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ECO Friendly Cooling System by Ram Air

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Abstract—*The basic idea of the project lies into nullifying the use of any kind of fuel for running the refrigeration system in automobiles for human comfort. The use of the apparatus will help to achieve the reduction in the emission of green house gases, ozone layer depleting gases in order to reduce the increasing global warming. The effect on the engine vehicle performance will be negligible or zero. Process involves the continuous circulation of fresh air in cabin without the use of any coolant or any refrigerant for cooling. The idea involved is inspired by the use of "Ram air cooling system" in air transport using basic concept of Thermodynamics, Heat exchanger, fluid mechanics and Refrigeration and Air Conditioning. But since solar cells[1] are used as the power source for running the equipment so weather and cost are the two main problem which may affect the performance of the system that's why there is still need of the some focus on the system for its successfully implementation for general public at a reasonable rate with reliability.*

Keywords: *Ram air[6], solar cells[1],Low pressure compressor[2], Heat exchanger[3], Automatic expansion valve[4], Nozzle[5]*

1. INTRODUCTION

In a country like India which stands second in the population in world the rate of fuel consumption here is also at alarming rate. And as we know that it is the non- renewable source of energy. Petrol and diesel are even consumed in running AC's of public and private vehicle at an high rate, which are one of the cause of increasing global warming.

In public transport like buses with A.C coaches there is now significant rise in the ratio of the population which is using it for there some or the other purpose.

The A.C's in the automobiles uses *Freon (R12) as the refrigerant* [30] which affects our ozone system to a great extent. So because of this major threats to environment this field has become a major area of interest of various scientist and engineer to carve out its alternative and thus there have been some advancement done in the countries like USA and also in Europe.

Europe is phasing out R134a due to its relationship to global warming. Carbon dioxide, the current E.U. favorite to replace R134a, is the least powerful greenhouse-gas, but requires high pressures, and is less effective. However, in the United States, the approved replacement is HFO-1234yf. This new refrigerant is dramatically less likely to affect climate change than R134a, and while it will not be required until the 2017 model year, automakers can get greenhouse gas credits from the 2012 to 2016 model years by using it. The new gas was created by Honeywell and DuPont[23].

And the power consumption for running the system is done through the main battery of the vehicle which in turn affects the engine performance and decreases the working efficiency of the engine.

So here this paper focuses on the zero use of refrigerant and only the use of natural air for cooling purpose. And an alternative power (solar power) source for running the air conditioning system which is used for charging the two sets of batteries which have the same rating as the main battery one of which is used as the power storage bank so as to avoid the weather dependency of the cooling system.

2. RAM AIR

The ram-air intake works by reducing the intake air velocity by increasing the cross-sectional area of the intake ducting. When gas velocity goes down the dynamic pressure is reduced while the static pressure is increased. The increased static pressure in the plenum chamber has a positive effect on engine power, both because of the pressure itself and the increased air density this higher pressure gives.

Ram-air systems are used on high-performance vehicles, most often on motorcycles and performance cars. Ram-air was a feature on some cars in the sixties, falling out of favor in the seventies, but recently making a comeback. While ram-air may increase the *volumetric efficiency* of an engine, they can be difficult to combine with carburetors, which rely on a venture-engendered pressure drop to draw fuel through the main jet. As the pressurized ram-air may kill this venturi effect, the carburetor will need to be designed to take this into account; or the engine may need fuel injection

At low speeds (subsonic speeds) increases in static pressure are however limited to a few percent. Given that the air velocity is reduced to zero without losses the pressure increase can be calculated accordingly. The lack of losses also means without heating the air. Thus a ram-air intake also is a cold air intake. In some cars the intake is placed behind the radiator, where not only the air is hot, but the pressure is below ambient pressure. The ram-air intake effect may be small, but so are other mild tuning techniques to increase cylinder filling like using larger, fresh air filters, high flow mass flow sensors, velocity stacks, tuned air box and large tubes from the filter to the engine

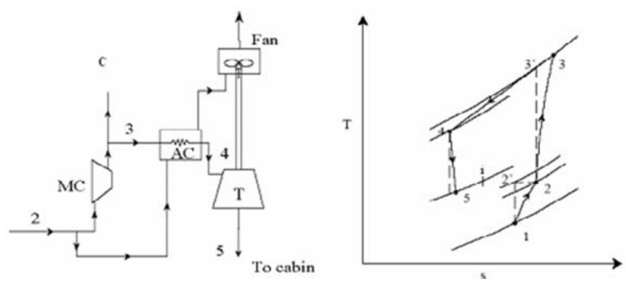

Fig. 1: Air craft refrigeration

Fig. shows the schematic of a simple aircraft refrigeration system and the operating cycle on T-s diagram. This is an open system. As shown in the T-s diagram, the outside low pressure and low temperature air (state 1) is compressed due to ram effect to ram pressure (state 2). During this: process its temperature increases from 1 to 2. This air is compressed in the main compressor to state 3, and is cooled to state 4 in the air cooler. Its pressure is reduced to cabin pressure in the turbine (state 5), as a result its temperature drops from 4 to 5. The cold air at state 5 is supplied to the cabin. It picks up heat as it flows through the cabin providing useful cooling effect. The power output of the turbine is used to drive the fan, which maintains the required air flow over the air cooler. This simple system is good for ground cooling (when the aircraft is not moving) as fan can continue to maintain airflow over the air cooler [6].

3. PROCESS

The process of the system can be cleary understood by Fig. 2. The only that has to be kept in mind is that air before moving to blower passes throgh the air filter which is used outside of the system before the inlet pipes.

It is to avoid entry of any unwanted pollutant in system.

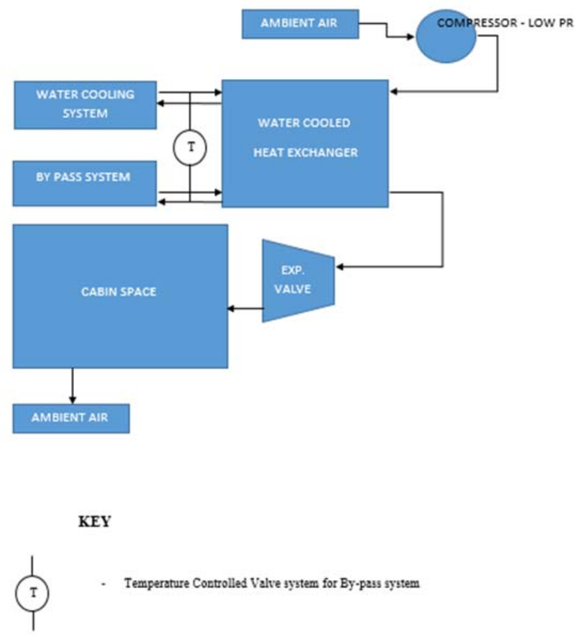

Fig. 2: Flow Process

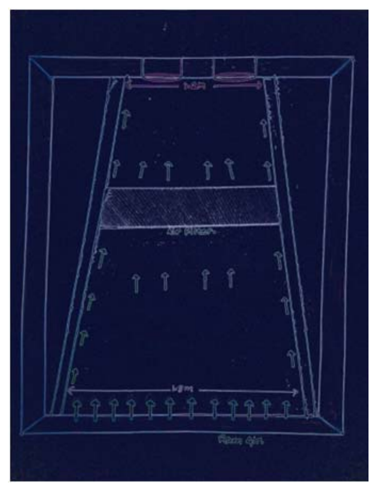

Fig. 3: Modification at roof top

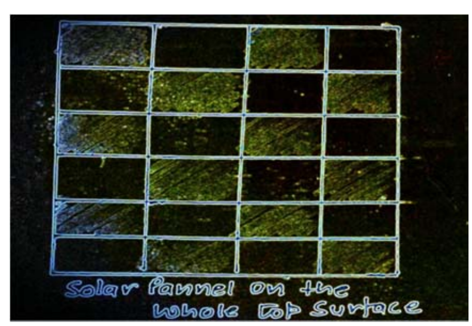

Fig. 4: Power source of our system

3.1 Process Description

Process of cooling inside the bus will begin when the bus begins to move. Due to the relative motion of the bus and air ram effect comes into play in which pressure increases temperature decreases

1. After getting ram air from the roof top arrangement, it will move to the *low pressure ratio compressor* [2].
2. *Solar panels* [1] are used to generate energy for the system that is generated at the roof of the bus. That has an arrangement of trapezium with solar panel over its surface.
3. Getting enough power from the solar cells, *compressor*[2] starts its working.
4. Then this air will be taken to *water heat exchanger* [3] which will be cooled by utilizing cooled water.
5. The cooled water for cooling the air in water heat exchanger is taken from the cooling water tank.
6. This cool air is then taken to the *expansion valve* [4] for getting drop in pressure which is accompanied by the drop in temperature.
7. This expanded air at low temperature and pressure is then moved to *nozzle* [5] which transfers it inside the bus from the bottom side.
8. *Nozzle* [5] is used because it will further expand the air before transferring it to the cabin which will make temperature drop further.

Fig. 4. Modelled system

4. APPARATUS

The model can be seen in Fig. 4 above. Process starts from the modification of the existing design in which height, roof and back seats of the bus are to be modified. This setup consists of several changes in the working design of vehicle.

Following is the setup:

1. We will be reducing the height of the bus a little bit so as to utilize the upper portion for our main setup.
2. This setup consists of *solar panels*[1], diffuser arrangement at the top of the bus.
3. At diffuser entry only *air filter*[7] used.
4. The entrance of the passenger will be lowered so that we get a sufficient height for our arrangement at the roof top.
5. The back portion will be made slightly shorter (by 2m approx) so that we could utilize that space for our setup.
6. A cool water tank is there to pump water continuously to the water heat exchanger.
7. A by-pass system same as main cool water tank is used so as to maintain the supply of water all the time in case the water of main tank get heat up.
8. Two small tanks for both the water supply tanks are used (separately for both) in order to receive the hot water from heat exchanger and cool it and pump it again to the main tanks.
9. The tanks are equipped with thermal sensors so that water supply from particular tank can be cut as it sense the rise in temperature from the required margin.
10. Other machinery equipments like *Compressor*[2], *heat exchanger*[3], *expansion valves*[4] are arranged in such a manner that we could easily initiate the process.

5. CALCULATION

Note: We are using the apparatus in the roadways buses.

The major assumptions that are made at this preliminary stage are as follows:

1. Bus will be standing at its origin point for about four hour before the scheduled departure in the day time so that solar cells get charged by required amount so as to supply the sufficient power.
2. The bus will take about 2 hour to reach to its destination.
3. The water temperature in the cool water tank can be maintained for about 2 hour if it supplies water continuously to the *heat exchanger* [3].
4. Expecting the drop of two to five degree Celsius in *automatic expansion valve* [4] and further the same amount of drop from *nozzle* [5].

5. The calculation is mainly divided into three parts which are likewise:

5.1 General

Taking road transport as the bus and doing calculation for that

5.1.1. Given (from the relevant sources): *Ambient pressure (p)* [8] =1.0325 bar or 101325 pa

Average Speed of the bus (v) [9] =10m/s

Density of the air (ρ) = 1.275kg/m^3

Average Speed of air [10] *(day-time mainly-v_a)* =3.3m/s

Height of bus from its floor (H) [11,24] = 2.5m

Diameter of the pipe at air inlet(d) = 1m

Compressor height from bus floor (h_{b1}) =1m

Compressor depth from bus roof top(h_{b2}) =1m

Pressure ratio of low level compressor taken

[r= (p_{b2}/ p_{b1})] [2] =1:3

Acceleration due to gravity (g) =9.81m/s^2

5.1.2. Solution: Pressure on air at entrance into system (p_e) =*ρgH*[12]= 31.26pa **….. (1)**

Pressure on air at inlet of blower (p_{b1}) = *$\rho g h_b$*[12]= 18.76pa **….. (2)**

5.1.3. Assuming- h_b that is height of compressor inlet for incoming air from bus floor as 1.5m and taking height of the compressor(device height only) as 500mm

Pressure at the outlet of the compressor (p_{b2}) =p_{b1}*(r) =56.28pa**….. (3)**

Total Ram air velocity(v_r) =v+ v_a =13.3 m/sec**….. (4)**

(using *relative velocity equation* [13])

5.1.2. Assuming- Air enters as *ram air*[6] *inside the compressor* so it's velocity at *compressor* inlet is v_r

Velocity at the outlet of the compressor after getting increment in pressure (v_b) = *Using Bernoulli's equation*[24] = 11.29m/s **….. (5)**

Bernoulli's equation:$(p_{b1}/\rho g)+(v^2_r/2g)+h_b = (p_{b2}/\rho g)+(v^2_b/2g)+h_{b1}$

Diameter of the blower outlet pipe(d_b)= *Using continuity equation*[25]= 1.08m **….. (6)**

Continuity Equation: $[(\pi/4)*(d^2)]* v_r=$

$[(\pi/4)*(d^2_b)]*v_b$

5.2 Power & Discharge

Dimensions of the trapezium type diffuser to be used by us for air intake:

Perpendicular length of the trapezium (l) =9m

Length of small parallel side (b_1) = 1.8m

Length of large parallel side (b_2) = 2.5m

Perpendicular height to be given to trapezium to get sufficient volume of air (h) = 0.25m

5.2.1. Solution: Area for use of solar-panel(A)= l*b_1=16.2m^2**…..(7)**

The average-sized solar panel takes up an area of ***17.6 square feet*** *and produces* ***265 watts*** *under direct sunlight. That translates to just over* ***15 watts*** *per square foot.* [14]..... **(8)**

As we know, 17.6 square-feet = 1.635 m^2 (taking it as 1.625m^2 for easy calculation)

Hence we can see the calculated area in **eq (7)** is 10 times the area given in **eq (8).** Therefore the power generation will be about 2650W **…..(9)**

Since, average size of solar panel for commercial use is 77"X39" [15]

And 77''=1.95m ~2m and 33''=0.99m~1m

Therefore for the given dimension of l & b_1 we

require to use about **4 panels** which will generate

10.6 kw of power (on multiplying eq (9) with 4)

…... (10)

And an average sized low pressure ratio

compressor consumes about ***2kw*** *of power* [16]

……(11)

Volume (discharge) of air coming inside through

inlet pipe (Q) = $[(\pi/4)*(d^2)]* v_r$

=10.44m^3/s **….. (12)**

(Using eq (4) and *discharge equation* [17])

DC Battery rating for the power supply connected to

solar panel and storage=24 volt (that is two batteries

are used of the same rating)

5.3 Water tank

Tank used is cube type the water inside. Its height kept as 0.05m.

The tank is made up of *asbestos because of its poor thermal conductivity* [18], from outside and inside it has steel cover so as to maintain the temperature of water at desired level..

Height of the tank (h_t)= 0.5m

Volume of water tank=h^3_t=0.125m^3

Temperature at which water kept inside (T_w) =

25°C or 298K **…..(13)**

The same specifications are for by-pass water tank.

5.4 Temperature drop

Atmospheric temperature [26] (T) =

40°C or 313 K..... **(14)**

Ram Air temperature [21] (T_r) =T+ [(v^2/2000)*C_p] =

313.050 K or 40.05 °C **…..(15)** (from eq (14))

Where,

C_p (Specific heat of pressure for air) =

1.005 kJ/kg k

1degree Celsius=273 K

Temperature of the air coming out from compressor

(T_b)=T_r*(r)$^{[(n-1)/n]}$[20]= 51.60°C **…..(16)**

Water and air heat exchanger details:

Effectiveness (ε) [21] =0.5 **…..(17)**

Formula to be used for calculating temperature

coming out of heat exchanger ε ={T_1-T_2/T_1-T_3} [21]

Where,

ε=0.5=Effectiveness of air and water heat

exchanger.

T_2=T_{aw}=Temperature of the air coming out from

water heat exchanger.

T_1=T_b=Temperature of air coming from

compressor.

T_3=T_w=Temperature of water from cool water tank

5.4.1 Solution: Using equation 13,16 and 17 in

effectiveness formula of water heat exchanger so:

T_{aw}= 38.3 °C **…..(18)**

Now air is moved *to automatic expansion valve* [4]

so we can assume a drop of 2°C or more for air

T_e= 36.3 °C **…..(19)**

Moving the air at T_e to the nozzles which are used on the floor of the bus before passengers cabin so as to *spray the air which will give further reduction in the temperature surely* [5]. Let the final temperature be **T_{cool}. ….. (22)**

5.5 COP(Coefficient Of Performance)

= refrigeration effect / work done [22]

Using equation 15, 16, 19 and 22 we get,

COP= 0.5**…..(23)**

(Let **T_{cool}** be 30.3°C after exiting from nozzle)

6. CONCLUSION

It is clear from the above preliminary calculation that the temperature drop for the cooling purpose can be achieved without the use of any refrigerant and compromising with the performance of engine. As the drop of 4°C in temperature proves it. The process has also been proven experimentally the model of the carried out experiment can be seen in Fig. 5.

The value of COP obtained is on the basis of some assumption as it is only preliminary calculation which shows that there is still need of emphasizing on some area for proving it in reality. The concentration should be given to modification of the system, the initial modification for the intake of air in the road transport required at the roof-top has been shown in Fig. 3 so for further modification the cost should also be kept in mind since it will add up to it, as there is already the use of some costly equipments like solar panel, heat exchangers, compressor, expansion valves and etc.

The reliability of the system on the weather has been tried to reduce up to some extent by the use of a storage battery which will work as a backup source for running the system at the time of dim weather.

And around the world it has become the hot research topic because of the significant climate change every year, major and important steps has been taken and are also needed to be taken to achieve the proper balance in our environment.

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