Design of ROVAC Air-Conditioning System for a Car

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***Abstract* — This study investigates the air compression air conditioning system which utilizes a rotary vane compressor that replaces the conventional mechanical compressor in automotives. The awareness for pollution, transportation contributing the major part has lead to measures taken by the Nation, demanding reduction of global warming refrigerants used in mobile air conditioning systems. Much of effort was to refurbish the system to safe operating condition and to evaluate its performance. The result of this study provides the basis for design of improved refrigeration systems for automotives and space conditioning applications.**

The queer system which is based on the works of Dr. Thomas C. Edwards, has been developed in which an oval shaped housing acts as a compressor and natural substance like air as refrigerant which offers a number of environmental and practical advantages.

***Key words*: Air Conditioning, Automobile, Brayton reversed cycle, Ram Compression, Rotary Vane Compressor**

INTRODUCTION

Comfort cooling of automobile with refrigeration equipment is one of the most popular accessory features. The industry has passed through several basic stages of development and has investigated many more that were found to be impractical from the stand of bad applications, poor performance or high cost.

Like most air conditioning systems, the auto air conditioner must provide adequate comfort cooling to the passengers in the conditioned space under a wide variety of ambient conditions. The cooling level is affected by many factors as:

1. Outdoor temperature and humidity
2. Air leakage into the conditioned space
3. The number of occupants
4. Quantity of fresh air taken in
5. Sun load

WORKING OF AN AUTOMOTIVE AIR CONDITIONERS

Figure.1 represents an installation of mobile air conditioner. The compressor is driven with the help of a belt from the crankshaft pulley. Further, there is a magnetic clutch, which disconnects the compressor, when there is sufficient cooling inside the passenger compartment. When control settings call for cooling, the magnetic clutch gets engaged and the compressor is driven. The refrigerant starts circulating through the system. The hot vaporized refrigerant from the compressor enters the condenser where it is cooled by a fast moving air stream and then changes into liquid. Now the liquid refrigerant enters the receiver drier and then into the evaporator through an expansion valve. Thus the low-pressure liquid refrigerant extracts heat at the evaporator and becomes vapour. The vapour refrigerant passes to the compressor, the cycle gets repeated. [1]

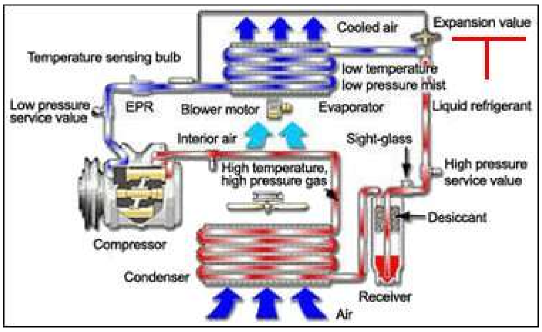

Fig 1: Working of mobile air-conditioner

Types of Automotive Air Conditioners:

1. Receiver drier (Filter drier) expansion valve system.
2. Accumulator orifice tube system
3. Suction throttling valve system

The system utilizes mechanical compressor and CFC refrigerants which consume engine power and are harmful to the environment respectively.

NEED OF AN ADVANCED AIR CONDITIONING SYSTEM

In recent history, effects of global warming and ozone depletion from mobile air conditioning systems have been brought to the main stream news. As a result governments around the world have united to create policies, such as the Montreal protocol (1987) and its amendments, which have forced refrigeration industries to replace harmful ozone depleting CFC's with newly developed refrigerants.

An automobile without air conditioning system gives more mileage than the vehicle with air conditioning system, because the mechanical compressor consumes more power developed by the engine itself. This drawback also knocks the door steps of Researchers to minimize the fuel consumption and simultaneously to protect the Planet from harmful emissions. [2]

PROPOSED SYSTEM – ROVAC AIR CONDITIONING SYSTEM

(ROVAC – Rotary Vane Air Compression Air Conditioning)

This system of air conditioning the car uses nothing but air as the refrigeration and is yet to be commercially developed in automobiles. The system has been designed by Dr.Thomas C. Edwards.[3]

The figure.2 shows a schematic layout of ROVAC system. It alternately compresses and expands the air. ROVAC uses no phase change like the conventional sealed units, except for the incidental moisture normally present in air. Edwards called this a reversed Brayton cycle. [4]

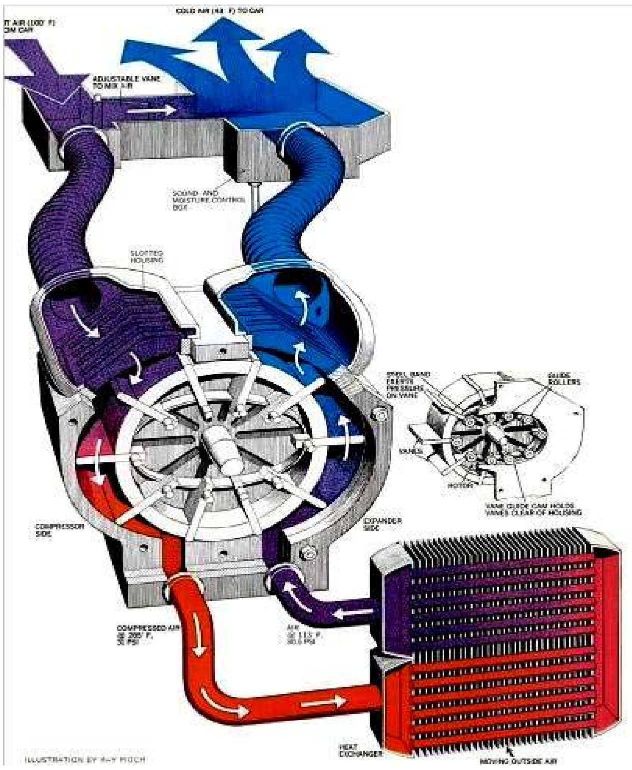

Fig-2: ROVAC air-conditioning system

Referring to the figure, we can observe that the oval shaped housing acts as a compressor at atmospheric pressure and passenger car temperature. This air is compressed and the compressed air travels through the heat exchanger, which is provided with fins. The inside air is cooled by the outside air flowing past the tubes. This drops the temperature of inside air and low appreciable change in pressure is observed. Now this air is lead through the expander where the pressure drops to atmospheric and the temperature of air drops to lower values (9°C). This low temperature air is circulated inside the passenger compartment thus cooling the occupants. The cycle gets repeated.

GENERAL DESIGN REQUIREMENTS

Like most air conditioning systems the auto air conditioner must provide adequate comfort cooling to the passengers in the conditioned space under a wide variety of ambient conditions.

The cooling load is affected by many factors such as outdoor temperature and humidity, air leakage into the conditioned space, quantity of outdoor air brought in, the number of occupants and sun load. These local factors however, are constantly and rapidly changing as the automobile travels on the highways at different speeds, in different directions, on different types of road surfaces and under various changing climatic conditions.

The unit capacity is the lowest at idle speeds with no car movement because the compressor is driven directly from the engine and the amount of air available to the cool the condenser is less. Operation in slow moving traffic is only slightly better than at idle conditions. The intermittent increases in engine speed give corresponding increase in compressor capacity and condenser and radiator air flow. This provides more idle and slow speeds in one of the major design and development challenges facing those engineering and applying automotive temperature when changing from open road traffic to city traffic, 15mph and idle.

The following design requirements are considered in starting out auto air conditioning design or application. (Referred from ASHRAE guide and data book.)

i. Capacity requirements

Cooling capacity is often prescribed in terms of cool down, steady driving, or both i.e., sufficient capacity to cool down to 80°F (25°C) in 10 minutes after being parked and closed in 110°F (43°C) ambient. The need for frequent rained cool down is one of the major differences between car air conditioning and residential air conditioning requirements. The unit must not only have adequate capacity to rapidly pull the air temperature down to a comfort level, but also reduce the temperature of seats, door panels ceiling floors and instrument panel, all totalling mass of 320kg. To cool this quantity of material from 135°F to 75°F (57°C to 25°C) in 15 minutes would require capacity of 8.2 kW, assuming an average specific heat of 0.46 KJ/kg.

At steady state conditions, as well as during cool down, the rate that outdoor air infiltration into the car plus the amount of insulation in the panels root and floor are very significant factors affecting cooling capacity needs. Use of heat absorbing glass to reduce the direct solar radiation transmission from 67% to 45% is also effective in reducing the cooling load. The cooling load of a typical automobile would be broken down into various major sources as described in the table below.

Table-1: Major sources of cooling load of an automobile.

Sources	Cooling Load
Solar radiation (roof, wall, glass)	800 watts
Normal heat gain through glass	350 watts
Normal heat gain through walls, roof, floor	1250 watts
Air leakage into car	280 watts
Passengers (2), plus driver (sensible heat only)	250 watts
Total	3010 watts

ii. Speed range

The air conditioning system must function properly over car speeds from idle to 120 mph. This extremely wide speed range 12 to 1 considerably complicates the design problems in accomplishing adequate capacity at the low speed end and reliability and endurance life at the high speeds.

iii. Life

It is reasonable to expect the air conditioning system to last the life of the car without major repairs. This is normally assumed to be 80000 to 100000 miles or 4 to 5 years. During this time some normal servicing and occasional addition of refrigerant is expected, but this should be confined primarily to good preventive maintenance practice.

iv. Air distribution

The method for distributing the cool air into the conditioned space is one of the most important factors in automobile air conditioning system design. The free space in a car available for circulating the cool air within the passenger compartment without direct impingement on the passengers is very limited.

Another air distribution problem arises from the fact that direct sun light through some portion of the glass that surrounds the top half of the car shines directly two of the four passengers. The type of distribution desired during the cool down period is much different than at normal relatively steady conditions after the car has reached the comfort temperature.

During cool down the air off temperature is quite high and with inside of the car being very warm, spot cooling or direct impingement on the occupants is desirable.

An ideal distribution system would be:

a. Supply adequate air to the car interior without excessive drafts or direct cold air blasts on the passengers.
b. Permit controlled amounts of cooling to the various areas of the car such as the sides, front floor area and rear seat area and breathe level.
c. Accomplish good distribution without objectionable noise from grilles and blowers etc. with minimum power requirements.
d. Provide for all re-circulated air during the cool down period. The tolerable air motion is considerable higher in an automobile due to more direct radiation through windows from sun and hot surrounding areas. The air velocity normally can be in the order of 200 to 300 fpm without discomfort.

DESIGN CONDITIONS

Inside and outside design conditions have to be specified for a proper design. It is necessary for air conditioning designers to know about the heat sources and their nature. Among many applications of air-conditioning important design conditions can be identified as (1) Cold storage (2) Industrial air-conditioning (3) Comfort air-conditioning.

- **Comfort Air Conditioning & Effective Temperature.**

Extensive tests have been conducted on the effects of temperature, humidity and air velocity, also, there is the problem of measuring comfort in measuring comfort in terms of a single parameter which could include all three parameters governing comfort, namely, air temperature, humidity and air velocity in addition to air purity. Often, a single parameter called the 'Effective Temperature' is used as an index of comfort. [5]

Effective Temperature (ET) is defined as that temperature of saturated air at which the subject would experience the same feeling of comfort as experienced in the actual unsaturated environment. Based on the concept of effective temperatures some 'Comfort Charts' have been developed. For example, we have the Frangers Comfort Chart. These may be referred to when a compromise in the inside conditions is to be achieved. In addition to the comfort charts, some comfort equations have also been developed, one of them is:

$dt = (t - 24.4) - 0.1276\,(c - 9.1)$ ------------------- Eq. (1)

Where't' is the local temperature in degree centigrade and 'c' is the local velocity in mpm.

According to Manohar Prasad [6], the effective temperatures and also the range of DBT at 50% RH for comfort are as follows.

Table-2: Particulars of DBT & RH

Climate	ET (in °C)	Corresponding DBT at 50% RH, °C
Hot and Dry	21.1 to 26.7	23.9
Hot and Humid	22 to 25.6	26.7

The general practice is to recommend the following optimum inside design conditions for comfort for summer air-conditioning.

ET --------- 1.7
OBT --------- 5 ± 1
RH --------- 0 ± 5
Air Velocity--------- 0.4 m/sec.

During winter the body gets acclimatized to with stand lower temperatures. Consequently a DBT of 21°C at 50% RH and 0.15 to 0.20 m/sec air velocity is quite comfortable.

In addition to the maintenance of temperature, humidity and air velocity, it is also important to maintain the purity of space air. Even if there are no sources of production of pollutants within the conditioned space, the carbon dioxide content of air increased because of the occupants. It is therefore, necessary to introduce fresh air into the space. The requirement of ventilation air is much more when some occupants are smoking.

- **Comfort**

The salient features governing human comfort are as follows.

a) Metabolic rate: The rate at which body produces heat is called the 'metabolic rate'. The heat produced by a normal healthy person while sleeping is called the 'basic metabolic rate'. It is of the order of 60W.

The temperature of the body remains comparatively constant at about 36.9 °C (98.4°F) for tissues at the surface or the skin and about 37.2 °C for the deep tissues are the core. If it is found that the body temperature in the afternoon. A value of 40.5 °C is considered serious and 43.5 °C (110°F) is certainly fatal. Human comfort is influenced by physiological factors determined by the rate of heat generation within the body and rate of heat dissipation to the environment.

b) Mechanism of body heat loss: The body loses heat to the surroundings mainly by convection C, radiation R and evaporation of moisture E The total heat loss from the body is thus

$Q = (C + R) + E$ ---------------------- Eq. (2)

There are two components of this heat loss C+R forms the sensible heat component Q_s and E forms the latent heat component Q_t. The sensible heat component depends on the temperature difference between the surface of the body and the surroundings. The latent heat component depends on the difference in the water vapor pressures, which is not considered for air – conditioning. In summer, the temperature difference available for sensible heat transfer is less. Thus the convective and radiative heat losses are reduced. To maintain thermal equilibrium the body starts perspiring to increase the evaporative loss. On the other hand, in the winter, the sensible heat transfer is increased, the evaporative losses thus tend towards zero.

c) Mathematical model of heat exchange between man and environment:

The heat exchanged between man and his environment can be expressed by the following energy balance equation.

$M - W = Q + S$ -------------------------------- Eq. (3)

Where M = Metabolic rate.
W = work done by man.
Q = rate of convective, radiative and evaporative heat losses.
S = rate of heat storage.

In summer the body temperature has a tendency to rise since the stored energy 'S' is positive. The blood flow rate through the extremities increases and the body starts perspiring. This is called the condition of "Vasolidation".

In winter the temperature tends to fall, the stored energy and the blood flow rate through the extremities becomes low. This leads to the condition of "Vasoconstriction" resulting in shivering.

For the condition of equilibrium or thermal neutrality of the body there should be no stored energy hence, no change in body temperature. For a feeling of comfort thermal neutrality is the required condition. The net heat release rate of the body due to oxidation is

$H = (M - W) = M(1 - \eta)$ -------------------------- Eq. (4)

Where 'η' is the thermal efficiency of the body heat engine. Work done 'W' is positive when the body performs work. Both 'M' and 'η' are governed by the activity of the man. The 'η' in most cases is zero, except in case of high activity.

d) Purpose of Ventilation:

The fresh air or ventilation air is a must in any comfort air conditioning system. Its purposes are the following

- To provide oxygen
- To remove carbon dioxide
- To remove odours
- To remove heat and humidity
- To dilute toxicity.

DESIGN OF CAR AIR CONDITIONING

The load estimation of the following five parameters is the criterion of designing an air conditioning system for car.

1. Solar radiation (roof, wall, glass)
2. Normal heat gain through glass
3. Normal heat gain through walls, roof
4. Air leakage into car
5. Number of passengers (sensible heat & latent heat)

Methods to calculate load for the following parameters:

1. Solar Radiation:

Solar radiation forms the greatest single factor of cooling load in cars. A part of the sun's radiation and reaches the earth's surface directly, this part is called Direct or Beam radiation. A part of this radiation is reradiated and reaches the earth's surface uniformly from all directions is called diffuse or sky radiation. The solar intensity is the sum of direct and diffuse radiations that increases with altitudes.

Solar heat gain through walls and roof: We can calculate the solar heat gain through walls and roof of a car by using sol-air temperature concept. Sol-air temperature is a hypothetical temperature used to calculate the heat received by the surface wall by the combined effect of convection and radiation. Mathematical sol-air temperature can be calculated as:-

$t_e = t_o + I\alpha/f_o$ --------------------------------------- Eq. (5)

Where t_e = Sol-air temperature.
t_o= outside air temperature.
I = total radiation intensity.
α = absorptivity of the surface.
f_o = outside film coefficient.

Now, we can estimate the solar heat gain through walls and roof by using the formula.

Solar heat gain = U A (t_e- t_i) ----------------------------- Eq. (6)

Where U = overall heat transfer coefficient
A = area of the surface exposed to solar radiation
t_i = inside temperature of the space to be cooled.

Solar heat gain through glass: The heat gain through the glass areas constitutes a major portion of the load on the cooling apparatus. When a sheet of glass is subjected to solar radiation (direct and diffuse), a part of it is absorbed, a part is reflected and remainder is transmitted directly to the interior of the surface.

The complete heat balance can be written as follows.

Net solar heat gain = (transmitted solar radiation) + (heat flow by convection and radiation heat exchanges between glass and indoor surfaces).

2. Normal Heat Gain Through Glass:

Mathematically this load can be calculated by using the formula

$U_g A_g (t_o - t_i)$ -- Eq. (6)

Where U_g = overall heat transfer coefficient of a glass.
A_g = total glass area.

3. Normal Heat Gain Through Roof and Walls:

The heat gain through the structure such as walls and roofs constitute the major portion of sensible heat load.

The heat transferred or gained through a wall under steady state condition is:

Heat gain = U A (t_o- t_i) ------------------------------- Eq. (7)

4. Infiltration or Air Leakage Into Car:

Infiltration is the name given to the leakage of outside air through door openings, through cracks, and interstices around windows and door into the conditioned space. The leakage takes place due to the following factors:-

- Stack effect
- Wind pressure
- Entry and Exit of occupants through doors and opening of windows cause change in air.

These factors contribute to the both sensible and latent heat gains.

There are two methods of estimating the infiltration of air,

a. Crack length method
b. Air change method

In most cases Air change method is used for calculating the quantity of infiltrated air. According to this method the amount of infiltrated air:

(L*W*H*A_c) / 60 m^3/ min. ------------------------------- Eq. (8)

Where L = length of the space
W = width of the space
H = height of the space
A_c= air changes per hour (taken 2 for car)

Sensible heat gain due to infiltration:

20.4*C_{mm}*$(t_o - t_i)$ W ------------------------------ Eq. (9)

Latent heat gain due to infiltration:

50000*C_{mm}*$(w_o - w_i)$ W ------------------------------ Eq. (10)

Where w_o and w_i are humidity ratios of outdoor air and indoor air respectively.

5. Occupancy Load:

The human body in a cooled space constitutes cooling load of sensible heat and latent heat.

The heat gain from occupants is based on the number of people that are present in the conditioned space. The occupants in a combined space give out heat at a metabolic rate that more or less depends on their rate of working.

The typical values of heat given out are taken directly from the table prepared by Carrier Air Conditioning Co.

6. Overall Heat Transfer Coefficient:

A wall may be composite, consisting o many sections of different construction and insulating materials. Also the outside and inside wall surfaces may exchange heat by radiation with the surrounding atmosphere.

q = U*Δt = Δt/R ------------------------------------- Eq. (11)

so that, the overall heat transfer coefficient may be calculated from the relation:

1/U = R = $1/f_0 + \frac{\Sigma\Delta x}{K} + \Sigma\left(\frac{1}{C}\right) + 1/f_i$ ---------------- Eq. (12)

Where f_o and f_i represent heat transfer coefficients for outside and inside wall surfaces.

C = conductance

K = thermal conductivity

Δx = thickness of the layer

The properties of thermal conductivity, conductance, specific heat, density etc. are referred as thermo physical properties.

LOAD ESTIMATION FOR TOYOTA QUALIS

The car Toyota Qualis has been chosen and an air conditioning system is designed by estimating loads as per the design procedure.

1. Specifications of Toyota Qualis

Dimensions and Weight:

Overall Length: 4425mm

Overall width: 1655mm

Overall height: 1880mm

Ground clearance:178.1mm

Kerb Weight: 1520kg

Gross vehicle weight:2275kg

Seating capacity: 10(9+1)

Engine:

Engine mode: 2L

Type: 4 cylinder in-line, 8 valve, OHC belt drive

Displacement: 2446cc

Bore and stroke: 92*92mm

Compression ratio: 22.2:1

Fuel supply system: Distribution type fuel injection

Maximum output: 54 / 4200 kw/rpm

Maximum torque: 151 / 2400 Nm/rpm

Maximum speed: 130 kmph

Fuel tank capacity: 53 ltrs

2. Calculation Sheet For Cooling Load Estimation

Surface used, Size = 3.5*1.6 = 5.6 m^2

Table-3: Required conditions

Conditions	DBT	WBT	%RH	Wkg/kg
OUTDOOR	50°C	30°C	20	0.016
INDOOR	22°C	16°C	50	0.008

Ventilation air per person = 0.28

Ventilation Cmm for 10 persons = 2.8

Infiltration – use air change method.

Total Load = Sensible Heat + Latent Heat = 6672.82 + 1470 = 8142.862 W

3. Solar Radiations

- Heat gain through Roof = 434.67 W
- Heat gain through Walls = 1266.77 W
- Heat gain through Glass:
    - From North side: 741.475 W
    - From North-East side: 738.679 W
    - From East side: 494.160 W
    - From South-East side: 610.654 W
    - From South side: 723.688 W
    - From South-West side: 790.423 W
    - From West side: 620.338 W
    - From North –West side: 722.775 W
- Normal Heat Gain Through Glass: 698.158 W
- Normal Heat Gain Through Walls and Roof:
    - Walls:- 697.4352 W
    - Roof:- 382.905W
- Infiltration (Air change method)
    - Sensible Heat Gain:- 1602.496 W
    - Latent Heat Gain:- 1120 W
- Occupancy Load

  Sensible heat / person a rest = 80 W
    - Latent heat / person at rest = 35 W
    - Sensible heat gain =800 W
    - Latent heat gain =350 W
    -

4. Psychometric Calculations

a. Sensible Heat (SH) = 6670 W

Latent Heat (LH) = 1470 W

Sensible heat factor = SH / (SH+LH) = 0.82

b. Ventilation Load (OATH)

OASH = 1.56 kW

OALH = 1.12 kW

OATH = OASH + OALH =2.68 kW

c. Grand Total Head (GTH)

TSH = SH + OASH =9.39 kW

TLH = LH + OALH =2.59 kW

GTH = TSH + TLH =11.98 kW

d. Effective Sensible Heat Factor (ESHF)

Take BPF =0.15

ESH =SH + (BPF * OASH)= 6.913 kW

ELH =LH + (BPF * OALH)= 1.638 kW

ESHF =ESH / (ESH + ELH)= 0.8

e. Apparatus Dew Point (ADP)

From Psychometric chart, ADP = 6°C

f. Dehumidified air quantity (Cmm_d)

Cmm_d =ESH / 0.0204*($t_i - ADP$)*(1-BPF) =24.92

g. Re-circulated Air (Cmm_r)

Cmm_r =Cmm_d - Cmm_o =22.12

h. Entering Air DBT

t_1 =(Cmm_r* t_i + Cmm_o* t_o) / Cmm_d =25.15°C

i. Leaving Air DBT

t_2= ADP + (t_1 – ADP) * BPF =8.8°C ≅9°C

PROPOSED AIR CONDITIONING SYSTEM FOR CAR

With the well known distinguishing features, ROVAC air conditioning system has been proposed. The features are as follows.

1. It replaces Freon gas by air as refrigerant, so the system is much simpler.
2. This system consumes less power of engine and hence there is fuel economy.
3. It gives instant cold.

4. It gives instant heat.
5. Vane type compressor and expander assembly is used in place of a compressor.

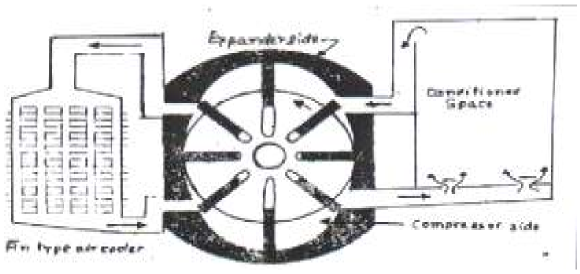

Fig-3: working principle of ROVAC air condition system

Vane type compressor and expander assembly consists of a rotor with vanes provided in the slots of the motor. The stator casing is so designed that on one side it compresses air from the cold room and delivers to the cooler which may be finned type heat exchanger. The cool air at this state passes through the other side of the rotor where it expands down to the cold room pressure. This cold air is then distributed in the conditioned space in appropriate manner.

Shape and size of the compression and expansion chambers are designed to suit the appropriate conditions. No need of a shaft or extra arrangement to transfer the power from the expander to the compressor. Since the shaft is common, there is no problem of leakage at the ends of two shafts.

There are some advantages due to warming up of cold air from the compressed air. This can be minimized using rotor, stator and vanes of low thermal conductivity materials such as polycarbonate, ebonite etc. instead of metallic parts. Also the leakage of hot compressed gas to the cold gas can be minimized using appropriate and minimum clearance space.

Air Refrigeration Cycle For Car With Ram Compression

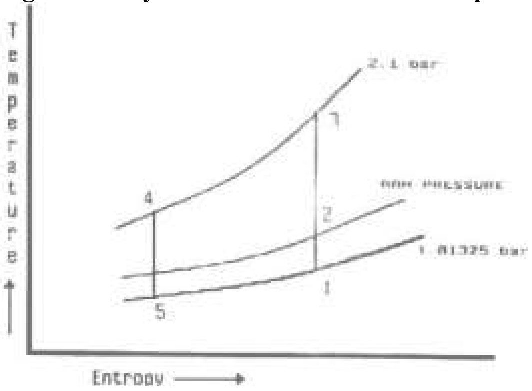

Fig-4: Representation of ROVAC process on T-S plot.

Process 1-2 is the ramming process. Due to the car moving at high speed, the air rams against the compressor intake system. Action here is that of diffuser. In the ramming process the total energy or stagnation enthalpy remains changed, if the process is assumed adiabatic, while pressure of the air increases. Ideal ramming action would proceed isentropic compression path such as 1-2, from pressure P_1(ambient) and temperature T_1(outside air temperature) to pressure P_2 and temperature T_2.

The kinetic energy of outside air relative to car is expressed as

K.E = $V^2/2$

Where V is the velocity of air relative to car or the speed of car in m/sec.

Thus , T_2 = $T_1 + V^2/(2 * C_p)$

The stagnation pressure after polytropic compression P_2 is given by

P_2/P_1 = $(T_2/T_1)^{n/(n-1)}$

With the help of these expressions we can find out all the salient temperatures

Air temperature entering into the system, T_1 = 323 °K
Temperature after ramming action, T_2 =323 °K
Temperature after compression T_3 =382 °K
Temperature after expansion T_4 =333.6 °K
Air temperature leaving the system T_5 =282 °K
COP of the system = $(T_1 - T_5) / (T_3 - T_2)$ = 0.7

ROVAC AIR CONDITIONING SYSTEM – ADVANTAGES

The conventional air conditioning system in automotives requires more fuel and the usage of CFC refrigerant pollutes the environment. These drawbacks can be overcome by using ROVAC air conditioning system in passenger cars.

1. FUEL ECONOMY: Although the air conditioning and power steering have penetrated more than 80% of the fleet and further increases will be small, other equipment such as power seats, sunroofs and power locks and windows may gain significant weight to the vehicle. In addition, four – wheel drive which can add 100 to 150 kgs to a vehicle and cut its fuel economy by 12-15% is gaining popularity.

This loss in fuel is effectively eliminated in ROVAC system as it uses vane type compressor, not connected to the engine.

2. AN ALTERNATIVE REFFRIGERANT:

Researchers at SINTEF have developed a new, efficient and environmentally benign automobile air conditioning system that uses $CO_2$and air as the refrigerant.

The use of a natural substance like air as a refrigerant offers a number of environmental and practical advantages. In practice, it is not necessary to produce new air for refrigeration purposes, as abundant amounts are available readily and naturally. The net global warming contribution made by the air is zero. Use of this no cost fluid will eliminate the refrigerant producer monopolies and terminate the present high cost and exclusively trend in fluorocarbon replacements and their lubricants. Furthermore recycling or recovery will not be necessary when using air, whether for environmental or economic reasons. This will reduce costs and simply work immensely during the life cycle of the system. [7]

CONCLUSIONS

The main evidence, shown through this study is that, the conventional mechanical compressor can totally be replaced by a rotary vane compressor of ROVAC system. ROVAC A/C system can be adopted effectively as it replaces Freon group refrigerants by air and thus the system becomes more simple.

The compressor in ROVAC system is independent of the engine, It consumes a little engine power and hence there is very much fuel economy.

By having minor modifications in the circuit, the same system can be used to heat it the car space in cold countries.

The ROVAC system is yet to be commercialized as it is still under research.

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