Utilization of Green Energy in Refrigeration & Air Conditioning System

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Abstract- *The most important aspect of today's world is to conserve energy. Cooling systems is one of the appliances that consume a large amount of power. The paper deals with the conservation of energy in such appliances. Today's challenge is the need of smart machines which consumes only considerable energy with at most efficiency. The energy crisis of world has led to innovation and up gradation of the systems. The machines operations should be revised for better utilization of energy. This also reduces the burden on the conventional energy resources leading to a green world for future.*

In conventional refrigeration and air conditioning system working on vapor compression refrigeration cycle, the expansion of working medium is accomplishedusing throttle valve which also act as a buffer. In this process huge kinetic energy imparted by the compressor is only utilized for mere expansion. This energy could be well harvested by a rotor system which is coupled with a compressor at the other end. Here the 2 stage compressor increases the efficiency and refrigeration capacity of the system. Hence the amount of power consumed by the compressor is actually not needed when we use the 2 stage compressor system which utilizes waste kinetic energy for its working. This unit could be an economic unit at places where high tonnage capacity compressors are used as well as providing comfort conditions to the people.

Keywords- Compressor, Condenser, Evaporator, Two stage compressor, Refrigerant.

I. INTRODUCTION

Air conditioning is an art of maintaining or to create an environment for human comfort. The challenge is to accomplish it with minimal energy consumption.

Vapour compression cycle is used in the proposed system as it is simple in construction. The vapour which is the working fluid goes through a cycle of condensation, expansion and evaporation. The conventional expansion system uses throttle value for expansion where the energy of the refrigerant is not utilized. Apart from throttle valve which involves isenthalpic expansion there are other devices like turbines which adopts isentropic expansion which leads to increased efficiency of process. Hence replacing a classic isenthalpic expansion with nearly isentropic one increases the cycle cooling capacity between 8% and 20% for the same compressor input power and generates an additional electric power by a turbine.

Research was done on using turbine as an expansion system in refrigeration system but not up to the fullest. U.S. Pat. No. 4,336,693 describes a refrigeration system that employs a reaction turbine as an expander stage. In this approach, a centrifugal reaction turbine preforms the expansion function, and operates to separate vapor from the liquid before extracting power. This produces increased efficiency over a conventional turbo-expander. In this prior patent, the energy produced by the turbine can be used to drive a load, such as a generator.

Ritzi et at. U.S. Pat No. 4,298,311, Hays et at. U.S. Pat. No. 4,336,693 and Hays et at. U.S. Pat. No. 4,438,638, these patents relate to turbines driven by a two-phase working fluid where most of the fluid mass (e.g., 90%) is liquid, and one or more nozzles directs the condensed refrigerant at a rotor so that the vapor and liquid mixture impacts the rotor. These turbines are designed as reaction turbines, so that kinetic energy of the expanding vapor is transformed into kinetic shaft output energy rather than into heat. This, in theory, maximizes the liquid fraction of the total mass of the working fluid after expansion.

However, in all these systems the common thing is expansion using turbine but the maximum efficiency is not yet achieved so we have taken one step Forward from here by using a turbocharger. The fullest utilization comes into picture only when we use this type of system that is a compressor is coupled to the turbine so that when turbine rotates compressor too rotates as it is connected in the same shaft which we call it as a turbocharger provided that act a secondary compressor which compresses the refrigerant depending on turbine speed thus reducing the load on main compressor which is electrically driven.

II. STATE OF THE ART STUDY

The conventional refrigeration cycle adapts a throttling device to achieve isenthalpic expansion at constant temperature where the medium expands pressure drops without doing work. Only the internal energy and expansion energy are interchanged whereas the kinetic energy recovery is not done.

One method to accomplish kinetic energy recovery method was developed by a group of scientists from City University (London).The literature search has revealed that the principal method to accomplish this task in the past was using the ejector instead of the throttling valve.

The velocity increase in the throat of the ejector device is used to entrain the refrigerant exiting the evaporator by momentum exchange. The following diffuser section of the ejector re-compresses the refrigerant by slowing down the mixed stream. Through the action of an ejector, the compressor suction pressure is therefore higher than it would be in a standard cycle, resulting in less compression work thus improvement in cycle efficiency. Latest work on ejectors had concentrated on using them in transcritical CO_2 systems where high pressures allow for better recovery of the kinetic energy.

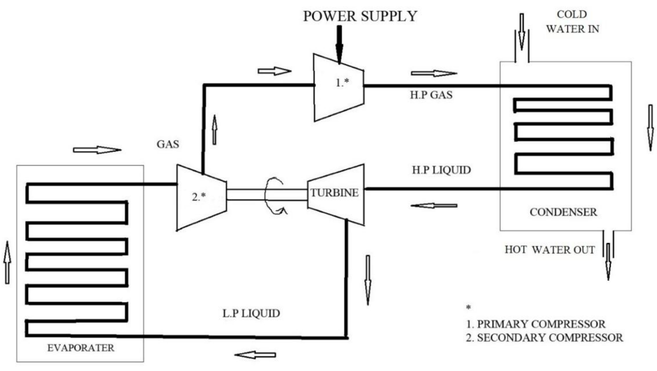
But our system involves kinetic energy recovery as well as load reduction on main compressor which is electrically driven.

III. PROPOSAL OF IDEA

The expansion of the working medium could be achieved through isentropic expansion using a turbine. Meanwhile the shaft work is obtained at turbine which is a high grade energy and could be used within or external of the system.

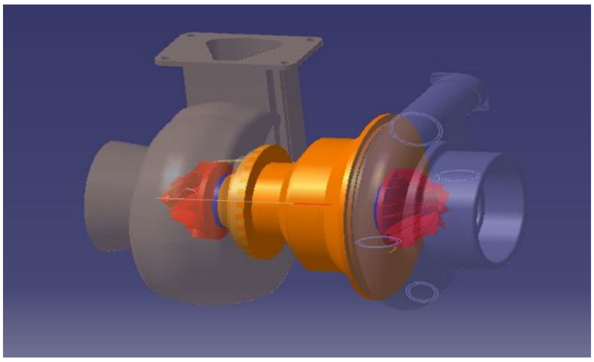
In the proposal this shaft work is used to run a rotary compressor to compress the working medium.This reduce the net compressor work input from external power source.

IV. PROPOSED SYSTEM



The working of the proposed system goes like this first the refrigerant is compressed by using a compressor which is electrically driven then high pressure high temperature refrigerant is passed through the condenser where heat is rejected. After condensation the high pressure refrigerant rotates a turbine where the expansion process occurs. The turbine is connected to a rotary compressor through a direct shaft drive, which acts as a secondary or boost compressor. The refrigerant after expansion enters the evaporator for evaporation and the evaporator outlet is given to secondary compressor which is directly run by the turbine. The outlet of the secondary compressor is connected to the primary compressor(electrically driven). At the time of evaporation it absorbs heat from the surrounding which is utilized as latent heat for changing it from liquid to vapor state. During cooling in condenser it emits heat to external body and creates cooling phenomena. The system saves energy with increased efficiency and low investment.

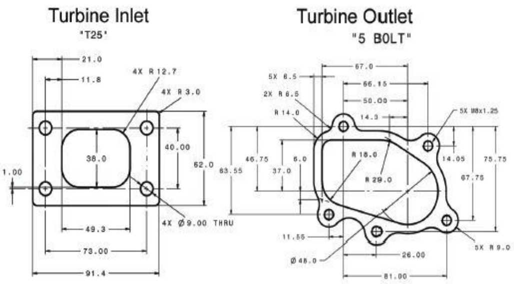
V. TURBINE – COMPRESSOR DESIGN



COMPRESSOR			
Ind wheel dia	Exd wheel dia	Trim	A/R
42.1mm	54.3mm	60	0.80

TURBINE		
Wheel dia	Trim	A/R
53.0mm	62	0.64

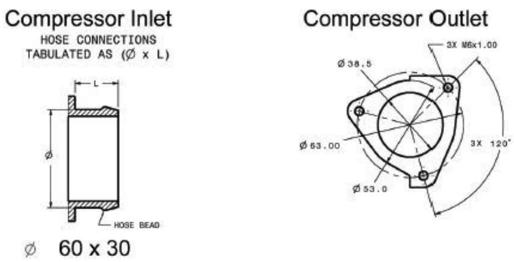
A) TURBINE DESIGN



The turbine has nine blades whose profile is presented.

It has spiral inlet casing made of cast iron. Turbine profile is based on "Francis turbine".It has radial inlet and axial outlet.Turbine is mounted on gas sealed journal bearing to avoid refrigerant leakage.The conventional system pressure loss at expansion is 12 bar.Turbine pressure drop range is 5 bar to 15 bar.

B) COMPRESSOR DESIGN



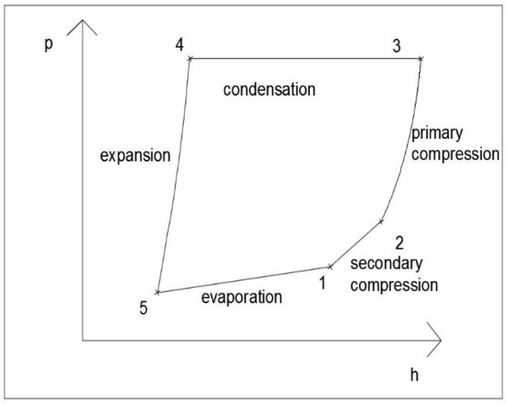
The compressor is of rotary type and has five pair of blades. It has aluminium volute casing and has axial inlet and radial outlet.It is mirror mounted on other end of shaft onto which turbine is keyed. Pressure difference achieved is 3 bar.

C) TESTING DATA

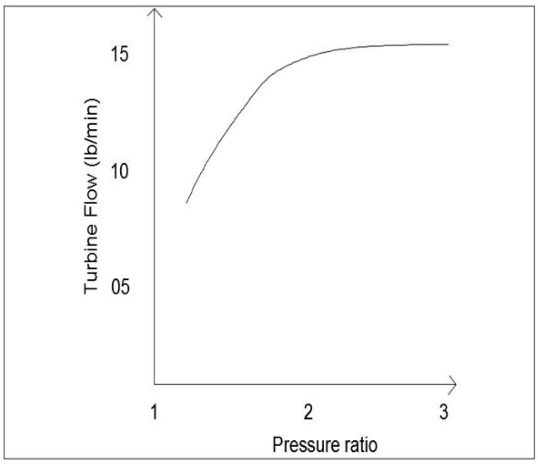
With R-22 as a working medium the system is tested. The temperature is measured using thermocouple and pressure is measured using gauge at requisite points. The valves of parameters are recorded with most possible accuracy at this stage. The exact measurements will be made on next stage of system development and optimization.

	Pressure (bar)	Temperature (°c)	Enthalpy (kj/kg)
Compressor outlet	29.97	70	416.10
Condenser outlet	23.24	58	303.28
Turbine outlet	3.8	-8	211.83
Evaporator outlet	8.6	18	411.1
Secondary Compressor outlet	9.6	22	412.2

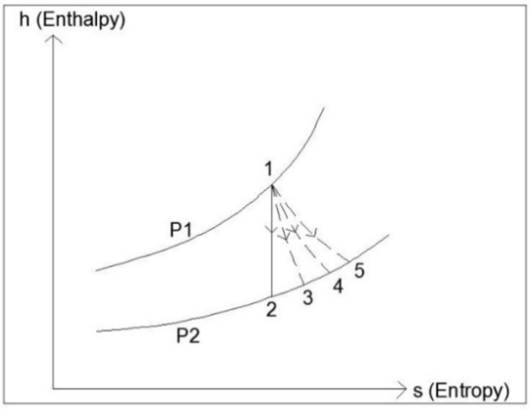
P-H DIAGRAM FOR PROPOSED SYSTEM



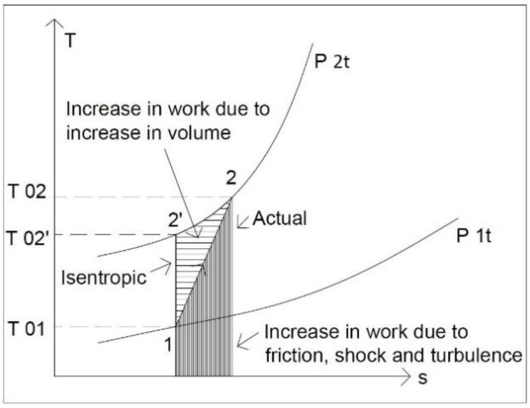
TURBINE FLOW VS PRESSURE RATIO



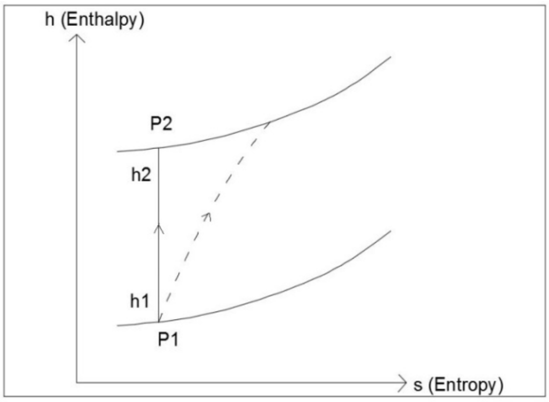
H-S DIAGRAM OF TURBINE



T-S CURVE OF TURBINE



H-S DIAGRAM OF COMPRSSOR



VI. CALCULATION

1. Inlet temperature of air = 25°c
2. Outlet temperature of air =15°c
3. Volume flow rate of air= Area of the duct* Velocity of air inlet = 0.225*0.45*4.5
4. Mass flow rate of air = volume flow rate * Density (1.16kg/m3) = 0.528kg/s
5. Coefficient of performance = Refrigeration effect / work input.
6. Specific heat for air (cp) = 1.005 KJ/Kg k
7. Heat extracted from the evaporator = m*cp*Δt = 0.528*1.005*(10) = 5.311KW
8. Work done by compressor = (N/t)*(3600/900) KJ/s
   Where,
   t = time for 10 rev of energy meter = 21.73s
   900 = energy meter constant.
   N =no of rev of energy meter =10
9. W = (10/21.73)*(3600/900) =1.840KW
10. C.O.P = 5.311/1.840 = 2.886
11. Work done without secondary compressor= $\frac{n}{n-1}(P_1V_1)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n}{n-1}}-1\right]$

$$= \frac{1.3}{1.3-1}(8.6*10^5*V_1)\left[\left(\frac{22.5}{8.6}\right)^{\frac{1.3}{1.3-1}}-1\right]$$

$$= 0.9257*10^5*V_1 \; W$$

12. Work done with secondary compressor= $\frac{n}{n-1}(P_1V_1)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n}{n-1}}-1\right]$

$$= \frac{1.3}{1.3-1}(9.6*10^5*V_1)\left[\left(\frac{22.5}{9.6}\right)^{\frac{1.3}{1.3-1}}-1\right]$$

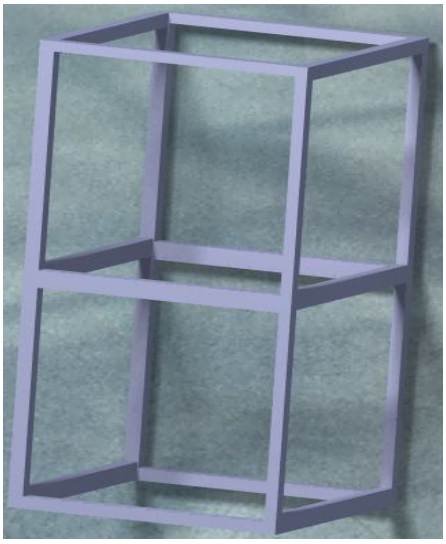
$$= 0.9036*10^5*V_1 \; W$$

13. % decrease in work done = 2.3%

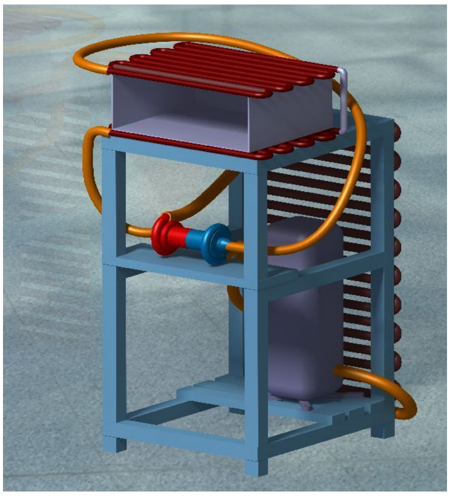
In our system the input power is 1840 watts. Therefore the decrease in power is 40 watts.

VI. EXPERIMENTAL SETUP

A) SKELETON FRAME



B) DESIGN OF THE SYSTEM



C) SPECIFICATION OF SKELETON FRAME

1. Diameter of piping = 6mm
2. Compressor capacity = 1.5 tonne.
3. Total duct length = 2m.
4. Length Of The Frame = 0.4m
5. Breadth Of The Frame = 0.4m
6. Height of the frame = 0.8m

VII. APPLICATIONS

- Plays a major role for Manufacturing Units and Industries.
- Storage for Medical Appliances.
- External Work of turbine can be used as energy storage.
- Water which is used to remove heat from condenser as forced convection process can heat water which can be used for various industrial purpose.

A) ADVANTAGES

- Traditional isenthalpic expansion has been replaced with isentropic expansion using turbine, the work so obtained is used to compress the medium to reduce power consumed by main compressor.
- Volumetric efficiency and overall performance has also been increased.
- More flexible for high capacity and industrial application.
- Easy to control operating parameters.
- Life of main compressor is increased.

VIII. CONCLUSION

The Refrigeration and Air-Conditioning systems are made smart by utilizing waste energy and thus reduced power consumption. Hence large amount of power could be saved if adopted in factories and multi storey buildings. Rotary expansion device helps to achieve dynamic metering of refrigerant flow depending on load requirement. Two stage compression leads to increased efficiency of the system. The power obtained from the turbine could also be used to generate electricity.

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