Design and analysis of AC system for automobile vehicle using exhaust heat

न हि ज्ञानेन सदृशं पवित्रमिह विद्यते।

Smt. S. R. PATEL ENGINEERING COLLEGE

Gujarat Technical University

Guided By:

Prof. Nitesh Rai

Prepared By:

Panchal Kaushik.P (110780119091)
Prajapati Hitesh.L (110780119087)
Parmar Raju.R (110780119088)
Nayi Jagdish.B (120783119019)

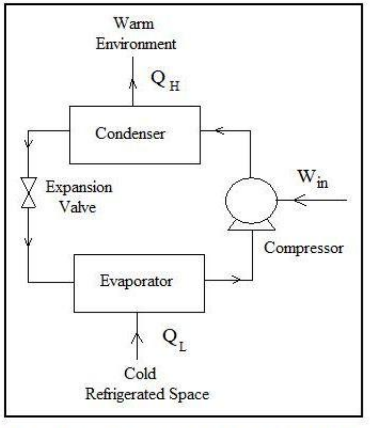
Contents

Introduction

- The refrigerating units currently used in road transport vehicles are

  of VCRS.
- In this system engine has produce extra work to run compressor of the refrigerating unit utilizing extra amount

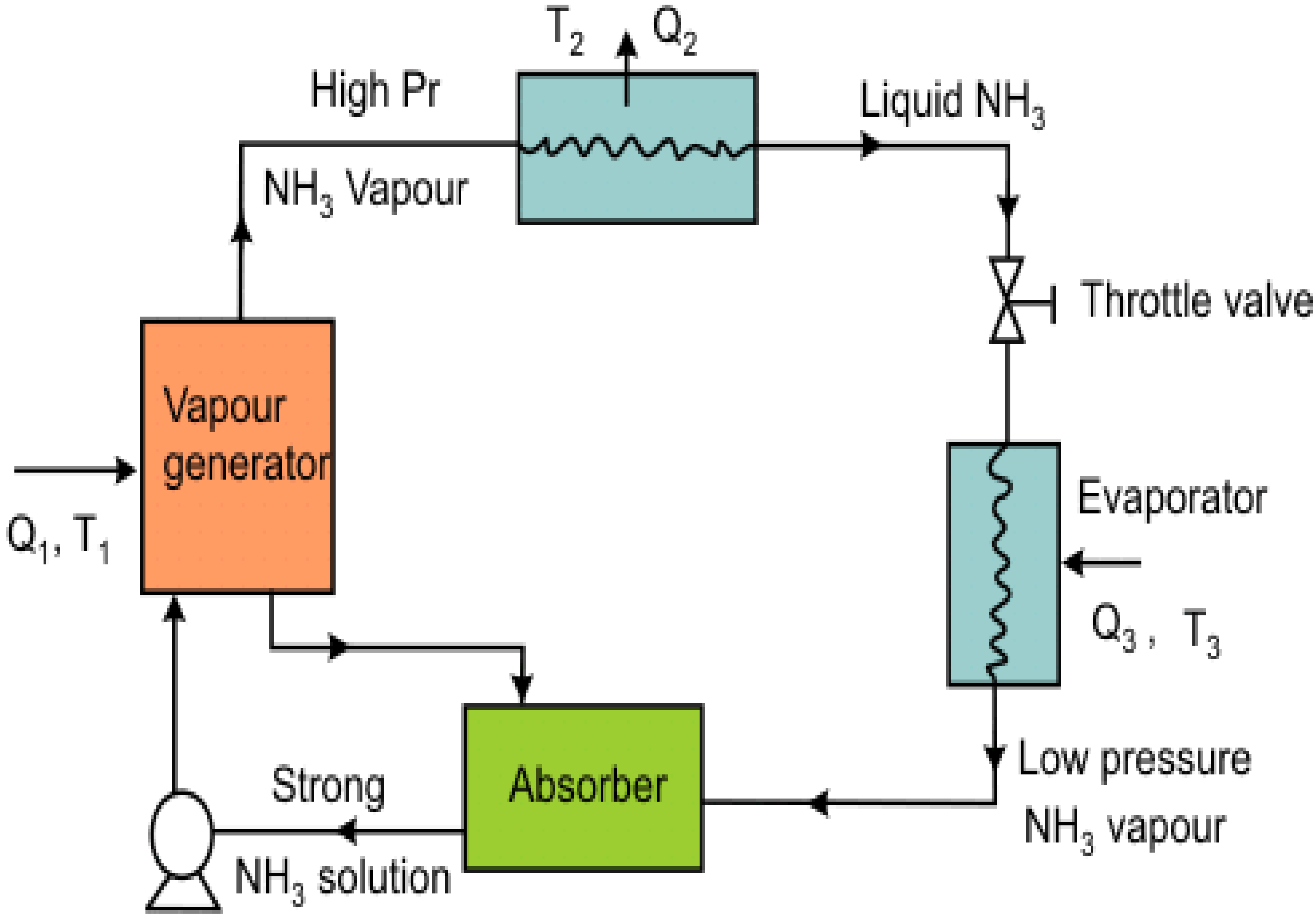
  of fuel.



Vapor Compression Refrigeration Cycle

(Cont..)

- The work done of VCRS can be replace by using some devices like Absorber , Pump , Generator and pressure reducing valve.
- The heat required for running the Vapour Absorption Refrigeration System can be obtained from that which is wasted into the atmosphere from an IC engine.



T_2
Q_2
High Pr
NH_3 Vapour
Liquid NH_3
Throttle valve
Vapour generator
Q_1, T_1
Evaporator
Q_3 , T_3
Absorber
Strong
NH_3 solution
Low pressure
NH_3 vapour

Objective

- To Reduce atmospheric pollution.
- To Reduce maintenance cost.
- Reduction in capital cost.
- Reduction of fuel cost.
- Exclusion of compressor.

Literature Review

Sr.	Title	Investigator	Remarks
1	Performance and Evaluation of Aqua Ammonia Auto Air Conditioner System Using Exhaust Waste Energy.	Khaled S. AlQdah	Ammonia absorbtion cycle should be considered as available alternative to mechanical vapour compression cycle. Flexibility in operation absence of compressor noice,very law maintenance and high reliability.

Sr.	Title	Investigator	Remarks
2	Thermodynamic Analysis of Vapor Absorption Refrigeration System and Calculation of COP	Sachin Kaushik 1, Dr. S. Singh2 Bipin Tripathi	• COP of the system is greatly influenced upon the system temperatures.

Sr.	Title	Investigator	Remarks
3	Thermal Analysis of a Car Air Conditioning System Based On an Absorption Refrigeration Cycle Using Energy from Exhaust Gas of an Internal Combustion Engine	S.LAKSHMI SOWJANYA	• Supplying the Generator of a Vapor Absorption Refrigeration System with the products of its combustion to produce the required refrigerating effect.

Sr.	Title	Investigator	Remarks
4	VAPOUR ABSORPTION REFRIGERATION SYSTEM FOR COLD STORAGE & POWER GENERATION IN AUTOMOBILES USING EXHAUST GAS	SREESHANKAR K. K, VIKAS P L	From VARS system we can produce a cooling effect of 5 C which is suitable for cold storage purposes and thus it can be easily incorporated in heavy automobiles used for such purposes.

Sr.	Title	Investigator	Remarks
5	COOLING OF A TRUCK CABIN BY VAPOUR ABSORPTION REFRIGERATION SYSTEM USING ENGINE EXHAUST	Shekhar D. Thakre1, Prateek D. Malwe	• The COP of ammonia/water system varies from 0.3528 to 0.3113. Hence from the discussion, ammonia/ water vapor absorption system is suggested for the application. • Though the COP of the system is less but since waste heat is given as input, it is not a matter of concern.

Sr.	Title	Investigator	Remarks
6	A REVIEW OF RESEARCH IN MECHANICAL ENGINEERING ON RECOVERY OF WASTE HEAT IN INTERNAL COMBUSTION ENGINE	Vijay chauhan	With the utilization of the wate heat of internal combustion engine the world energy demand on the depleting fossil fuel reserves would be reduced
7	AN AUTOMOBILE AIR-CONDITIONING SYSTEM BASED ON AN EJECTOR REFRIGERATION CYCLE USING HEAT FROM EXHAUST GAS OF AN INTERNAL COMBUSTION ENGINE	Satish k maurya	Hence by using such way of cooling there is no need of additional work input of any additional major modification or construction in the running system rather than that of exhaust heat of engine.

Sr.	Title	Investigator	Remarks
8	VAPOUR ABSORPTION BASED AUTOMOBILE AIR CONDITIONING USING EXHAUST WASTE HEAT OF DIESEL ENGINE THROUGH PLATE AND FRAME HEAT EXCHANGER	1Sohail Bux* and 2A.C. Tiwari	• Balance the fluctuation in cooling capacity of automobile cabin due to changing of speed, traffic Aped and cruse speed.
9	Technologies to recover exhaust heat from internal combustion engines	R. Saidur a	By increasing the exergy efficiency,sustainability index willincreaseandleadstolessproductionofpollutantslike NOx and SO2 duringcreatingthesameamountofpower

Sr.	Title	Investigator	Remarks
10	Review on Exhaust Gas Heat Recovery for I.C. Engine	J. S. Jadhao, D. G. Thombare	For waste heat recovery thermoelectric generator is use low heat, which has low efficiency. It is helpful for the same amount of increases in thermal efficiency and reduction in emission.
11	EXHAUST GAS HEAT RECOVERY SYSTEM FOR I.C. ENGINE	P.R. Ubarhande 1, Saurabh Jagdish Sankhe2	In an attempt to explore the possibilities of waste heat recovery in an IC engine, there are large potentials of energy savings through the use of waste heat recovery technologies

Sr.	Title	Investigator	Remarks
12		Frank etal	During a heat generating apparatus & system for an automobile to use for an absorption air conditioning system including temperature control
13		Robert & frosch	Investigated the automobile air conditioner utilizing the solar &motor waste heat
14		Bing hadi & agraval	La-Br –ZaBr as a working fluid using a computer aided analysis of the thermal system

Plan of Work

Measurement of Exhaust heat

↓

Analysis of VAR cycle

↓

Calculation of heat required for cycle from analysis

↓

design of generator

Theoretical background

- Heat available from engine exhaust
- **Calculated as follows:**
- FP=mf*Cv
- Where , mf=fuel mass flow rate

  Cv=calorific value of the fuel 42000kj/kg

- Taking 12 liter per hour fuel consumption for a 150 BHP engine. The available heat rejected by the cooling system can be expressed

$$Q_{rej}=0.3*mf*Cv$$

$$=34\ kw$$

Conti.

2. Load calculation

- The cooling load required for cabin cooling is calculated by using standard method of load calculation.

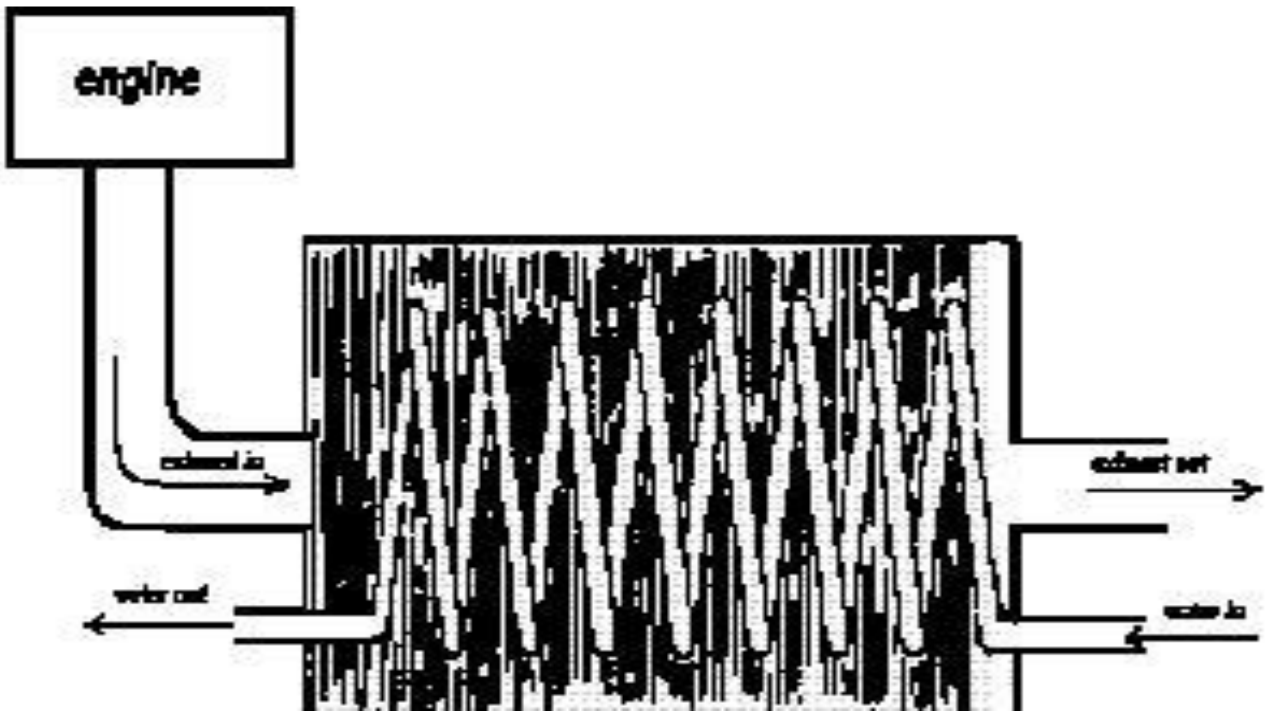
- The various factors of heat load like solar radiation (roofs, walls, glasses) normal heat gain through glass, normal heat gain through wall, air infiltration, number of persons in cabin sensible heat load, Latent heat load can be calculated using ASHRAE Hand book

System observations

Parameter	Value
Cabin Dimensions	$(2\times1.75\times1.5)\ m^3$
Ambient Temperature	$45\ ^0C$
Cabin Temperature without cooling	$50\ ^0C$
Design temperature of cabin	$25\text{-}28\ ^0C$
Solar radiation (roof, walls glasses)	300 kJ/hr
Normal heat gain through glasses	1200 kJ/hr
Normal Heat gain through walls	4300 kJ/hr
Air leakage	1000 kJ/hr
Passenger including driver	1200 kJ/hr
Heat radiated from engine	2000 kJ/hr
Total	10000 kJ/hr

Conti.

- Based on estimated cooling load calculations, the cooling capacity or heat must be removed from the evaporator space is 5 kW or (Q_e = 4.8 kW).
- In order to measure the exhaust waste energy to know the amount of heat that can be utilize by the generator (Q_g).
- Shell and tube heat exchanger has been used.
- Water passed through the tube and hot gases from the exhaust flow in the shell and touch the pipe wall as shown in figure1.


engine

Conti.

- The waste heat from the exhaust which can be transferred to the water and the heat gain by water can be estimated from the following

$$Q_g = \dot{m}\, cp\Delta T$$

Where, Q_g= generator heat (kW)

m=water mass flow rate

Cp=specific heat at constant pressure

to find the c.o.p of the absorption cycle is

$$COP = \frac{Q_e}{Q_g}$$

Table 1. Summarized the measured heat gained by water which equal to the available heat for the generator

RPM	T_{in} (°C)	T_{out} (° C)	Q_g (kW)	COP
950	16	70.05	4.548	1.09930
1150	16	72.8	4.748	1.01086
1300	16	77	5.099	0.9413
1420	16	81	5.434	0.8833
1500	16	83.2	5.617	0.8544
1590	16	84.8	5.751	0.8345
1780	16	86.4	5.885	0.8155
2000	16	89	6.102	0.7865

Table 1 represents measured values for waste heat at different temperatures and engine

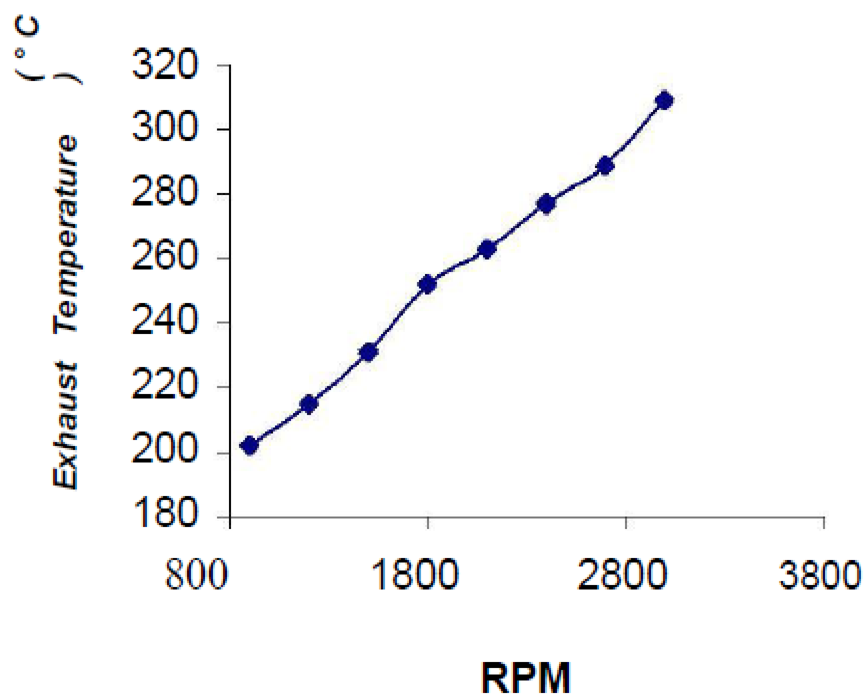


Figure 2. The effect of diesel engine speed on the exhaust gas temperature

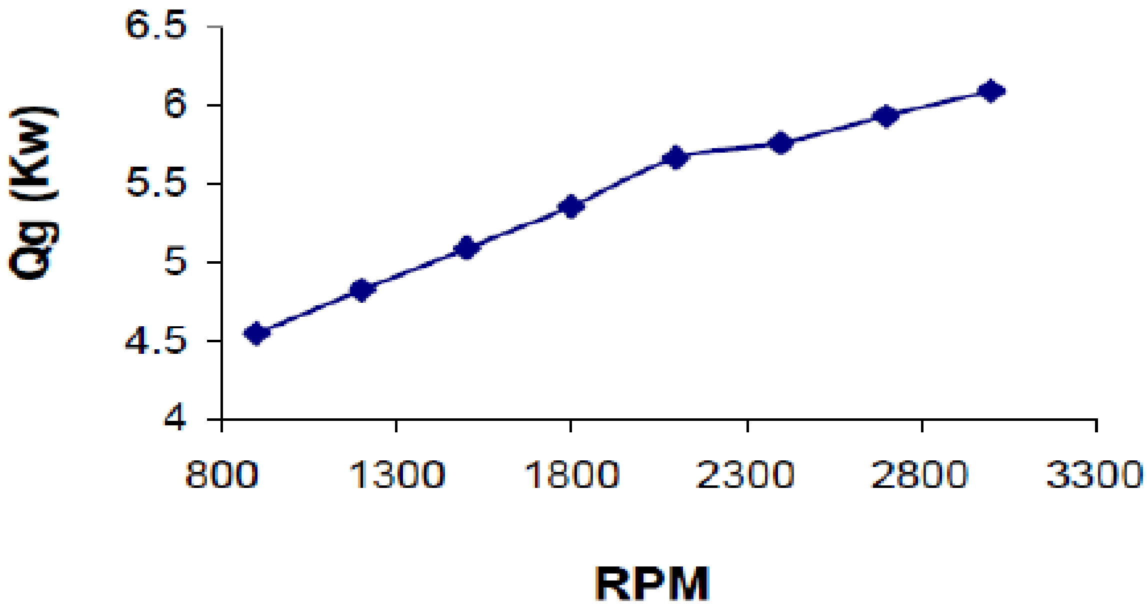


Figure 3. The effect of diesel engine speed on the exhaust heat generation (Qg)

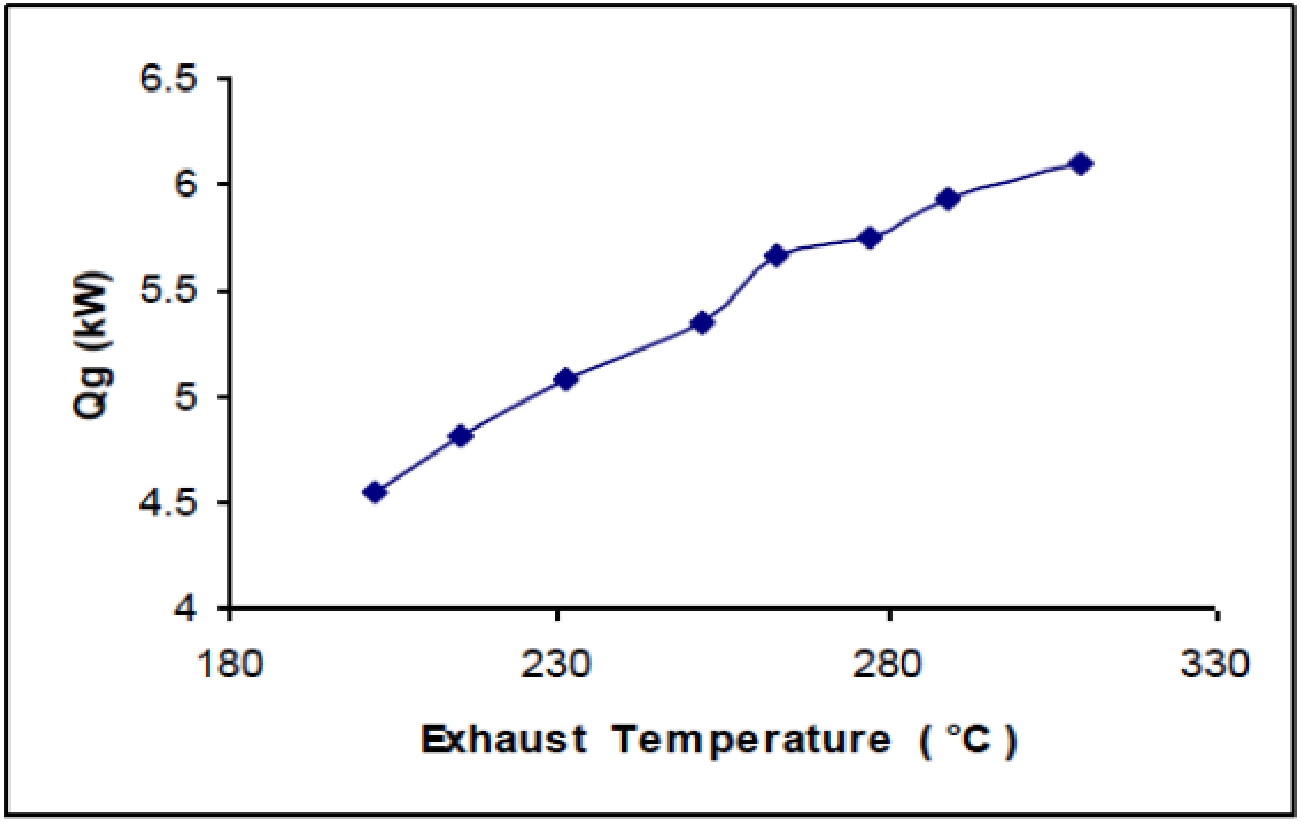


Figure 4. The effect exhaust gas temperature on heat generation (Qg).

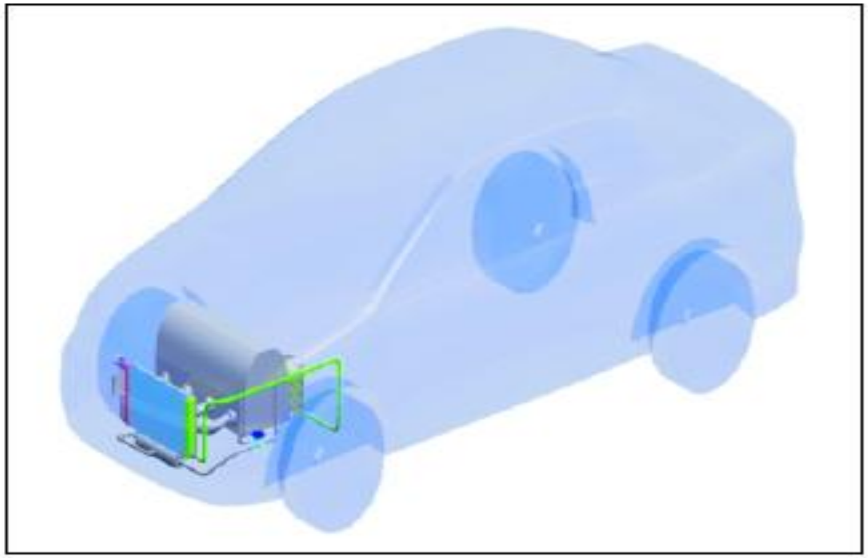
Conti.

- **Shell and Tube Heat Exchangers**
- A heat exchanger is a device built for efficient heat transfer from one fluid to another, whether the fluids are separated by a solid wall so that they never mix, or the fluids are directly contacted. They are widely used in refrigeration, air conditioning, space heating, power production, and chemical processing.
- One common example of a heat exchanger is the radiator in a car, in which the hot radiator fluid is cooled by the flow of air over the radiator surface.
- Types of heat exchangers
  A typical heat exchanger is the shell and tube heat exchanger which consists of a series of finned tubes, through which one of the fluids runs. The second fluid runs over the finned tubes to be heated or cooled.

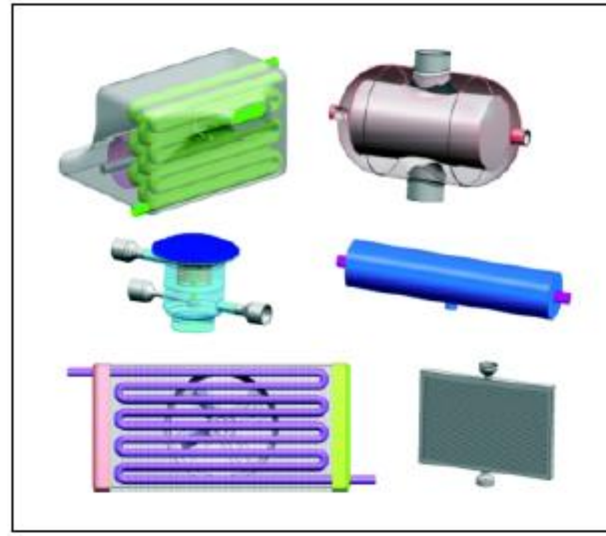
Design and analysis of proposed model

- The generator is used to create the same task of the compressor in the conventional compression refrigeration cycle. It is located where the heat is available from the exhaust gases, and the important limiting factor the space occupied by generator. The generator used to evaporate the mixture of ammonia that react with water and leaves pure ammonia or mixture with high ammonia concentration.

- The generator is design to have a capacity of 4.6 kW with temperature around 90 °C and pressure of 19 bar. The maximum space available in the automobile that this component can be installed is 50 cm long, 25 cm wide and 15 cm high



Location of VAR components in the car



Main components of VAR cooling system

Conti.

- Assuming that the overall heat transfer coefficient through the generator, mass flow rate and specific heat are constant, and that there is no heat loss to the atmosphere, the external heat transfer area of the generator can be calculated

$$A = \frac{Q}{U \Delta LMTD} \quad (3)$$

- To find ΔTLMTD: log mean temp difference

$$\Delta LMTD = \frac{\left[(T_{hi} - T_{co}) - ((T_{ho} - T_{ci}))\right]}{\ln\left[(T_{hi} - T_{co}) \Big/ ((T_{ho} - T_{ci}))\right]}$$

(4)

Conti.

- T_{hi}= = 543 k and T_{ho}= outlet exhaust temp= 473 k $\Delta LMTD$ = 182.6^oC

- The overall heat transfer coefficient, neglecting the fouling resistance of the tube, is given by the equation

- $$\frac{1}{U} = \frac{1}{h_i} * \frac{d_o}{d_i} + \frac{d_o}{2k_s} * \ln\left(\frac{d_o}{d_i}\right) + \frac{1}{h_o}$$

- To find inside heat transfer coefficient(h_i) from nusselt number

$$Nu = \left(\frac{h_i D_i}{k_L}\right) \qquad (6)$$

Conti.

- As the flow inside the generator is two-phase flow. The following equation can be used as long as liquid wets the wall

$$Nu = 0.06\left(\frac{\rho_1}{P_v}\right)^{0.28}\left(\frac{D_i G_x}{\mu_1}\right)^{0.87}(\Pr)^{0.4} \qquad (7)$$

$$Nu = 1246.549 = \frac{h_i D_i}{k_l} \qquad (8)$$

$$h_i = 25.4763 (kW / m^2 k)$$

Conti.

- For flow outside the tubes, the equation for normal to the bank of tubes can be used , and the outside film coefficient can be calculated

$$\left(\frac{h_o * D_o}{k_g} \right) = C(\mathrm{Re})^n (\mathrm{Pr})^{0.36} \left(\frac{\mathrm{Pr}_\infty}{\mathrm{Pr}_s}\right)^{0.25} \quad (9)$$

Where,

C and n: constant depending on Re.

K_g: thermal conductivity of exhaust gases.

Conti.

$$N_{UD} = C\,(Re)^{n}\ (pr)^{0.36}\ \left(\frac{pr_{\infty}}{pr_{s}}\right)^{0.25} \quad (11)$$

- A steel tube can be used for the generator material because the steel does not reacted with the ammonia solution A schedule 40 steel tube of 1.6 cm inner diameter and 2.134 cm outer diameter was used for the generator, then according to this size:

- V_{∞} was measured be 7 m/s. and V_g =14 m/s.

Conti.

- Which is seemed to be in a good agreement for the model proposed by [6] for four stroke spark ignition engine.
- The properties of ammonia and water mixture and air are available in literature and from

$$C = 0.35\left(\frac{S_T}{S_L}\right)^{0.2} = 0.37073 \qquad (12)$$

- Pr_∞= Prandtls at fluid temperature = 0.703
- Pr_s= Prandtls at surface temperature = 0.705 n = 0.6, C = 0.37073
- T_f = 510 k So we take the properties at T = 510k Pr = 0.69

Conti.

- From Silva and Costa , the properties for the exhaust gas can be found as :

$$\rho_g = \frac{353}{T_g} = \frac{353}{508} = 0.694\left(kg / m^3\right)$$

- μ_g = 1.348*10^{-5}+ 2.68*10^{-8}´(T_g)

  = 2.74 *10^{-5}(Ns / m^2)

K_g = 8.459´10^{-3}+ 5.7 ´10^{-5}´(T_g)

= 0.037915 (W / mk)

V_g = 14 m/sec

Where ,Tg is the exhaust gas temperature

Conti.

- Re = 7567.13
- Nu= 69.88
- Substituting values in U k_{steel}= 42 w/m^2k [16] U= 122.139 W/m^2k
- Q_g= 4.6 kW
- $Q_g = UA_s \Delta LMTD$
- So the Area required A_s= 0.196 m^2 and L=2.932 m
- In order to distribute the available length in the specified space we have a space for tubes of long 8 cm and outside diameter 2.134 cm to leave space for the solution to be collected through the other space. Therefore the number of tubes required is 37.
- We need 37 tubes of outside diameter 2.134 cm and inside diameter of 1.6 cm
- The recommended shape of the proposed generator as shown in figures 6 and 7

Conti.

- The recommended shape of the proposed generator as shown in figures 6 and 7.
-

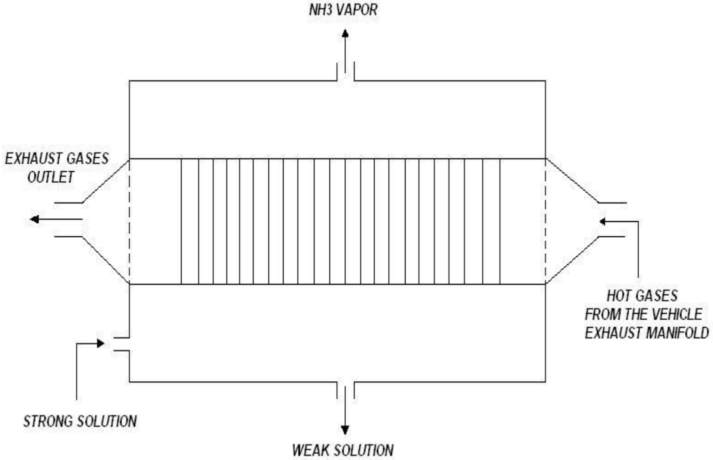


Figure 6. Schematic diagram for fluid flow in the proposed generator

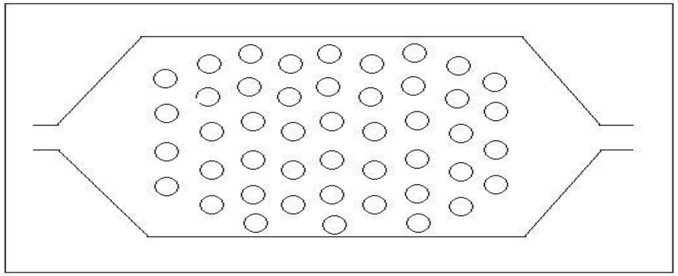


Figure 7. Schematic diagram for the tubes arrangement in the proposed generator From the other side of the generator

Result and descussion

- Based on the data reported figure 2 shows the variation of the coefficient of performance with the energy available in the exhaust or heat available in the generator.
- This energy obtained without additional energy input and from equation the COP inversely proportional with heat generated in the exhaust.
- The main components that controlled COP are evaporator and generator heat, in other words exhaust and evaporator conditions. So, changing the values of these two quantities will change the COP

Conti…

- Fig.2. Shows the variation of the exhaust gas temperature with the diesel engine speed at different loads.
- This temperature increases with the engine speed and the vehicle load. This means that the higher the engine speed and vehicle load, the higher the amount of heat provided to the passenger compartment.
- For the vehicle loads of 20% and 80%, the maximum exhaust gas temperatures were 230 and 280 °C, respectively. It is seen that this temperature had sufficiently high values when the engine speed was between 1500 and2500 rpm.
- Furthermore, exhaust gas temperatures at different vehicle loads diverge with the increasing engine speed.

Conclusion

- Diesel engines can be considered as a potential energy sources for absorption refrigeration systems, because of the energy wasted through the exhaust gas.
- the absorption refrigeration system may be able to take advantage of the exhaust gas power availability and provide the cooling capacity required for automotive air conditioning.
- The waste heat energy available in exhaust gas is directly proportional to the engine speed and exhaust gas flow rates. The coefficient of performance found to be between 0.85 and 1.045 which has a good agreements with data reported in literature. Reducing the fresh air intake and sealing the automobile body can result in a saving in cooling requirements such as door sealing and tinting the glass.

References

- [1]International Journal of Engineering and Innovative Technology (IJEIT) Volume2, Issue12, June2013INTERNATIONALJOURNALFORENGINEERINGAPPLICATIONSANDTECHNOLOGY
- [2] Schwarz. H., Brouwer, L., Knall,G,Schlerege, F., Miiller-Frank, U.Kopnarski. M.,Emrich, S., "Olalterung and Verschlei. ImOttomator: MTZ, 2008-10(Germany)
- [3]Will F., "Process And Device For Lubrication Of Rotating And Oscillating Components" ,Patent application no.DE 102009013943.5 field19/03/2009 (Germany)
- [4]WilF "A Novel Exhausts Heat Recovery System to Reduce Fuel Consumption"F2012A073, FISTIA conference Budapest Hungry 2010.
- [5] Will.F. "Comparison of Advance Waste Heat Recovery System with a Novel Oil Heating System". International Journal of Automation Engineering 4 (2013) 33-40 30134100(Australia)

Conti.

- International Journal of Engineering and Innovation Technology (IJEIT) Volume 2, issue12, June 2013.
- [7]Hakan Özcan, M.S. Söylemez, "Thermal Balance Of A LPG Fuelled, Four Stroke SI En[6]J.S Jadhao, DG. Thombare, "Review on Exhaust Gas Heat Recovery for I.C. Engine," gine With Water Addition," Energy Conversion and Management 47 (5) (2006) 570-581.[7]P. Sathiamurthi, "Design And Development Of Waste Heat Recovery System For Air Conditioning," Unit European Journal of Scientific Research, Vol.54No.1 (2011), pp.102-110, 2011
- [8] Aphornratana S, Eames IW. Thermodynamic analysis of absorption refrigeration cycles using the second law of thermodynamics method. International Journal of Refrigeration 2008
- [9] D'Accadia MD, de Rossi F. Thermo economic optimization of a refrigeration plant. International Journal of Refrigeration2009
- [10] Wall G. Optimization of refrigeration machinery. International Journal Refrigeration 2010

Conti.

- [11] Bejan A, Tsatsaronis G, Moran M. Thermal design and optimization. New York: John Wiley and Sons Inc; 1996.
- [12] “Bus air conditioning” ASHARE Applications Handbook, 8.7-8.9, 2010
- [13]Ackerman J.R, automotive air-conditioning system with absorption SAE paper no 710037, 2009
- [14]Boatto P., Boccaletti, C. Cerri, Malvicino, C., Internal combustion engine waste heat potential for an automotive absorption system of air conditioning part 2: The automotive absorption system, proceeding of the MECHE part D journal of automobile engineering, 214, 983-989,2000
- [15]Christy V Vazhappilly et al. Int. Journal of Engineering Research and Applications. Vol. 3, Issue 5, Sep-Oct2013, pp. 63-67
- [16]”.Alam Shah (2006), A Proposed Model for Utilizing Exhaust Heat to run Automobile Air-conditioner, The2ndJoint International Conference on “Sustainable Energy and Environment (SEE 2006)” 21-23 Nov; 2006, Bangkok, Thailand.

Conti.

- [17]I.W. Eames, S. Aphornratana, H. Haider, A theoretical and experimental study of a small-scale steam jet refrigerator, Int. J. Refrig. 18 (6) (2008) 378–386.
- [18]S. Aphornratana, I.W. Eames, A small capacity steam-ejector refrigerator: experimental investigation of system using ejector with movable primary nozzle, Int. J.Refrig.20 (5) (2009) 352–358.
- [19]D.-W. Sun, Variable geometry ejectors and their applications in ejector refrigeration systems, Energy 21(10) (2008) 919–929.
- [20]Y.-J. Chang, Y.-M. Chen, Enhancement of a steam-jet refrigerator using a novel application of the petal nozzle, Exp. Thermal Fluid Sci. 22 (2009) 203–211.
- [21] I.W. Eames, S. Aphornratana,H. Haider, A theoretical nd experimental study of a small-scale steam jet refrigerator, Int. J. Refrig. 18 (6) (2006) 378–386.
- www.howautoworks.com
- www.sciencedirect.com