# Engine Cooling Through Engine Exhaust

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**Abstract:** ***IC engine cooling uses either air or a liquid to remove waste heat from an internal combustion engine. Cooling is important because as whole engine fails if just one part overheats. Only 35% energy obtained from fuel is converted into useful work. Present work on paper is to design a engine cooler by using waste heat which obtained from engine exhaust. The process which used for cooling is vapor absorption refrigeration system (VARS).For good result and simple design we used $NH_3$-$H_2O$ as refrigerant mixture. The aim is to obtained better engine cooling by using waste heat of IC engine.***

**Keywords:** VARS, Engine Exhaust, Engine Cooling

## 1. Introduction

IC engine cooling is important because high temperature in cylinder damage engine material and lubricants. Cooling becomes very important when surrounding temperature of the chamber becomes very hot. Engine cooling set temperature low such that engine can survive. Engine cooling done by the water or coolant. Also there are two methods of cooling by natural convection or by forced convection. Natural convection is due to density difference and forced convection is done by external power supply.

Refrigeration is process of removing heat from enclosed controlled space . The primary objective of the refrigeration is to maintain the temperature less than surrounding temperature. The basic objective of developing cooling system is to cool engine by using engine exhaust. For cooling we are going to use vapor absorption cooling system. IC engine has an efficiency of about 35%-40%.Which means that only one-third of the energy in the fuel is converted into useful work and about 60%-65% is wasted to environment. In which 28%-30% is lost by cooling and around 32% lost by exhaust gases. The heat required for vapor absorption system can be obtained from the waste gases of IC engine.

## 2. Working Principle

The principle of cooling works on vapor absorption refrigeration system (VARS). Also cooling water is provided in condenser and absorber to carry out heat. The radiator is used as condenser and cold water is circulated in water jacket as shown in Fig.(2). There are four main components of VARS.

1) Absorber
2) Generator
3) Condensor
4) Evaporator

The main advantage of VARS over VCRS is VARS uses low grade energy and can work on lower evaporator pressure without affecting COP.

In this process we used Aqua-Ammonia solution as refrigerant because of following advantage and properties -

**Advantage**

1) Ammonia has high solubility in water.
2) Having large difference in their boiling point and it is greater than 200 $^0$C
3) It exhibit small heat of mixing so that high C.O.P can be achieved
4) It has high thermal conductivity.
5) It has low viscosity.
6) Low melting point.
7) It is non corrosive and chemically stable.

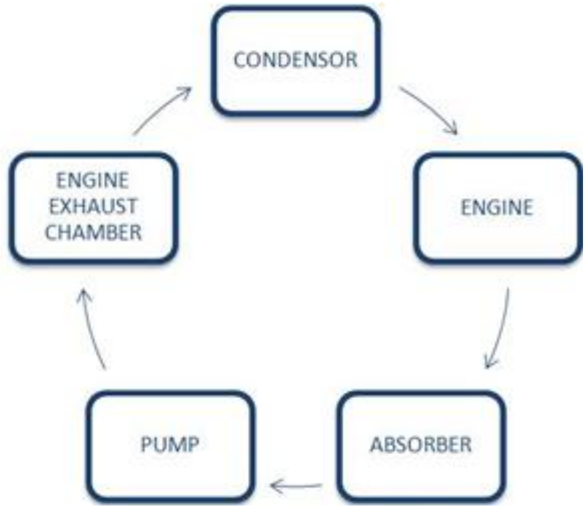



**Figure 1:** Process of a Engine cooling process

The above Fig.(1) shows the working cycle of the VARS cooling system for Engine cooling through its exhaust. Fig.(3) shows schematic diagram of a VARS .There is around 60% - 70% waste heat obtained from exhaust gases. This heat can be regained from exhaust gases.

In fig.(2) is shows that the exhaust temperature that can be obtained for different engine rpm and engine load. We assume 3500 RPM and 50% load. Generator is connected to the exhaust system such that heat Qex easily transfer to the generator without any loss.

| NO. | ENGINE LOAD | ENGINE SPEED (RPM) | EXHAUST TEMP. (°C) | AVG.TEMP. (°C) |
|---|---|---|---|---|
| | | | | |
| | 25% | | 155 | |
| 1. | 50% | 2500 | 183 | 181 |
| | 75% | | 205 | |
| | 25% | | 199 | |
| 2. | 50% | 3000 | 218 | 220 |
| | 75% | | 243 | |
| | 25% | | 234 | |
| 3. | 50% | 3500 | 261 | 262.3 |
| | 75% | | 292 | |
| | 25% | | 278 | |
| 4. | 50% | 4000 | 282 | 288.4 |
| | 75% | | 305 | |

**Figure 2:** Engine load vs Engine speed vs Exhaust temperature

Ammonia vapor is produced in the generator at high pressure from strong solution of NH3 by an heat obtain from exhaust source. The water vapor carried with ammonia is removed in the rectifier and only dehydrated ammonia gas enters into the condenser. High pressure ammonia is condensed in condenser. In condenser or radiator cooling water is circulated through pump as shown in fig.(3).Due to heat exchange in between ammonia and water the temperature of cooling water increase. The cooled NH3 solution is passed through a expansion valve and the pressure and temperature of the refrigerant are reduce below the temperature to be maintained in the evaporator. Then cooled ammonia passes through heat exchanger. In heat exchanger the cooling water is cooled down and pass it to reservoir.

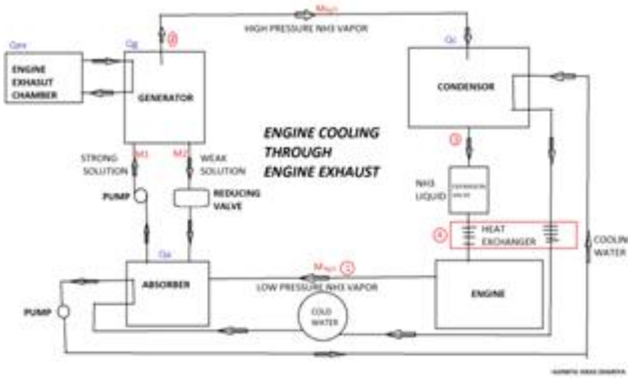



**Figure 3:** Schematic diagram of Engine Cooling through Engine Exhaust

The low temperature refrigerant enters the evaporator. In this case evaporator is engine cooling system. It absorbs the required heat from the engine and leaves the engine as saturated vapor. Slightly superheated, low pressure NH3 which is sprayed in the absorber.

Weak NH3 solution entering the absorber becomes strong solution after absorbing NH3 vapor and then it is pumped to the generator .The pump increases the pressure of the strong solution to generator pressure. The heat is carried out in absorber by using cooling water as shown in fig.(3).The pump is used to circulate cool water. The strong solution of NH3 coming from the absorber absorbs heat form high temperature weak NH3 solution in heat exchanger. The solution in the generator becomes weak as NH3 vapor comes out of it. The weak high temperature ammonia solution from the generator is passed through throttle valve. The pressure of the liquid is reduced to the absorber pressure by throttle valve as shown in fig.(3).Hence cycle is completed.

## 3. Design and Calculation

Assume generator temperature is same as exhaust temperature. Also assume engine RPM of 3500.

Qex-262.3 $^0$C
Therefore,
Qg - 262.3 $^0$C

Atmospheric temperature is 35$^0$C
Qc - 35 $^0$C

Evaporating temperature is -20$^0$C
Qe - -20$^0$C
Qa- 40$^0$C

We are going to use Aqua ammonia solution as refrigerant in VARS.
Assuming 100% pure $NH_3$ saturated at 40$^0$C
At absorber exit
From aqua-ammonia refrigerant chart,

| *No.* | *Solution* | *Concentration (x)* | *Enthalpy (h-kg/kg)* |
|---|---|---|---|
| 1. | Strong | 0.35 | 22 |
| 2. | Weak | 0.1 | 695 |

At 40$^0$C
From Aqua-Ammonia refrigerant chart,
$h_2$ - 1473.3 Kj/Kg Saturated vapour
$h_3$ -371.9 Kj/Kg Saturated liquid

At -20$^0$C
$h_1$ - 1420 Kj/Kg

Heat carried by exhaust gases- 36571.2 Kj/h
Heat supplied - 134400 Kj/h
For an IC engine heat lost in cooling medium is around 45144 Kj/h.
Therefore required refrigeration effect is 3.5 tonne.

1. Mass flow rate of Ammonia in the evaporator (M) -

Re = $(h_1 - h_4)$
= $(h_1 - h_3)$
= 1420 - 371.9
= 1048.1 Kj/Kg

$$M = \frac{14000*9}{3600*1048.1}$$
= 0.0334 Kj/s

2. Overall mass conservation and mass conservation of ammonia in absorber -

Overall mass balance for absorber is give as-
M + M2 = M1

$NH_3$ balance for absorber

$M + 0.1\ M2 = 0.35\ M1$
$= 0.35\ (M + M2)$

$$M2 = \frac{M(1 - 0.35)}{(0.35 - 0.1)}$$

$$= \frac{0.0334(1-0.35)}{(0.35 - 0.1)}$$
$= 0.0868$ Kg/s

$M1 = M + M2$
$= 0.0334 + 0.0868$
$= 0.12$ Kg/s

3. Making energy balance for absorber -
$M\ h_1 + M2\ h_2 = M1\ h + Qa$
$0.0334*1420 + 0.0868*695 = 0.12*22 + Qa$
$Qa = 105.11$ Kj/s

Making energy balance for generator-
$M1\ h_1 + Qg = M2\ h + M\ h_2$
$0.12 * 22 + Qg = 0.0868 * 695 + 0.0334 * 1473.3$
$Qg = 106.88$ Kg/s

$Qc = M\ (h_2 - h_3)$
$= 0.0334\ (1473.3 - 371.9)$
$= 36.79$ Kj /s

4. Coefficient of performance-
$$C.O.P = \frac{Re}{Qg}$$
$= 0.327$

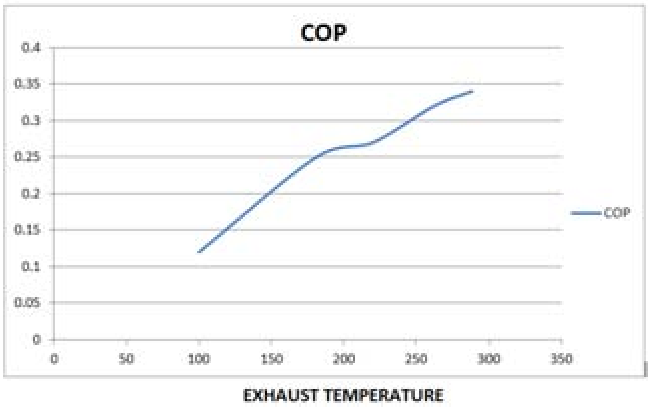
For different engine rpm, engine load and exhaust temperature different values of COP obtain. As shown below in table no. (1)

| *Engine Speed (rpm)* | *Engine Load (%)* | *Exhaust Temperature ($^0c$)* | *COP* |
|---|---|---|---|
| 2500 | 50 | 181 | 0.25 |
| 3000 | 50 | 220 | 0.27 |
| 3500 | 50 | 262.3 | 0.32 |
| 4000 | 50 | 288.4 | 0.34 |

## 4. Component Design

1) **Absorber**
According to specified design segments we used 3ltr mild steel cylinder and done welding, drilling on that. We add thermocouple in that to measure the absorber temperature.
2) **Generator**
The generator is made from 3ltr mild steel cylinder. In which heat is added from engine exhaust from brass pipe.To measure generator temperature we add another thermocouple in it and done proper brazing.
3) **Condensor**
We used Maruti 800 radiator as condenser because it matches required specification. We joined cooling water pipe to it.
4) **Evaporator**
In this case engine acting as evaporator. the output pipe obtained from condenser is passed through engine cooling lines to carried away its heat.
5) **Heat exchanger**
The efficiency is greatly affected by the enthalpy of solution which entering in generator and temperature which entering in absorber. The proper Heat exchanger must be used for it. Depending on requirement we used simple two way heat exachnger.
6) **Pump**
We used 12w DC pump that is used in air conditioner.

**Design Analysis**
The input parameter i.e. Engine speed and engine load varied to obtain different values of COP obtain.




## 5. Conclusion

As proper engine cooling is very much important for smooth working the internal combustion engine we design the engine cooling through engine exhaust by using vapor absorption refrigeration system. We studied how engine cooling affected by engine exhaust. This method will provide good cooling effect. It uses low grade energy and It is pollution free. This is economical and provide efficient engine cooling.

## 6. Definition /Abbreviations

**VARS** Vapor absorption refrigeration system.
**VCRS** Vapor compression refrigeration system

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