Automobile Air Conditioning system Using waste heat of Exhaust Gases

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DEPT. OF MECHANICAL ENGINEERING

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- VAR System in Automobiles.
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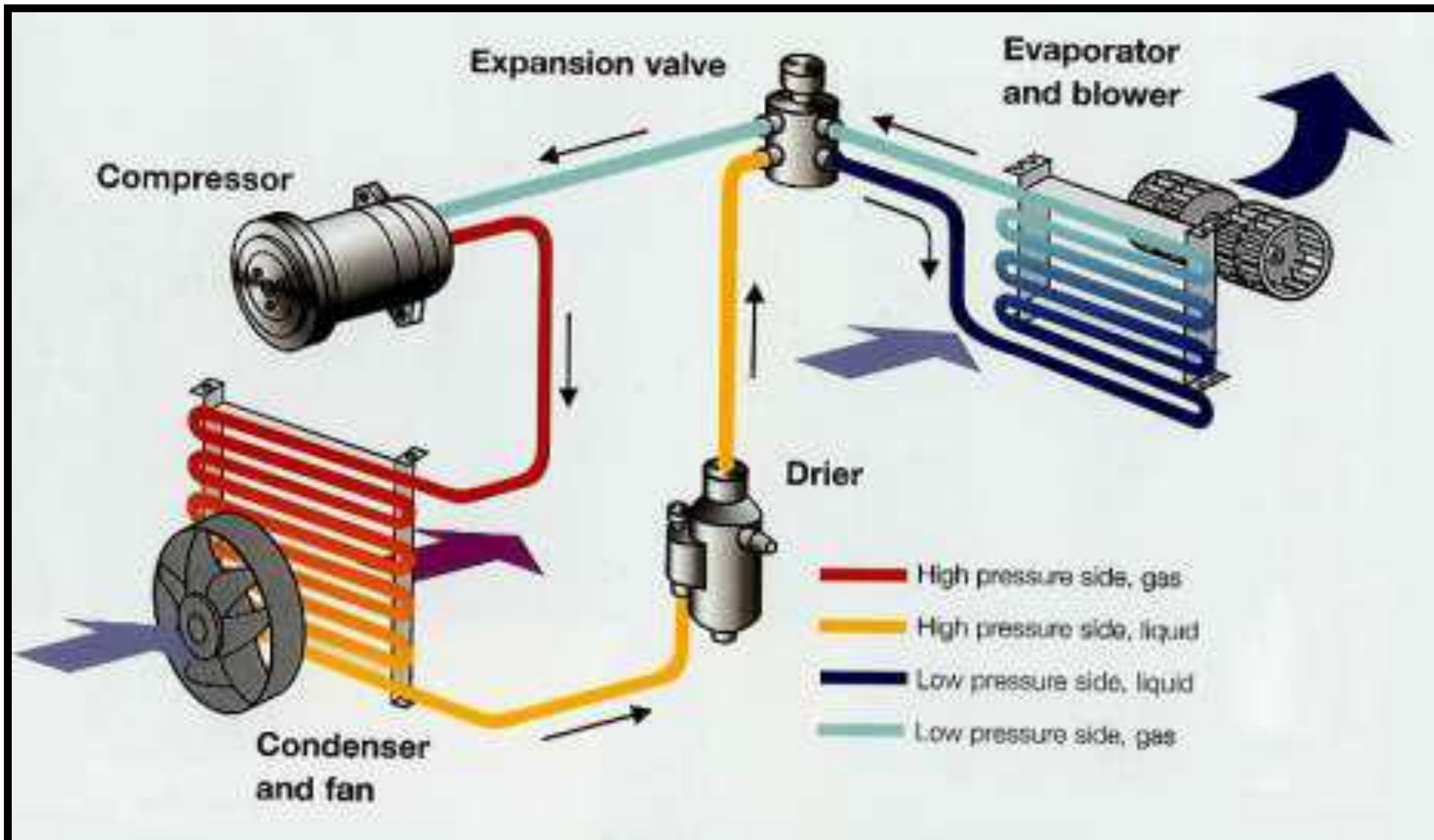
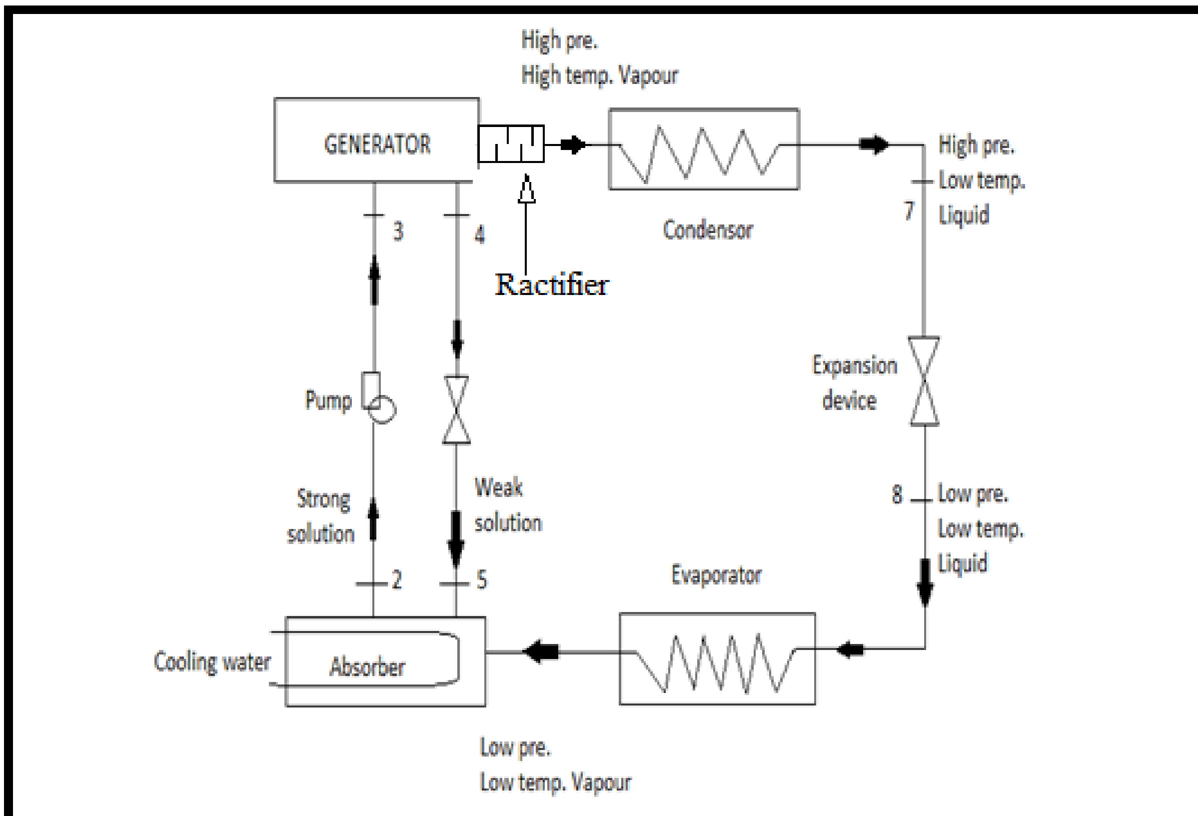
Vapour Compression System in Automobile



Vapour Absorption System in Automobile



Comparison between VAR & VCR

Vapour Absorption Cycle	Vapour Compression Cycle
➢ It uses low grade heat energy therefore, it can operator on exhaust from I.C. engines or on kerosene lamp or an process heat.	➢ It uses high grade work energy . It needs electrical energy for its operation.
➢ It has pump only as moving part, hence, It is quiet in operation.	➢ It has compressor & motor. Therefore, it is noise in operation.
➢ Wear & tear is less.	➢ Wear & tear is high.
➢It has low COP.	➢ It has high COP.
➢ Charging of refrigerant is difficult.	➢ Charging of refrigerant is simple.

Vapour Absorption Cycle	**Vapour compression Cycle**
➢ Possibility of leakage is very little.	➢ Possibility of leakage of refrigerant is more.
➢ Reduced load have no effect on its performance.	➢ Performance is adversely affected on part loads.
➢Liquid traces in the refrigerant at exit of evaporator is not harmful to any component.	➢ Liquid traces in the suction line may damage compressor.
➢ It can be located outdoor without shelter.	➢ It can not be located outside without shelter.
➢ It is bulky.	➢ It is less bulky.

TEMPERATURE READING OF VARIOUS CAR ENGINE AT DIFFERENT RPM

RPM		1000			2000			2500		
1100CC	Time	1m	2m	3m	1m	2m	3m	1m	2m	3m
Petrol	Temp. C	33.7	37.4	43.6	40.8	46.9	54.5	-	-	-
1400CC	Time	1m	2m	3m	1m	2m	3m	1m	2m	3m
Petrol	Temp. C	34.4	39.6	43.6	47.4	53.3	62.5	50.8	58.7	67.9
1717CC	Time	1m	2m	3m	1m	2m	3m	1m	2m	3m
Diesel	Temp. C	36.5	42.3	52.9	54.7	60.2	69.8	-	-	-

Engine Parameters

- Let us consider an engine of an automobile on which the vapour absorption refrigeration system is to be implemented.
- Manufacturer - Hindustan Motors
- Model - Ambassador
- No of cylinders, n = 4.
- Power, P = 60 bhp at 2000 rpm.
- Capacity = 1717cc.
- No of strokes = 4.
- Fuel used = Diesel.
- Air-fuel ratio, A/F =15:1

WASTE HEAT OF THE ENGINE

- The main two areas through which the heat is exhausted into the atmosphere from the engine are the cooling water and the exhaust gases. It is necessary to calculate the amount of heat energy carried away by the exhaust gases and the cooling water.

Exhaust gas heat

- Volumetric efficiency of the engine, E_{vol} = 70%.
- Rated speed, N = 2000 rpm.
- Mass flow rate of air into the cylinder,

$$m_a = VN\ E_{vol} / 2$$
$$= 0.001717 \times 2000 \times 0.7/2$$
$$m_a = 0.02 m^3/s.$$

- Mass flow rate of fuel, $m_f = m_a/(A/F\ ratio) = 0.02/15.$

$$m_f = 0.001335\ kg/sec$$

- Total mass flow rate of exhaust gas,

$$m_e = \mathbf{m_a + m_f} = 0.021335\ kg/s.$$

- Specific heat at constant volume of exhaust gas

$$Cp_e = 1\ kj/kgK$$

- Temperature available at the engine exhaust,

$$t_e = 300\ C.$$

- Temperature of the ambient air, $t_a = 40\ C$
- *Heat available at exhaust pipe*

$$Qe = m_e Cp_e\,(te - t_a)$$

$$= 0.021335 x l x (300-40)$$

$$\mathbf{Q_e = 5.5 kW}$$

Cooling Water Heat

- Temperature of water entering the cooling water jacket $t_cj = 68^0C$
- Temperature of water exiting the cooling water jacket, t_{co} = 54°C.
- Mass flow rate of water for a 4 cylinder diesel engine, $m_w = 0.1$ kg/s.
- Specific heat of water,

$$Cp_w = 4.18 \text{ kj/kgk}$$

- Heat carried away by cooling water

$$Q_w = m_w Cp_w (t_cj - tc_0)$$

$$= 0.1 x 4.18 x (68-54)$$

$$= 5.852 \text{ KW}$$

FINAL VALUE OF HEAT

- Heat available at exhaust gas = 5.5 kW
- Heat carried by cooling water = 5.852 kW

COP Calculation

- Taking Temperatures of the system as given below,
- Temperature at generator, t_g = 100 C
- Temperature at Condenser, t_c = 40 C
- Temperature at Evaporator, t_e = 10 C
- Temperature at Absorber, t_a = 35 C

- COP of a vapour absorption system

$$COP = (Te/(Tc-Te))((Tg-Tc)/Tg)$$
$$= (10/(40-10))((100-40)/100)$$
$$= 0.2$$

FINAL VALUES OF COP

- To produce 0.5 TR inside the automobile cabin it is required to have,
- mass flow rate of refrigerant, **m_r = 0.71 gm/s**
- mass flow rate of strong solution from absorber to generator, **m_g = 8.804 gm/sec**
- mass flow rate of weak solution from generator to absorber, **m_a = 8.094 gm/sec**
- Co-efficient of Performance, **COP = 0.2**

Generator

- It is basically a container where the solution is maintained at constant level. The exhaust pipe is passed through it and its heat is extracted in the generator. It has two exits and an inlet. From the two exits, one is for the flow of refrigerant to the condenser and the other for the flow of solution back to absorber. The exhaust pipe passing through the generator is made of copper while the other components are made of steel.

- ## Dimensions of the designed generator:-

Outside Diameter of the exhaust gas tube,

$\mathbf{D_0}$ = 0.04 **m**

Taking inside diameter of the exhaust gas tube,

D; = 0.038 **m**

Length of the tube required for the required heat transfer,

L = 1 m

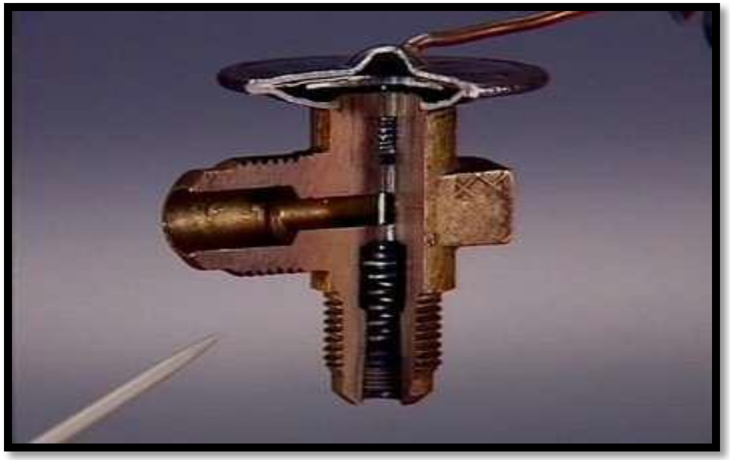
Condenser

- Usually the condenser of an automobile is of an oval cross-section. It is made of aluminum to have easy transfer of heat from the refrigerant coming from generator to the atmosphere.
- A large number of fins are provided to increase the surface area and thereby increase the heat transferred from the refrigerant to the atmosphere.

- Dimensions of the designed condenser
- Width of the tube, **b = 0.018 m**
- Thickness of the tube, **a = 0.005 m**
- Length of the tube, L = 7**.45 m**

Expansion valve

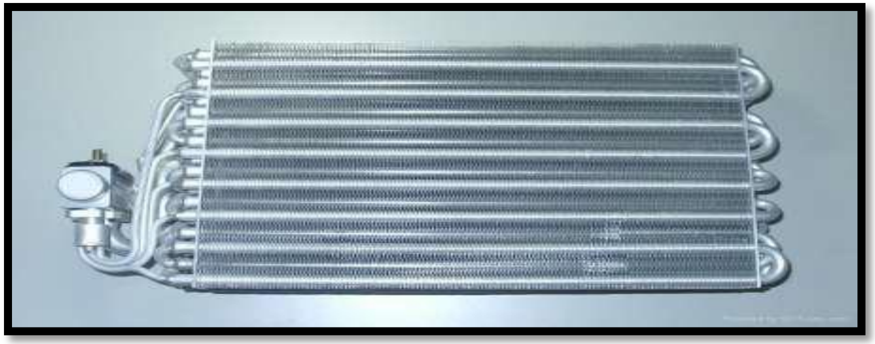
- A needle valve is used to drop the pressure of the refrigerant from high pressure to low pressure side. A needle valve can be easily adjusted to obtain the required pressure within the system.



Evaporator

- The refrigerant from the expansion valve enters the evaporator where the cold refrigerant absorbs heat from the surroundings. To have maximum heat transfer from surroundings to the refrigerant the evaporator is made of copper tubes.

- Dimensions of the designed evaporator:-
  - Outside Diameter of the tube, $\mathbf{D_0}$ = 0.01 **m**
  - Inside Diameter of the tube, **Di** - 0.008 **m**
  - Length of the tube, L = **6.26 m**



Absorber

- This is the container which has two inlets, one for the refrigerant coming from the evaporator while the other for the weak solution coming from the generator. The one exit is for pumping the solution to the generator. It has a perforated sheet to strain the solution coming from the generator to have a proper mixing of the weak solution with the refrigerant coming from the evaporator. Fins are provided around the container to increase the surface area, to remove the heat developed during the mixing of the refrigerant and the weak solution.

- Dimensions of the designed absorber:-
- Outside diameter of the absorber, D_o = 76 mm
- Total length of the absorber, L = 205 mm
- Outer diameter of the fins, D_f = 109 mm
- No. of fins, n = 7

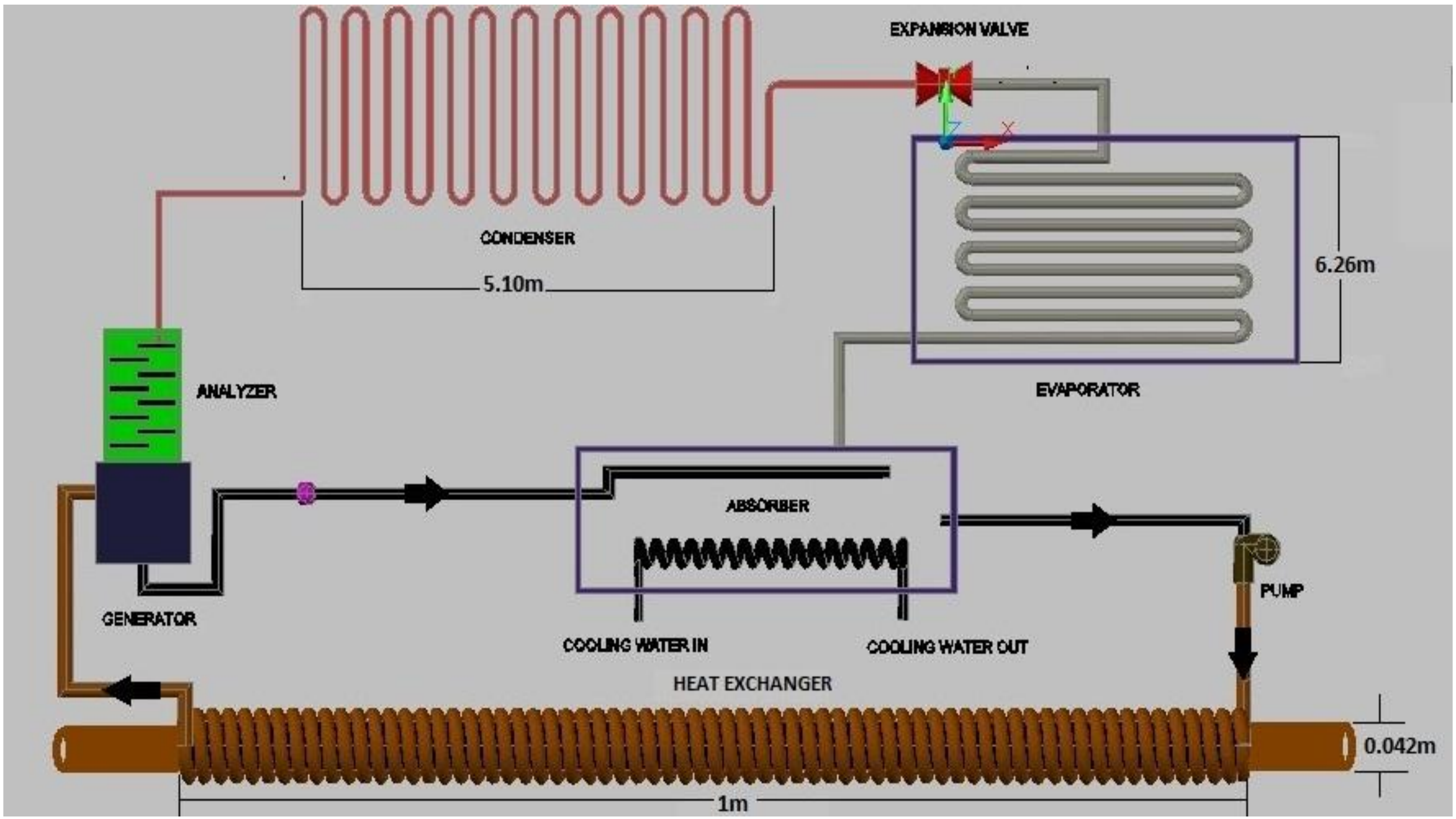
Pump

- Since the system is small the flow rate required is also small. Hence a fuel pump is used to pump solution from the absorber to the generator. The power to run the pump is derived from the engine battery.

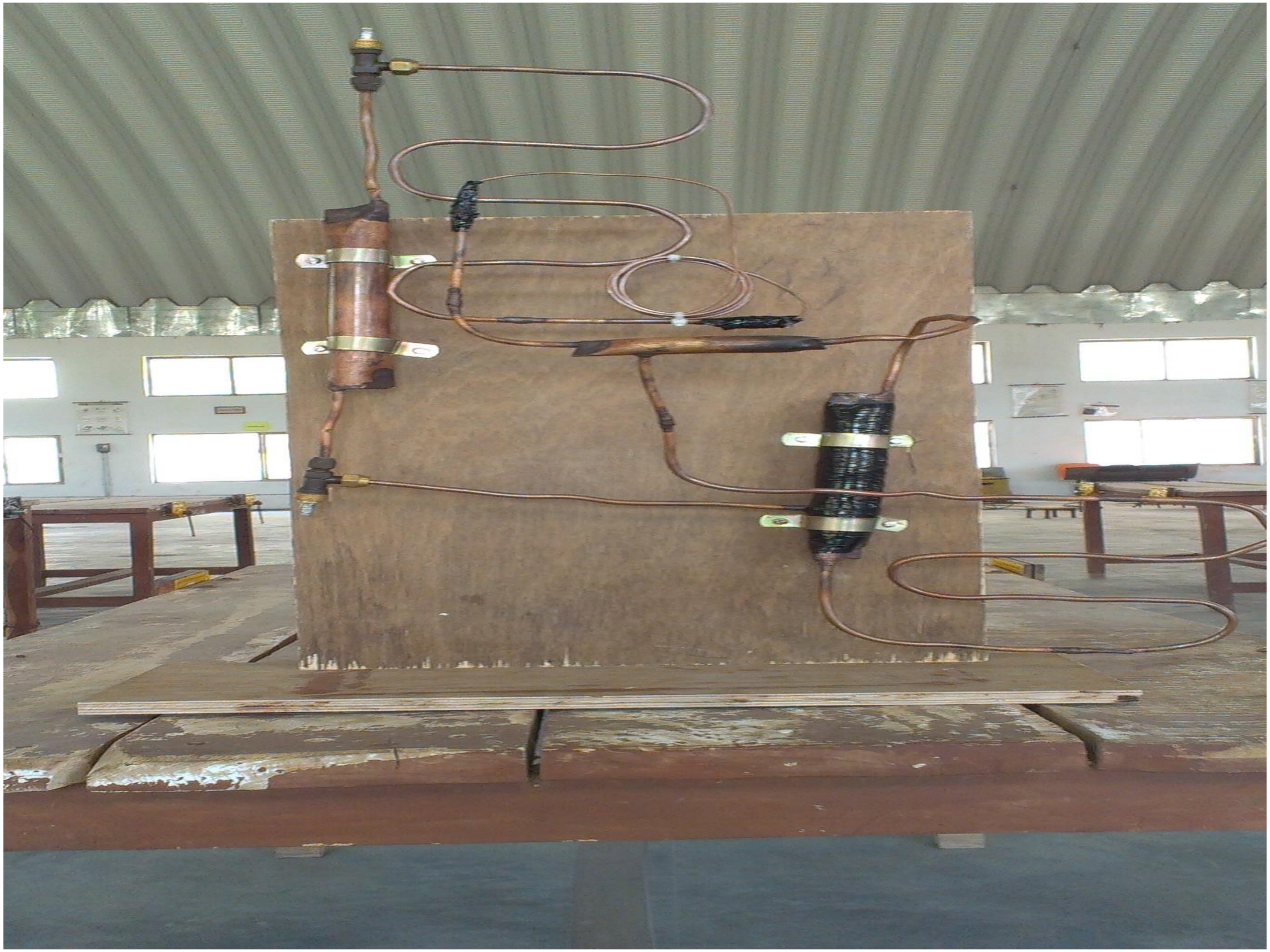
Control valve

- This is placed in between the generator and the absorber to bring the solution pressure from high pressure to low pressure. The control valve may be another needle valve which could also be used to control the flow rate of the weak solution back to the absorber.

Diagram of VAR System With Designed Components



Experimental Setup



Conclusion

- With all the designed components it is possible to install a vapour absorption refrigeration system in an automobile working using the waste heat of the vehicle engine to produce refrigerating effect inside the automobile cabin. Using a vapour absorption refrigeration system within an automobile as an air conditioner will not only reduce the fuel consumption of the vehicle while working but will also provide many other advantages.

- **Advantages:**
- No dedicated IC engine is required for the working of the refrigerating unit.
- No refrigerant compressor is required.
- Reduction in fuel consumption.
- Reduced atmospheric pollution.

- **Disadvantages:**
- The refrigerating effect produced using a Vapour Absorption Refrigeration System is less compared to a Vapour compression Refrigeration System.
- It takes more time to getting cooling effect compared to Vapour Compression System.

THANK YOU