position from being a net importer to becoming self-sufficient with regard to food production. Over half of its population is engaged in agriculture related activities. The agricultural produce market accounts for 17-18% of the GDP of the nation (Ministry of Finance, Government of India, 2017-18). While there has been a significant increase in the productivity from the 1950 " s, the wastage of food produce is extremely high.

Estimates place post-harvest food wastage due to inadequate cold storage at 40% (Desai, October 2011) for fruits and vegetables alone without including dairy produce and food grains. This has a bearing on India's contribution to the world with regard to international food trade as although the country is self-sufficient, the export volume is comparatively low (Alam, 2006).The Ministry of Food Processing in India identified the cold chain to be a weak link in the food- processing sector. There exists much room for improvement in the cold storage and integrated cold chain infrastructure with regard to both capacity and operation. (MoFPI, Government of India, 2010). India is developing and while electrification is considered a top priority by the planning commission, there are still a great number of villages that are still to be electrified. Even the ones that are electrified have unreliable power (Gopal & Suryanarayana, 2011). This poses a challenge with regard to the energy required for refrigeration of food produce.

Hence, there exists a pressing need to develop a smaller capacity refrigeration system which can be operated independent of the electrical grid. This thesis is an investigation into the methods of refrigeration that can be adopted for the purpose of reducing food produce wastage. Specific focus on solar based refrigeration is placed due to the tropical position of the country that ensures adequate delivery of solar energy through the year.

Key Words: cold storage, sunlight , refrigeration , solar , electric

1. INTRODUCTION

The vapor-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. Figure 1 depicts a typical, single-stage vapor-compression system. All such systems have four components: a compressor, a condenser, a thermal expansion valve (also called a throttle valve or metering device), and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapor[2] and is compressed to a higher pressure, resulting in a higher temperature as well. The hot, compressed vapor is then in the thermodynamic state known as a superheated vapor and it is at a temperature and pressure at which it can be condensed with either cooling water or cooling air flowing across the coil or tubes. This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried away by either the water or the air (whichever may be the case).

2. METHODOLOGY

Solar powered refrigerators are characterized by thick insulation and the use of a DC (not AC) compressor. Traditionally solar-powered refrigerators and vaccine coolers use a combination of solar panels and lead batteries to store energy for cloudy days and at night in the absence of sunlight to keep their contents cool. These fridges are expensive and require heavy lead-acid batteries which tend to deteriorate, especially in hot climates, or are misused for other purposes.[1][3] In addition, the batteries require maintenance,[4] must be replaced approximately every three years, and must be disposed of as hazardous wastes possibly resulting in lead pollution.[1] These problems and the resulting higher costs have been an obstacle for the use of solar powered refrigerators in developing areas.[2][3]

In the mid-1990s NASA JSC began work on a solar powered refrigerator that used phase change material rather than battery to store thermal energy rather than chemical energy.[5] The resulting technology has been commercialized and is being used for storing food products and vaccines. Solar direct-drive refrigerators don't require batteries, instead using thermal energy to solar power. These refrigerators are increasingly being used to store vaccines in remote areas.[6]

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The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto-refrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and vapor refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.

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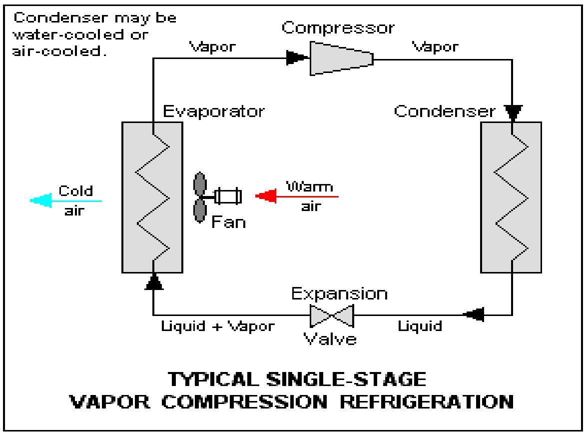
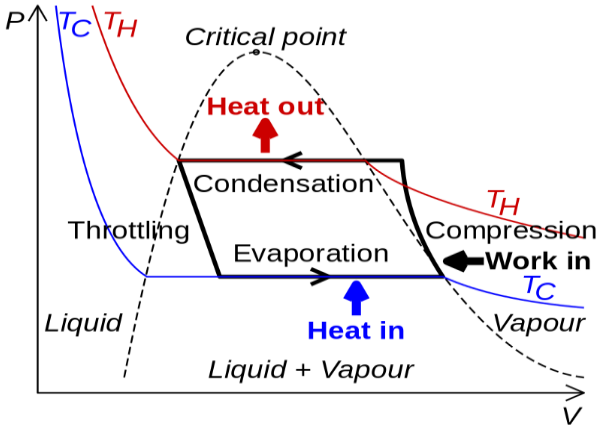
The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapor mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature. The evaporator is where the circulating refrigerant absorbs and removes heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser.

To complete the refrigeration cycle, the refrigerant vapor from the evaporator is again a saturated vapor and is routed back into the compressor.





1. Schematic of VCR System

2. PV Diagram of cycle

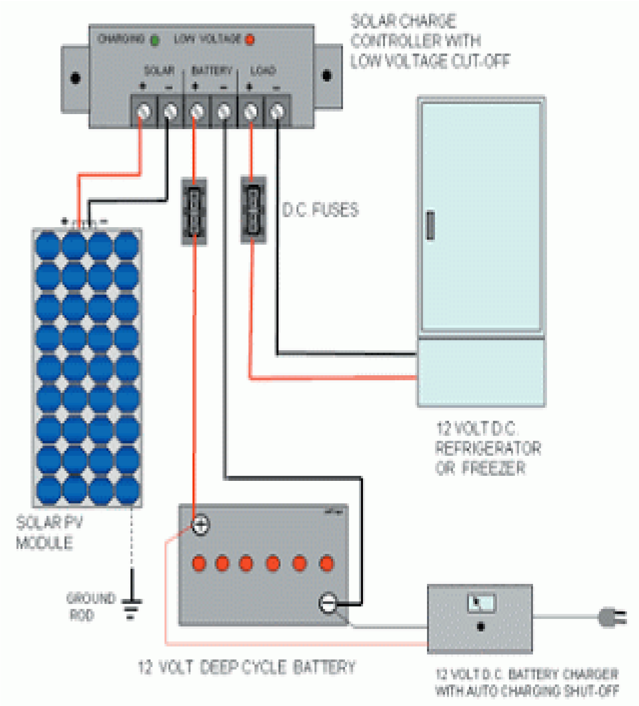


Fig 3 . Experimental Setup

3. SUB SECTION

This project is a study on a performance of a Vapor Compression Refrigeration System VCRC. The performance of this type of refrigeration system is being investigated by using different type of expansion valves or also known as throttling valves. I am using three types of valves upon conducting this study which are thermostatic expansion valve, capillary tube expansion valve and constant-pressure expansion valve. Performance of refrigeration systems will be investigated on two kind of surrounding which are closed and open surrounding. A light bulb will act as a heating load which will increase the inlet temperature of air on evaporation. This project also discuss about the ideal application of each type of expansion valves. Which mean, where, when and what application the three types of expansion valves should be used for a better result.

Refrigeration is the action of cooling, and in practices this requires removal of heat and discarding it at higher temperature. Therefore, refrigeration is a science of moving heat from low temperature region to the high temperature region.

The most important applications of refrigeration are the preservation of perishable food products. Refrigeration systems also used for providing thermal comfort to human beings by using air conditioning. Air Conditioning refers to the treatment of air so as to simultaneously control its temperature, moisture content, cleanliness, odor and circulation, as required by occupants, a process, or products in the space. The subject of refrigeration and air conditioning has evolved out of human need for food and comfort, and its history dates back to centuries.

In refrigeration system, heat must be removed from the space area specifically the goods or matter we need to cool and released to the environment. Nature of heat movement is, heat always moves from the hotter to the colder space. To transfer heat from hot region to cold region, special device is required. The device is called Refrigerator. Refrigerator is a cyclic device and it is using a fluid called refrigerant as a working fluid.

Sl. No.	Fruits / Vegetables	Temperature Range (ºC)
1	Apples	-1 – 4
2	Bean/Carrots/Cauliflower	0
3	Lychees/ Orange	4 – 7
4	Onions	0 – 2
5	Strawberries	0
6	Sprouts	0 – 2
7	Potatoes	7 – 10

PERFORMANCE CHRACTERSTICS

NOMNECLATURE

A	surface area of tube
C	specific heat
COP	coefficient of performance
h	specific enthalpy

SUB SCRIPTS

ac	actual
b	brine
c	condenser
e	evaporator

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m	mass flow rate	i	inlet
M	mass	isen	isentropic
P	pressure	m	mean
Q	heat transfer rate	o	outlet
t	temp	r	refrigerant
U	overall heat transfer coefficient	th	theoretical
W	power consumption of compressor	w	water

GREEK SYMBOLS

τ	time point
η	efficiency
▲	difference

Data reduction

All the readings of pressure, temperature, flow rates, power etc. as suggested before are noted down at each time point ‘τ’ separated by fixed time interval ‘Δτ’ through the total time period of one trial. In one trial of system for cooling a fixed mass of brine from initial room temperature to final refrigeration temperature taking place under transient conditions, a large data was recorded. Many trials were conducted with different capillary tubes. All this data was transformed in the Excel worksheets. The properties of refrigerant are calculated using computer subroutines. Other performance parameters of the system are also calculated for each time point as per the procedure given below.

Heat transfer rate or refrigeration rate in evaporator at a time point `τ` is given as;

$Q_{e,\tau} = M_b c_b(t_{b,\tau-\blacktriangle\tau} - t_{b,\tau}) = mr,\tau(h_{1\tau} - h_{4\tau})$

Heat transfer rate in condenser at a time point ‘τ’ is given as:

$Qe,\tau = m_{w,\tau} c_w(t_{w,o,\tau} - t_{w,i,\tau}) = m_{r,\tau}(h_{2\tau} - h_{3\tau})$

Isentropic power consumption of compressor at a time point ‘τ’

$W_{isen,\tau} = m_{r,\tau}(h_{2\tau} - h_{1\tau})$

Isentropic efficiency of compressor

$\eta_{isen,\tau} = W_{isen,\tau} \div W_{ac,\tau}$

Theoretical COP at a time point ‘τ’ is

$COP_{th,\tau} = (h_{1,\tau} - h_{4,\tau}) \div (h_{2,\tau} - h_{1,\tau})$

Actual COP at a time point ‘τ’ is

$COP_{ac,\tau} = Q_{e,\tau} \div W_{ac,\tau}$

Overall heat transfer coefficient over evaporator at a time point ‘τ’ is

$U_{e,\tau} = Q_{e,\tau} \div (t_{b,\tau} - t_{r,e,\tau})\, A_e$

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Overall heat transfer coefficient over condenser at a time point 'τ' is

$U_{c,\tau} = Q_{c,\tau} \div \blacktriangle t_{m,c} A_c$

COP variation with time and with different size capillary tubes

The comparison of variation in COP values of vapour compression refrigeration system with different size capillary tubes under transient conditions is shown in. The sizes of four different capillary tubes used are given in table**.**

Table 1 Sizes of capillary tubes used in "Vapour compression refrigeration system".

Capillary Tubes	Available Sizes		Conversion in SI Units	
	Internal Diameter (Inches)	Length (Inches)	Internal Diameter (mm)	Length (m)
Tube 1	0.044	30	1.1176	0.762
Tube 2	0.044	33	1.1176	0.838
Tube 3	0.044	54	1.1176	1.372
Tube 4	0.05	48	1.27	1.219

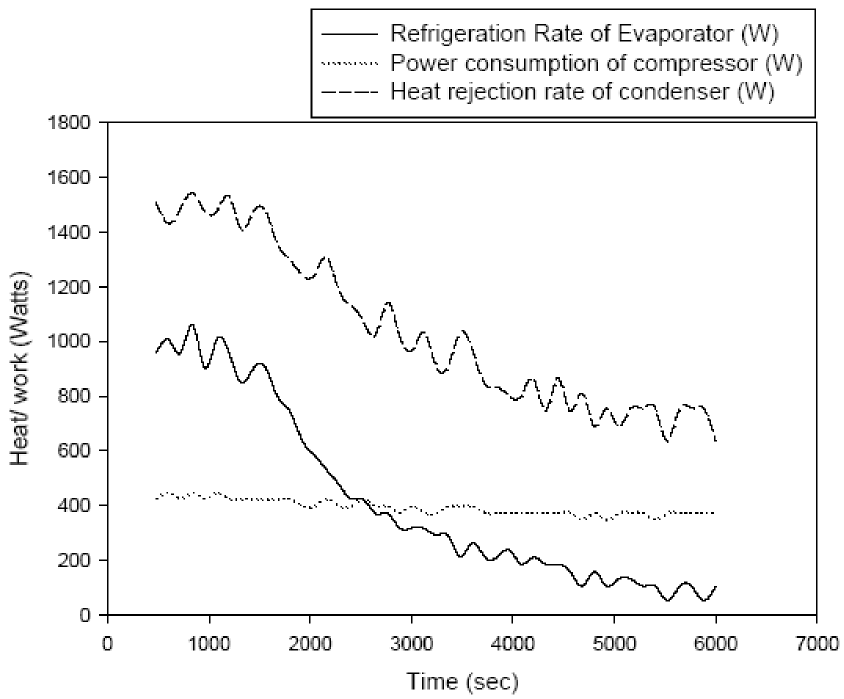

Figure 4 : Performance of VCR system under transient conditions

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4.CONCLUSION

India is the second largest producer of horticulture commodities producing fruits and vegetable in millions of metric tons each year. However, since the very nature of these commodities is perishable in nature, these have to be sold out within a stipulated time before getting spoilt.

None of us are ignorant about the hassles of an Indian farmer. With all his problems, when he is ultimately successful in having produced these commodities, he still has to struggle to earn a good price for all his efforts. He will have to sell his produce even at a low price if that is the rate prevailing in the market. It is estimated that about 30% of the national produce gets wasted due to lack of proper storage facilities. With 10 million tones of cold storage capacity required in India, there is a huge dearth of storage infrastructure in the country

A **solar-powered cold storage unit** offers the best solution in this regard. The cold storage chamber comes with a puff insulated walk-in type structure fitted with a vapour compression refrigeration system and a humidifier. It has solar panels attached to it rooftops and comes with a minimum battery backup. The solar plant generates about 70–110 kWh/day which is sufficient to operate the cold storage unit. The maintenance cost is also quite less. Farmers are also finding it simple to use with apps directing the usage. For example, a farmer just has to select which fruit/ vegetable is required to be stored. The unit itself makes the necessary settings and starts functioning. It is portable and can also be moved from one farm to another thus serving a community purpose.

At present, the cost of a **solar-powered cold storage unit** is about INR 10-20 lakhs. Note: A lot of the cost also depends upon the size The payback period of the cold storage system is expected to be 10 years. Many states in India are considering subsidizing the product for the well being of the farmers and citizens who can get fresh food.

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