Analysis of Air Jet Refrigeration

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ABSTRACT

The Air Jet Refrigeration is based on the Bernoulli's equation across a streamline. Here a jet of air is used to cool the water when passed through the reducing section with the help of fan. The cooling effect takes place due to the suction pressure created at the throat when the jet of air is passed through the reducing section. Due to high velocity of air, the appropriate suction pressure is created and air takes latent heat of water and water gets cooled.

***Keywords*-**Bernoulli's principle, suction pressure, coefficient of performance, reducer Section.

I.NOMENCLATURE

RPM :Révolutions per minute.
C.O.P : Coefficient of Performance.
KW : kilowatt.
t:Time in minute.
M_w: Mass flow rate of Water.
C_P: Specific heat at constant pressure.
P: Input Power.
Δt: Final temp-Initial temp
ρ : Density of water.
V : Voltage applied to fan.
I : Current
z: Potential at a point.
A_1,A_2 :Areas of reducer section at inlet and outlet sections
V_1,V_2: Velocities of air at inlet and outlet Sections
v:Velocity at a point in a flow path
Q : Heat removed from water
p:Pressure at a point in a flow path

II.INTRODUCTION

Air Jet Refrigeration equipment features unequaled reliability since there are no moving parts. Mechanical systems rely on complex high speed reciprocating or centrifugal compressors for operation. Very fine clearance, high speed, requirement of very effective lubrication , wear and tear lead to the requirement for standby system i.e. simply more capital cost. Reliability enables Air Jet Refrigeration systems to be operated and maintained by plant personnel with minimum supervision. The risk of leaking hazardous refrigerant is over come and maintenance cost is very less. Highly corrosive and toxic refrigerants make mechanical and absorption equipment potentially dangerous if they are not properly maintained and operated. Absorption units' main disadvantage is the difficulty in maintaining "tight" system with the highly corrosive Lithium Bromide and an operating pressure of 5 torr in the absorber and evaporator.

Special foundations or mounting structures are not required since steam jet refrigeration system exhibits little or no vibration due to no moving parts. Floor space requirements are typically half of what is required for mechanical or absorption units.

Mechanical and absorption refrigeration units require many tubes that are fouledeasily and require periodic cleaning; therefore, they are not suitable for locations with hard industrial water. Steam jet refrigeration systems fitted with a barometric condenser, can typically tolerate up to an inch of scale build-up without reducing efficiency. Hard industrial water can be used for the condensers. Our many installations near by the sea, uses directly sea water into the direct contact condenser to cut down the capital cost on cooling towers. Air Jet Refrigeration systems do not require complex control equipment; the instrumentation and controls are similar to those used throughout most plants. Mechanical and absorption units require a multiplicity of controls that increase first cost, installation cost and maintenance cost. It is flexible in operation; cooling capacity can be easily and quickly changed. The main objective is to provide experimentation for Air Jet Refrigeration and to determine the effects of reducer geometry, and fluid flow.

To accomplish this goal, the following specific objectives were undertaken:

1. Construction of a physical model of the reducer section.
2. Testing of the physical model under different air flow rates
3. Comparison of the results from both numerical and experimental work
4. Increasing the C.O.P of the system by increasing the R.P.M of the fan delivering the required air.
5. Increasing the cooling rate by wounding a thermally insulating material around the tank containing water.

Ian W.Eames et al[1] evaluated the results of an experimental investigation in to a novel thermally activated jet pump refrigerator and a jet spray thermal ice storage system, in which a steam driven jet pump is used to create a vacuum pressure in a hermetic vessel into which water is sprayed through a nozzle.X. Yang et.al [2]investigated the effects of different nozzle structures on the performance of a steam ejector numerically with the computational fluid dynamics technique namely conical, elliptical, square, rectangular and cross-shaped for different parameters such as entrainment ratio and back pressure and had varied conclusions. Sung Ku Park et.al.[3] simulated the operating characteristics of air cycle refrigeration for fixed speed and variable speed and showed that for variable speed all the performance parameters can be evaluated with good efficiency.Liu Shengjun et.al.[4]showed that the factors responsible for the performance of air cycle depends upon pressure ratio, isentropic efficiency of rotors, working temperature required for engineering design. GiuseppeGrazzini et.al.[5] showed that for a two stage steam ejector, primary flows are highly supersonic further showing the existence of metastable conditions and this showed existence of distinct condensation at nozzle exit which further helped in optimization of the experimental ejector design.NatthawutRuangtrakoon et.al [6] investigated steam jet refrigeration with various operating temperatures and various primary nozzles. Results were plotted for different Mach numbers which showed that geometry of primary nozzle has strong effects to the ejector performance and thereby C.O.P. A.J.Meyer.et.al [7] investigated the possibility to run a steam jet ejector on boiler temperatures below 100^0Cand predicted that if it can be achieved by conventional solar flat plate or evacuated tube water heaters used to power a steam jet ejector to produce refrigeration or cooling.Jianlin Yu et.al.[8] proposed a new ejector refrigeration system(NERS) and compared parametrically with conventional ejector refrigeration system for parameters of generator temperature and backpressure for two refrigerants viz.R134a and R152a.and showed that C.O.P. of NERS can be effectively improved.CostanteIntermezzi [9] et.al.dealt with potential use of ejector powered refrigerating cyclesfor heat recovery and analyzed ejector performance. The different thermodynamic fluids are selected.The heat recovery for following three cases are investigated. First complete recovery of heat, secondly generation of refrigerating thermal power and thirdly the partial recovery of heat. G.K.Alexis[10]described the calculation of main cross sections of steam –ejector, operating in a refrigeration system which employed ejector cross section as function of generator pressure ,condenser and evaporator temperature and confirmed that ejector dimensions depends upon all these parameters and operating conditions.

III. METHODOLOGY AND EXPERIMENTATION

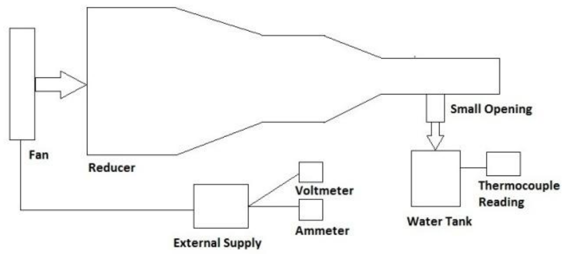

Fig. 1 Experimental Setup of Air Jet Refrigeration

Vacuum cooling process is basically evaporative cooling process. Air is passed through the reducer section using the fan as shown in fig.1. The reduction in area causes the absolute pressure at the top of the water in the water tank to reduce, which results in lowering of the boiling temperature of the water. The lowering of the boiling temperature of water results in water vapor formation due to extraction of sensible heat from the water and thus refrigeration effect is produced. There is a small opening provided at the throat for connecting the reducer section to the water tank. When the air jet is passed using the fan sufficient suction pressure is created at the throat (It is approximately 0.1 bar) which sucks the water vapor from the water tank through the throat along with it and is carried towards the other end of the reducer from where the heat exits to the atmosphere. The lower the pressure at throat, lower will be boiling point of water and more the refrigeration effect.

The geometry of the reducer is as shown in the fig.2 below. Both the ends of the reducing section are open. One end is bigger while the other end is smaller in comparison to the first end. The reducing section is supported by a rigid structure.

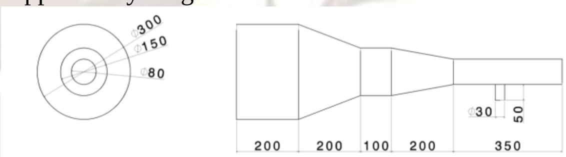

Fig.2 Geometry of reducer section (All dimensions in millimeter).

The geometry is designed with the study of Bernoulli's equation and continuity equation to get the desired effect.

Bernoulli's equation:

$p/\rho g + v^2/2g + z = \text{constant}$. (1)

Continuity equation:

$A_1V_1=A_2V_2$(2)

Energy equation:

$Q= M_w*Cp* \Delta T$(3)

Input power:
P= V*I (4)

Pressure difference: $\Delta P = ((V_2^2 – V_1^2) \rho) / 2$ (5)

The Equation (1) is used to get pressure difference equation & equation (2) is used to get velocity at the second section of the reducer by considering area of both the sections& velocity at the first section of the reducer. This will then help to get pressure drop at the second section.

When the jet is passed using the fan, sufficient suction pressure is created which sucks the water vapor along with it which is carried towards the other end of the reducer from where the heat exits to the atmosphere.

IV RESULTS& DISCUSSIONS

Interest of engineer in such experiment is to know various results by changing different parameters. It can be observed that with increase in the speed of the fan the cooling of water takes place at a faster rate i.e. the C.O.P of the system improves which is due to increase in the suction pressure at the throat opening.

We know that

COP =Desired effect / Input Power.

Refrigeration capacity = $(M*Cp* \Delta T)/t$. KW

It can be observed thatwith the increase in the fan speed less time is required for obtaining the same desired result. It is found that COP increases with the increase in fan speed.

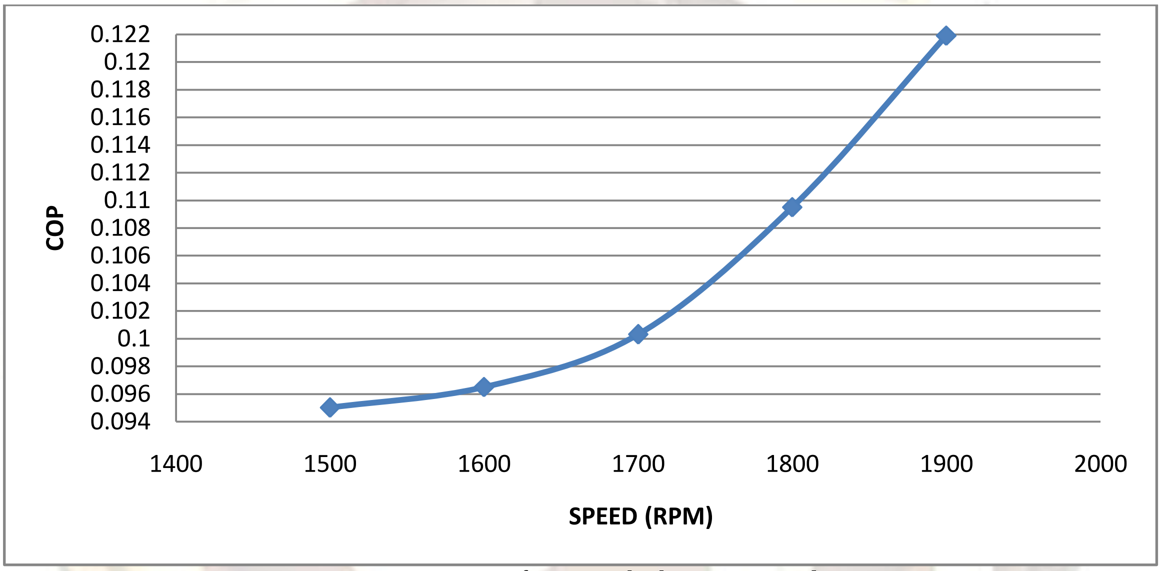

Fig.3 Variation of COP with change in speed.

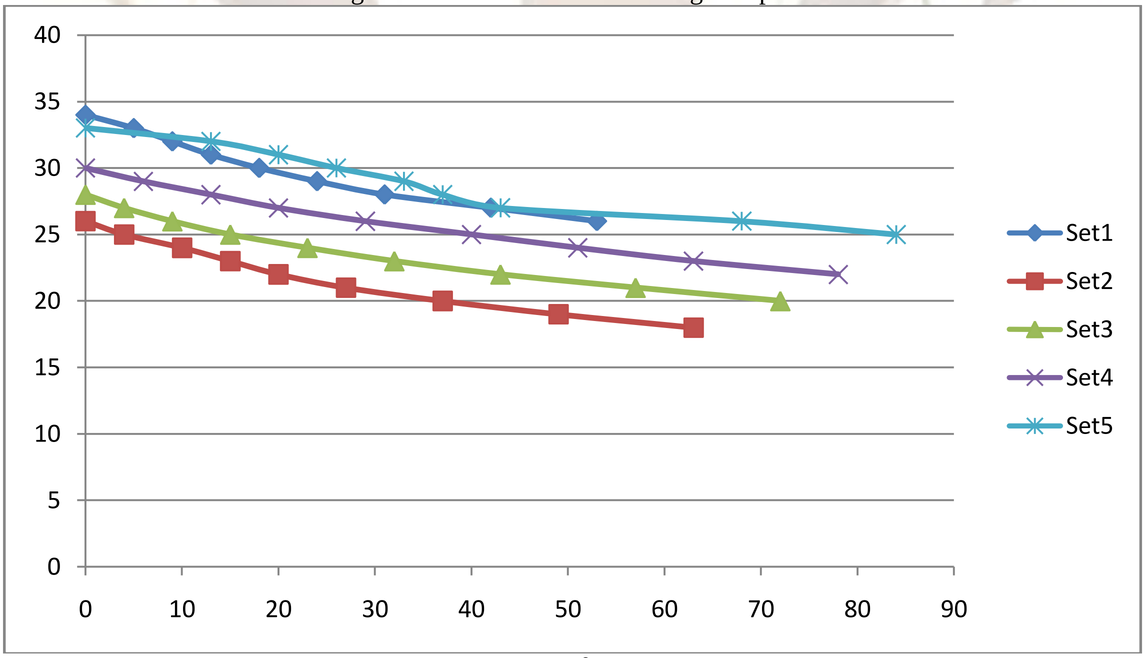

Fig.4 Variation of Temperature (°C) with increase in Time(min)

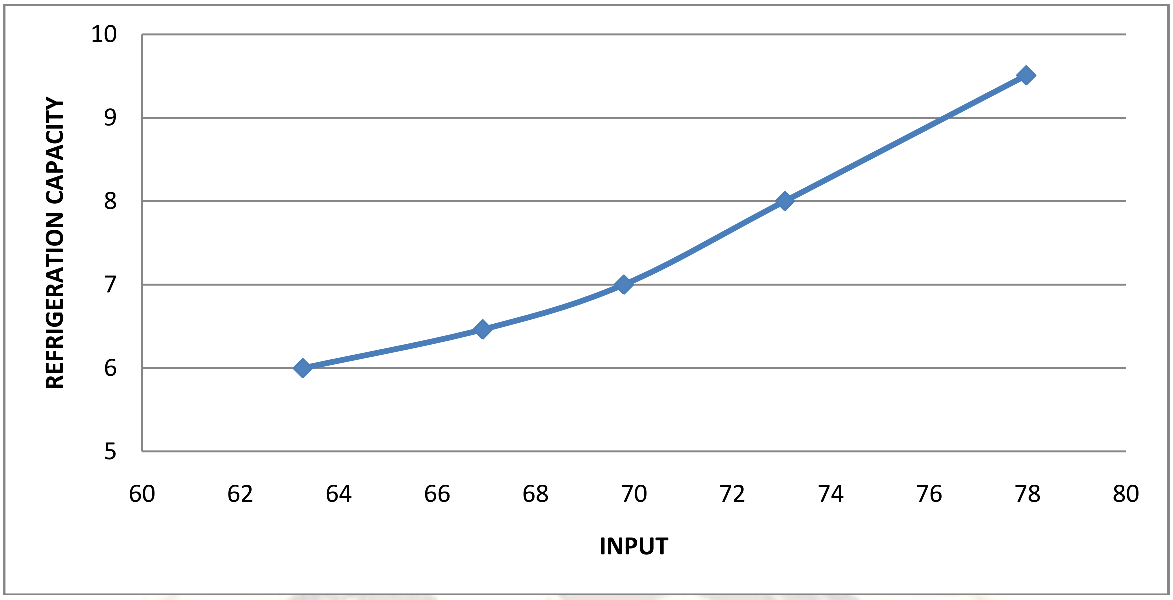

Fig. 5 Graph of input power (KW) v/s output power. (KW)

1. With the increase in speed of fan i.e. RPM of the fan, there is increase in coefficient of performance of the setup.
2 As starting temperature reduces, more amount of time is required to obtain the desired cooling effect.
3. Also the refrigeration capacity increases with increase in input power.

V CONCLUSIONS

1.With the increase in speed of fan i.e. RPM of the fan, there is increase in coefficient of performance of the setup. If speed increases, the velocity of air increases. From Bernoulli's theorem we know that increment in velocity causes decrement in pressure, hence low pressure zone is created which increases suction at throat. Increment in suction results in increased cooling effect, thereby enhancing the C.O.P.
2As temperature reduces more amount of time is required to obtain the desired cooling effect. In other words, this follows Newton's law of cooling which states that the rate of cooling varies directly with temperature difference.
3.Also the refrigeration capacity increases with increase in input power.

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