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# Aqua Power Generating Silencer

**E.Nirmala Devi, V. Dinesh Bhargav**

***Abstract:*** ***Management of Air contamination is most significant issue from the general public health of view, because each distinctive individual breaths around 22000 times each day. Air contamination causes around 7,000,000 deaths per year around the world. Development and convergence of the population in urban communities, just as the manner by which we consume various sources of energy in urban zones through transport or air conditioning and heating systems, among others, causes the emission of harmful gases at huge quantity that are dangerous to people health. Automobile vehicles are a significant pollution contributor, delivering critical measures of carbon monoxide, nitrogen oxides, and other contamination. In 2013, transportation contributed the greater part of the carbon monoxide (CO) and nitrogen oxides (NOx), and one-fourth of the hydrocarbons (HC) emitted into atmosphere. These vehicles don't seem to be the only sources of pollution, different sources like power generating stations, Exhaust from industries and factories, refuse burning etc. and also contribute intensely to defilement of our environment. So it is crucial that serious endeavors should be made to protect our environment from degradation. In the present study an Aqua Power Generating Silencer is an attempt, in this direction; it is mainly dealing with control of emission, noise & recovery of waste heat from exhaust gases to generate electricity.***

***Keywords: Aqua Power Generating Silencer, Air Contamination, emissions, Recovery of waste heat.***

## I. INTRODUCTION

An Aqua Power Generating Silencer is fitted to the exhaust pipe of engine. Sound produced under water is less hearable than it produced in atmosphere. This mainly because of small sprockets in water molecules, which lowers its amplitude, thus, lowers the sound level [1], [3], [6], [9]. Because of this property water is used in this silencer, and Heat absorbed will utilized and hence its name AQUA POWER GENERATING SILENCER. The noise and smoke level is considerable less than the conventional silencer, it is cheaper, no need of catalytic converter and easy to install. It is imperative that serious attempts should be made to conserve earth's environment from degradation. It is needed to utilize the available heat energy stored in exhaust gases of an I.C engine, thermo-electric module is used for this purpose [10], [12], [14], [16]. An aqua power generating silencer is an attempt in this direction; it is mainly dealing with control of emission and noise and recovery of waste heat.

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## II. LITERATURE REVIEW

**Rahul.S.Padval et.al [1]** had observed that heating is increasing on our earth because of major increase within the pollution. The fundamental part because of which the air contamination is expanding are (CO), (NOx) and lead which is get uncovered from vehicles. Also that the sources like huge factories, massive power generation plants, large scale industries etc. therefore it's needed to unravel these issues by taking numerous serious tries. Aqua silencer is one among the try taken to lessen the air contamination. It's fitted to the fumes funnel of engine or framework. This Silencer is employed to diminish the noise and for management of the emission of dangerous gases.

**Akhil Anil Kumar et.al [2]** had analyzed that heaps of effort is being made to scale back the pollution from gasoline and diesel engines and laws for emission limits also are obligatory. Moreover, developments in gasoline and diesel engines, combined with enhancements within the vehicles, can create fuel consumption reduction at great level within the future cars. One such advancement is improvement of the silencer unit of a motor.

**P.Balashanmugam et.al [3]** were proposed a scrubber tank which contains water to play an important role in absorbing the harmful products of combustion like the CO, $CO_2$, UBHC, oxides of Nitrogen and etc. Water can be replaced by a solution of lime to allow for the chemical reaction to happen at a quicker pace. Some of the reactions takes place between lime solution and toxic gases are,

$Ca(OH)_2 + SO_2 = CaSO_3 + H_2O$

$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$

Recognizable reduction in characteristics smell of the diesel smoke is observed. Smoke of the diesel comprises particles of ash blended in with burned or incompletely burned oil. Unburned hydrocarbons (UBHC) are not exceptionally toxic however they incorporate smell and irritants, for example, aldehydes. A dissolve of unburned hydrocarbons and different particulates with solutions of alkaline, to a substantial extent, the smell of the diesel smoke is decreased when water scrubbers are utilized.

**G Maruthi Prasad Yadav et.al [4]** had done analysis on the 4-stroke multi cylinder diesel engine which is connected with an aqua silencer. They concluded that amount load will increase the contaminations slowly when using the ordinary type of silencer however by using the aqua silencer, the contaminations diminishes. They discovered correlation of various silencers for sound attribute of an engine. In ordinary type of silencer the value of sound level is 83 decibels yet in an aqua silencer is 75 decibels without any load. Nearly at 50% of load in conventional silencer it produces a sound of 84.5 decibels and in an aqua silencer the sound produced is 76.5 decibels at same load.

When engine runs at full load condition the ordinary silencer produces 86 decibels of sound and in an aqua silencer the value of sound is 78 decibels. Experimentally they proved ordinary silencer produces more noise compared to the aqua silencer.

**Alen. M.A et.al [5]** investigated on how actually an Aqua Silencer can control the noise and toxic emission. Aqua silencer basically manages control of emission and clamor in vehicle exhaust. By utilizing enacted charcoal, punctured cylinder and external shell it is built. An aqua silencer is fitted to the fumes funnel of an internal combustion engine. The enacted charcoal channels the harmful sulfur and nitric substance created from the engine. Sound made underneath water is a smaller amount sounding than it made in atmosphere. This in the main due to tiny sprockets in water atoms, that lowers its amplitude so, lowers the sound level. Due to this property water is employed during this silencer and therefore its name AQUA SILENCER.

**Sarath Raj et.al [6]** had been found that using water as a medium noise generated can be minimized. The principle pollutants contribute by vehicles are CO, UBHC, NOx and Lead and so on., sources like industrial and residential fuel utilization, power generating stations, refuse burning, industrial processing are also playing their own role in increasing atmospheric pollution. Therefore it is important to consider all these factors and should make some serious attempts in the direction of controlling the air pollution. An aqua silencer is an effort, to control the percentage of exhaust emissions of the automobile engines.

**Rawale Sudrshan.S et.al [7]** was designed the dimensional features of aqua silencer for 2-stroke gasoline engine. The exhaust pipe of the engine is connected with aqua silencer. The main component of the proposed type of silencer is perforated tube. The layer of carbon is glued over the outer portion of the perforated tube. The amount of sound produced is less in the case of aqua silencer contrasted with conventional silencer. The quantity of carbon monoxide (CO) is also reduced nearly 60% to 70 % when aqua silencer is replaced with the conventional type of silencer.

**Keval I. Patel et.al [8]** proposed a silencer which mainly consists of lime water as a medium to reduce noise and emissions of exhaust. The proposed type of silencer was tested by connecting it two stroke petrol engines. Sound and harmful content of oxides carbon and oxides of nitrogen were reduced by using the proposed silencer.

**B.Jothi Thirumal [9]** designed a type of silencer for controlling the air contamination. The proposed system mainly deals the control of emission by two techniques; they are lime water wash method and absorption method.

**Dr.D.S.Deshmukh et.al [10]** practically it is not possible to create any device which is capable of converting all the input energy into output energy, there are always some losses of energy takes place. No system in the universe is 100% proficient, because of energy losses system efficiency may reduce in real practices. Approximately 75% of the energy generated because of combustion of fuel in I.C Engines is lost through the exhaust or coolant of the engine in the heat energy form.

**Dr. P M Meena et.al [11]** was researched on Thermo electrical power generation from exhaust gases of an internal combustion engine. According to their research work proper utilization of thermal energy and crises of energy have been important issues in in this 21st century. They proposed framework comprises of waste warmth recuperation that gives a thermal energy source to thermoelectric generators. Thermoelectric generators are the type of devices which are capable to convert available heat energy into electrical power. In contrast to conventional dynamic heat engines, thermoelectric generators contain no moving parts and are totally quiet. Such generators have been utilized dependably for more than 30 years of support free activity in profound space tests, for example, the Voyager missions of NASA. Compared to enormous conventional heat engines, thermoelectric generators have lower effectiveness. But when it comes to small applications, thermoelectric generators are become competitive because they are smaller in size, less cost and maintenance-free.

**Punith.N et.al [12]** thermoelectric is field of science have a long history of giving basic, reliable type of electric power generation solutions. In 1821 German physicist Thomson J.Seebeck finds that a circuit made by using two different conducting materials produces voltage when their intersections were maintained at various temperatures, this effect is called as "Seebeck effect". Thermoelectric power generators works on this principle. Thermoelectric (TE) materials, found in 1821, are semiconductor materials that generate an electric flow when connected with each other and exposed to a temperature variation over the intersection.

**Ajay Kumar et.al [13]** management of the engine exhaust is the significant topic of discussion for automobile industries during the recent years and in I.C engines, exhaust gases and cooling system of the internal combustion engine absorbs heaps of heat energy and out of the overall energy provided to the engine in the form of chemical energy by fuel around 30-40% is been utilized to converted into useful work output and the remaining energy will be wasted because of exhaust gases and this exhaust gases carries a lot of heat energy that can be utilized and recovered by employing a waste warmth recuperation framework.

**J. Vazquez et.al [14]** developed two kinds of engine exhaust models are dissected on CFD to check the rate of heat transfer and drop in pressure by considering the driving conditions for a car of a 1.3 L petrol engine.

**Douglas Crane et.al [15]** investigated on various working condition for example urban, rural and higher traffic roads and the correct location for the TEG module. The amount of electrical power produced from thermoelectric generator is determined to be a direct function of the cross-sectional area and temperature of the exhaust. The effectiveness of the heat exchanger should be good, which is important to increase the quantity of heat energy extracted from the exhaust gases. It is determined that the parameters of exhaust gas and heat exchanger structure have a significant impact on the output power and the pressure drop.

**Dipak Patil et.al [16]** were proposed a technique for recovering the waste of engine exhaust.

A thermoelectric generator produces electrical force from heat stream over a temperature slope. As the warmth streams from hot to cool, free charge a bearer (electrons or holes) in the materials are also flows from high temperature zone to low temperature zone.

The subsequent voltage (V) is relative to the temperature difference (ΔT) through the Seebeck coefficient, α, ($V = \alpha \Delta T$).

**Basel Al Ghabet et.al [17]** were showed one among the helpful techniques to benefit from waste heat available from I.C engines and create electric flow by utilizing thermoelectric generators, the primary advantage of this framework is reducing the fuel consumption per unit overall output and helps in minimization of pollution for ecological protection. This paper discloses techniques of converting waste heat into electricity.

**Remeli, F.Z et.al [18]** designed theoretical techniques to analyze the electrical effectiveness of thermoelectric generators to generate current using heat energy available from the exhaust gases. A cogenerating framework consisting of heat pipes and thermoelectric generators (HPTEG) incorporates a thermoelectric generator which was fixed in between the two finned thermal pipes to produce a thermal difference across the thermoelectric generator for the purpose of electric power generation. The results of experiments showed that the TEG modules of 8 rows can generate 10.39 Watts of electrical power by recovering 1.35 kilowatts of heat energy.

**Orr, B et.al [19]** used thermal pipe and TEG module for the purpose of recovering the heat energy available from the exhaust gases of internal combustion engine and further heat energy was utilized to generate electric power. The entire framework consisted of 8 TEG modules and 6.03 Watts of electrical power was generated. The electricity conversion efficiency is increased by employing this system.. To control the overheating of the thermal pipes, a pre exchanger of Naphthalene heat pipe model was proposed. The working temperature of Naphthalene thermal pipes have in between of 250 °C - 450 °C.

**Suraj S.Prajapati et.al [20]** were inspected under various conditions of vehicle speed and power output of the internal combustion engine. The mean difference in temperature of 2400C for an average thermoelectric generator had 183.24 watts of power output. But it is observed that when 4-TEGs system were checked on practical working condition on road side test generated the power of 600 watts with 1820C value of temperature difference.

## III. CONSTRUCTION OF AQUA POWER GENERATING SILENCER

The pipe carrying exhaust gases of the engine was connected to aqua power generating silencer. The inside diameter of the engine exhaust pipe is 3cm; it is also the inlet diameter of the aqua power generating silencer. Fundamentally an aqua power generating silencer comprises of a perforated tube which is connected to the end of exhaust pipe. The perforated tube consists of holes of various diameters. The aim of providing completely different diameter holes is to break up gas mass to create smaller gas bubbles. The opposite end of the perforated tube is shut by plug. Around the circumference of the perforated tube a layer of activated carbon and glass wool is provided and further a metallic mesh covers over it. The total unit is then placed in a container called outer shell. A small opening is provided at the top of the outer shell to remove the exhaust gases and a drain plug is provided at the bottom of the outer shell for periodically cleaning of the outer shell. Also a filler mouth is provided at the top of the container, through this lime water was filled into the silencer. At the inlet of the exhaust pipe of silencer a non-return valve is provided, which prevents the back flow of gases and lime water from silencer. Thermo-electric module was fitted to the exhaust pipe of the aqua power generating silencer for generating electrical power from waste heat energy of exhaust gases. The development and design of the aqua power generating silencer will be done by considering the following factors.

- Exhaust gas pressure
- Rate of discharge of exhaust
- Location & Space availability
- Temperature of exhaust gases
- Size & Capacity of an engine

Aqua silencer mainly consists of the following components for its construction.

### A. Outer shell

Outer shell is the cylindrical body which acts as an encloser for perforated tube and also used as sump for lime water. The following are the various specifications of outer shell.

- Length – 98 cm
- Diameter – 12 cm
- Thickness- 0.2 cm
- Material – Iron

### B. Activated Carbon

Activated carbon is also called as activated charcoal. It is a kind of carbon processed to have little, low volume pores that increase the availability of surface area for absorption or chemical reactions [2], [4], [7]. It will separate and traps the oxides of sulphur ($SO_x$) and fluoride when the sulphur present in the gas. Activated carbon is usually derived from charcoal and is some of the time utilized as biochar. It will be pasted around the perforated tube in aqua power generating silencer and it helps to remove odor, and different hydrocarbons from the exhaust gases. Activated carbon is additionally utilized for compound refinement, gas purification, water treatment, analytical chemical applications. The following are the various specifications of activated charcoal used in aqua power generating silencer.

(1) Grain size-0.82 to 1.3mm
(2) Shape- Cylindrical palates

### C. Perforated Tube

Perforated tube is the circular hollow metallic pipe. It consists of holes of different diameters on its circumference. The diameter of those holes will varies from 2mm to 4mm.It will be fitted in inside of the outer shell and connected to the engine exhaust manifold pipe. The following are the various specifications of the perforated tube.

- Length of the perforated tube 105cm
- Inner diameter of the perforated tube 3.5cm

- Thickness of the perforated tube 0.2cm
- Metal of the perforated tube Mild steel

### D. Metal Mesh

Metal mesh was fixed around the perforated tube and it will be helps to holding the activated charcoal and glass wool around the perforated tube. It was made with alloy metal with high thermal resistance.

### E. Lime Solution

Lime water is that the common name for a saturated solution of calcium hydroxide. Calcium Hydroxide, generally known as slaked lime, is a chemical compound with the chemical formula $Ca(OH)_2$. It is a colorless crystal or white powder and is acquired when calcium oxide (called lime or quick lime) is blended, or slaked with water. This lime solution was stored inside the outer shell and aides for expelling oxides of carbon and Sulphur from exhaust gases {5], [8].

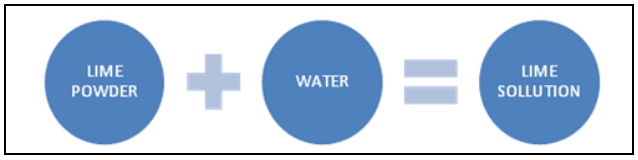


**Fig.1 Formation of Lime solution**

### F. Glass Wool

Glass wool is an insulating material produced using strands of glass arranged utilizing a binder into a texture similar to wool. Glass wool was arranged around the perforated tube inside the aqua power generating silencer for sound insulation and also for trapping the solid particles, particulates and soot presented in the exhaust gases of an engine.

### G. Non-Return Valve

Non-return valve was fitted to the pipe connecting the aqua power generating silencer and exhaust manifold of an engine. It prevents the lime water in aqua power generating silencer to flow back into the exhaust gas pipe of an engine.

### H. Flange

It helps for connecting the aqua power generating silencer pipe to the engine by bolting it to the engine exhaust manifold.

### I. Thermo-Electric Module

A thermo-electric module is a semi-conductor as shown in fig.2 (a,b). Which converts heat energy into the electricity by using seebeck effect [13], [17], [18]. After applying the heat on one side and cold on other side of this device, it will start generating the voltage which depends upon the value of applied heat. It helps in recovery of heat energy available in exhaust gases [11], [15], [19]. Thermoelectric module was fitted to the aqua power generating silencer to generate current from high temperature surface of silencer.

**Specifications of Thermo-Electric Module**

- Material: Ceramic / Bismuth Telluride
- Color: White
- Parametric model: SP1848-27145
- Temperature(C): 150 degree
- Open-circuit voltage(V): 5 V
- Current(MA): 20/0.97/225; 40/1.8/368; 60/2.4/469; 80/3.6/559; 100/4.8/669
- Module weight: 30g
- Module size: 4x4x0.4cm (L x W x H)

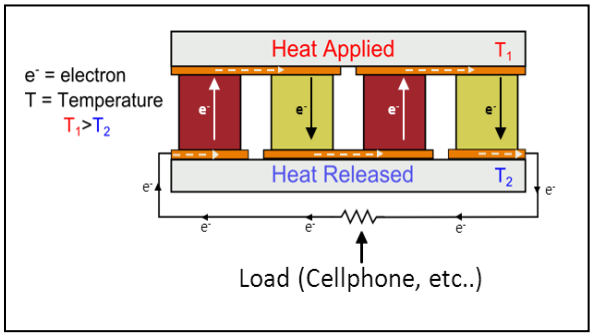


**Fig.2 (a) Thermo-Electric Module**

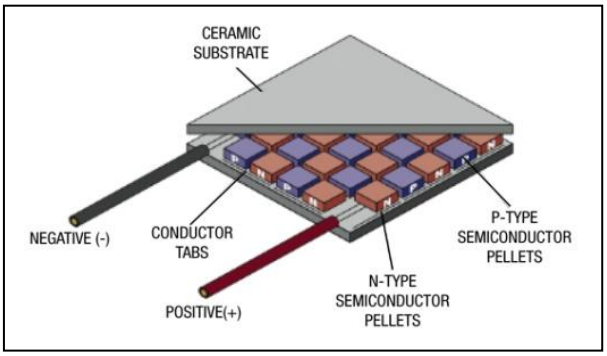


**Fig.2 (b) Internal construction of Thermo-Electric Module**

## IV. WORKING PRINCIPLE

During the working of petrol engines, it will emit the following exhaust emissions.

- Unburnt hydrocarbons, (HC)
- Oxides of carbon, (CO and $CO_2$)
- Oxides of nitrogen, (NO and $NO_2$)
- Oxides of sulphur ($SO_2$ and $SO_3$)
- Particulates, Soot and Smoke.

Aqua power generating silencer will controls the percentage of pollutants as explained below. The high temperature and high pollutant exhaust gas is allowed to pass through the perforated tube by connecting the silencer inlet pipe to engine exhaust system. Exhaust gas will expands inside the perorated tube due to the difference of area between the exhaust pipe of the engine and perforated tube. This allows the gas to expand considerably. The expansion of gas allows it to have reduced pressure and helps in minimization of back pressure. After expansion of gases inside the perforated tube, the emission gases will comes out through the holes of perforated tube and these gases will passes through the glass wool and activated carbon. Glass wool will trap the solid particles, particulates and soot from the exhaust emissions. Activated carbon is highly porous and possesses extra free valences. So it possesses high absorption capacity, Activated carbon absorbs the emissions and helps in minimization of percentage of harmful pollutants presented in exhaust gas [2], [4], [9]. Exhaust gases now comes in contact with the lime water and reacts with it and gets dissolved chemically by it. The following reactions may takes place between lime water and the emission gases for dissolving of emissions in lime water.

Chemical reaction between Lime solution and $CO_2$

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O \quad [3],[9]$$

$$CaCO_3 + H_2O + CO_2 = Ca(HCO_3)_2 \quad [3],[9]$$

Chemical reaction between Lime solution and $SO_2$

$$Ca(OH)_2+SO_2 = CaSO_3+H_2O \quad [3],[9]$$

After reacting with lime water, the purified exhaust gases leaves from the silencer through the discharge opening provided at the top of the outer shell. Sound produced under the water is always less hearable than the sound produced in the atmosphere. This is mainly due to little sprockets in water particles, which lowers its amplitude [2], [4], [5], [9]. As the gases traveling through the lime water, noise generated will be minimized. Hence, aqua power generating silencer generates less noise compared to the conventional silencer. Thermo-electric module is fitted to the exhaust pipe of the silencer for electric power generation. A thermo-electric module is a semiconductor device, which converts heat energy into the electricity by using seebeck effect [17], [18], [19]. After applying the heat on one side and cold on other side of this device, it will start generating the voltage. As hot exhaust gases are flowing through the silencer pipe, exhaust pipe will gets heated and its surface temperature will be raises. This heat energy available in the hot exhaust pipe of the silencer will be utilized for generating electrical power with help of thermo-electric module [10], [17], [20].

## V. RESULTS AND DISCUSSIONS

An experimental study of aqua power generating silencer for its emission control, it was fitted to the 4-stroke petrol engine. Performance of the aqua power generating silencer was tested at Pollution test station authorized by Transport department, Government of Andhra Pradesh, India. The following results are obtained for conventional silencer and aqua power generating silencer as shown in table.1.

**Table-I: Test results comparison between Aqua power generating silencer & Conventional silencer**

| Type Of Pollutant | Prescribed Regulation As Per Government Rules | Conventional Silencer | Aqua Power Generating Silencer |
|---|---|---|---|
| **Carbon monoxide (CO)** | 3.5% | 0.386% | 0.149% |
| **Carbon dioxide ($CO_2$)** | -- | 1.40% | 1.22% |
| **Un-burned Hydrocarbons (HC)** | 4500 PPM | 1476 PPM | 990 PPM |

As per test results, we can understand that the content of exhaust emissions such as carbon monoxide (CO), Carbon dioxide ($CO_2$), Un-burned hydrocarbons (UBHC) are less in the case of aqua power generating silencer compared to the conventional silencer.

### A. Carbon Monoxide

Comparison of CO contained in exhaust emission between Conventional and Aqua power generating silencer as shown in fig.4. It was observed that the content of CO in exhaust is minimized from 0.386% to 0.149% by replacing conventional silencer with an aqua power generating silencer.

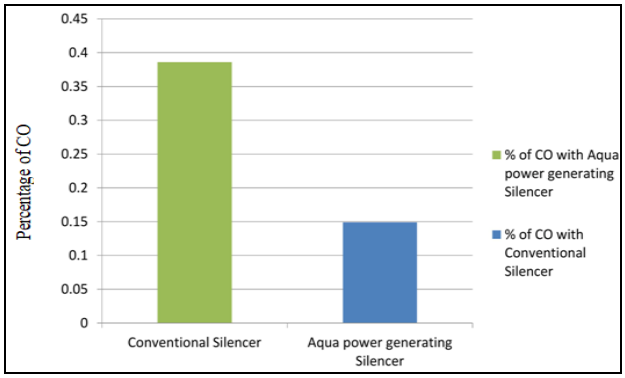


**Fig.4 Comparison of CO (%) contained in exhaust emission between Conventional and Aqua power generating silencer**

### B. Unburned hydro carbons

The Fig.5 shows the graph which represents the Comparison of HC content per PPM in exhaust emission between Conventional and Aqua power generating silencer. It was observed that the content of HC in exhaust is minimized from 1476 PPM to 990 PPM by replacing conventional silencer with an aqua power generating silencer.

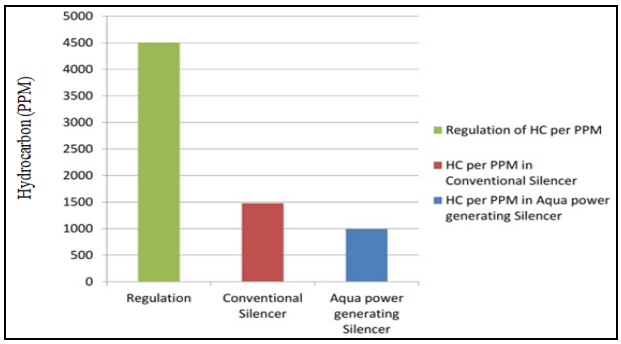


**Fig.5 Comparison of HC (ppm) in exhaust emission between Conventional and Aqua power generating silencer**

### C. Carbon dioxide

It was observed that the content of $CO_2$ in exhaust is minimized from 1.40% to 1.22% by replacing conventional silencer with an aqua power generating silencer. The Fig.6 shows the Comparison of $CO_2$ contained in exhaust emission between Conventional and Aqua power generating silencer.

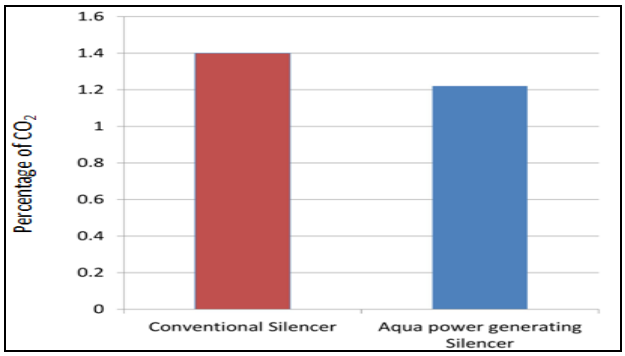


**Fig.6 Comparison of $CO_2$ (%) contained in exhaust emission between Conventional and Aqua power generating silencer**

**Table 2. Current generated and Voltage developed by recovering the waste heat using Thermo-Electric module connected to the Aqua power generating silencer**

| | | | | | |
|---|---|---|---|---|---|
| Temperature ($^0$C) | 100 | 80 | 60 | 40 | 20 |
| Open Circuit Voltage (V) | 4.8 | 3.6 | 2.4 | 1.8 | 0.97 |
| Current (mA) | 669 | 558 | 469 | 368 | 225 |

The Fig.7 shows the graph of Current generated (mA) vs Temperature ($^0$C). It was observed that nearly 669 mA of current was produced by using single thermoelectric module. By using increased number of thermoelectric modules connected to the silencer, the power generated can be increased.

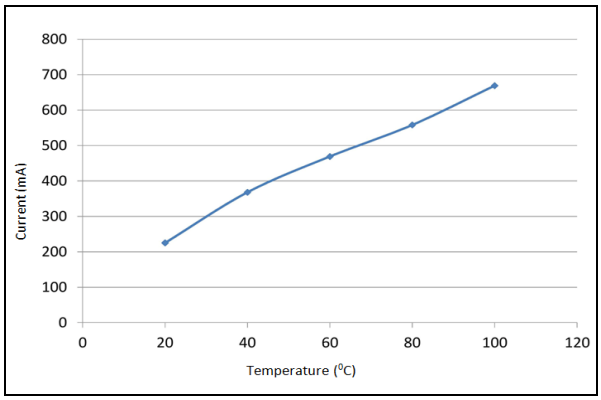


**Fig.7 Current generated vs Temperature**

The Fig.8 shows the graph of Voltage (V) vs Temperature ($^0$C). It was observed that nearly 5 volts of voltage is developed by using single thermoelectric module by utilizing recovered waste heat from exhaust of the engine.

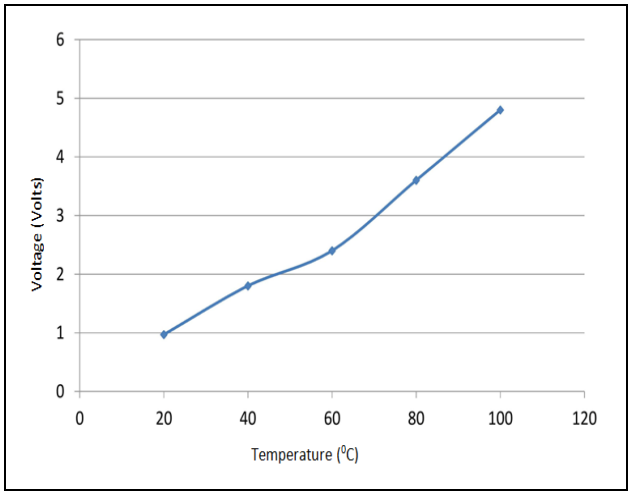


**Fig.8 Voltage vs Temperature**

Content of CO and HC in engine exhaust when aqua power generating silencer is used compared with the content of CO and HC in engine exhaust when silencer proposed by Keval.I[8] is used by graphs shown in Fig.9 and Fig.10. It is observed that the aqua power generating silencer is more effective in reducing emissions of engine like CO and HC. Content of CO is reduced from 0.22% to 0.149%.

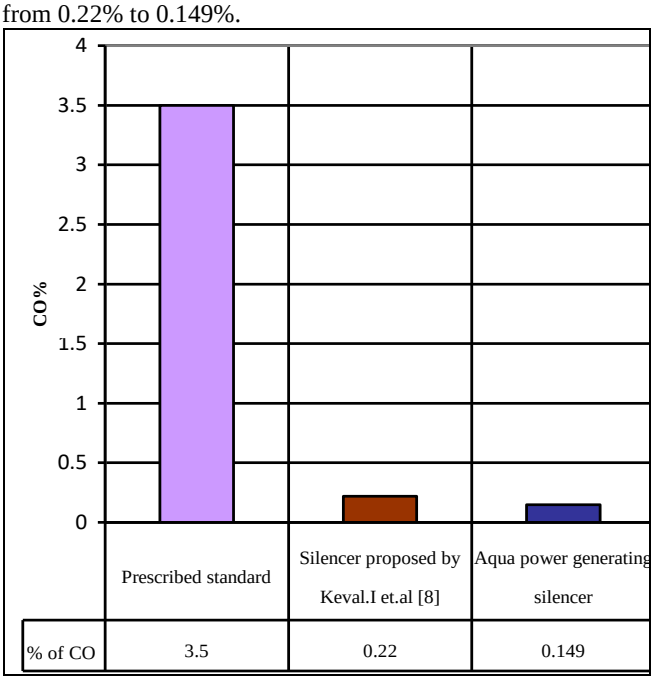


**Fig.9 Comparison of CO reduction between Aqua power generating silencer and the silencer proposed by Keval et.al[8]**

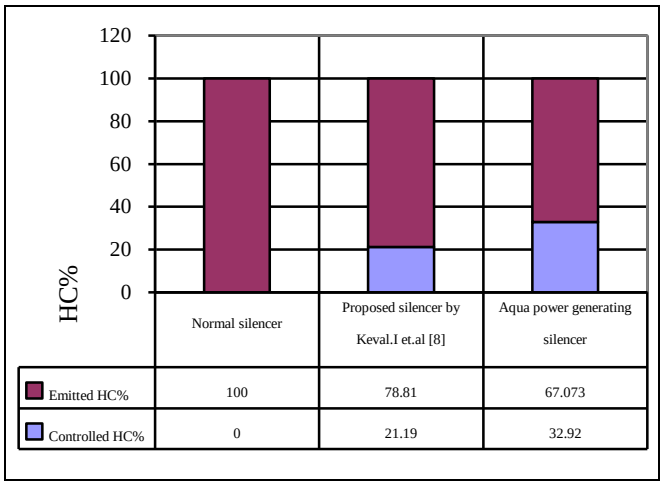


**Fig.10 Comparison of HC reduction between Aqua power generating silencer and the silencer proposed by Keval.I et.al [8]**

## VI. CONCLUSION

The Aqua power generating silencer is more effective in minimization of exhaust emission gases from the engine exhaust using perforated tube, activated carbon, and lime solution. By using the water as a medium the sound can be lowered. Hence, aqua power generating silencer generates less noise compared to the conventional silencer. Exhaust gases consists less amount of pollutants when aqua power generating silencer is used and it will helps for controlling environment pollution. Aqua power generating silencer is also capable of generating electrical power by recovering the waste heat energy available from exhaust gases with the help of thermoelectric generator. Thermo-electric module is fitted to the exhaust pipe of the silencer for electric power generation.

Aqua power generating silencer is very cheap and it can used for both two and four wheelers vehicles and also can be used for also for industrial applications with few modifications.

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