HYBRID AQUA SILENCER

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CHAPTER ONE

INTRODUCTION

1.1 Background

Vehicles are a major source of environmental pollution after industries. Air contamination is serious issue from the public health point of view. Polluted air causes unexpected physical and physiological effects on human health. Air pollution can be defined as addition of unwanted material to our atmosphere, which will have a speedy effect on life of living things upon our planet. The main pollutants contributed by engine exhaust are carbon monoxide (CO), un-burnt hydrocarbon (UBHC), oxides of nitrogen (NOx) and Lead.

Emissions may be divided into two group 1) Invisible emission and 2) Visible emission. Major emissions in exhaust gas are as follows

1. Invisible emission.
    a) Un-burnt hydro-carbon (HC)
    b) Oxides of carbon (CO_X)
    c) Oxides of sulphur. (SO_X)
    d) Oxides of nitrogen. (NO_X)
2. Visible emission
    a) Soot and Smoke (carbon particles)
    b) Particulates

It's impossible to conclude simply by saying the only cause of air pollution is automobile specifically. Because of that, other sources such as electric power generating stations, industrial and domestic fuel consumption, industrial processing etc. also contribute heavily to pollution of our environment, so it is mandatory that serious efforts should be made to conserve of our environment from deprivation.

Engines are used for various purposes in power plants, automobiles, locomotives and in various manufacturing. Pollution in a sense not only the air emission part but also the noise produced should be in consideration. Noise created by these engines becomes a vital concern in domestic areas or areas where noise creates various hazard. Scientifically noise level an average of more than 80 dB is hazardous for human being naturally. The main sources of

noise in an engine are the exhaust and that produced due to friction of various parts of the engine. So in this type of silencer it absorbs the gases from the engine and releases much less portion to the environment. The noise and smoke level is considerable less than the conventional silencer further there is no need of catalytic converter and easy to install. Activated charcoal layer is highly porous and posse's extra free valences so it has high absorption capacity along with this lime water chemically reacts with the exhaust gases from the engine and release much less pollution to the environment [7, 28].

Diesel engines are playing a vital role in Road and sea transport, Agriculture, mining and many other industries. Considering the available fuel resources and the present technological development, diesel fuel is evidently necessary. In general, the consumption of fuel is an index for finding out the economic strength of any country. Inspire, we cannot ignore the harmful effects of the large mass of the burnt gases, which erodes the purity of our environment every day. It is especially so, in most developed countries like USA and EUROPE. While, constant research is going on to reduce the toxic content of diesel exhaust, the diesel power packs find the ever increasing applications and demand.

This project is an attempt to reduce the toxic content of diesel exhaust, before it is emitted to the atmosphere. This system can be safely used for diesel power packs which could be used in inflammable atmospheres, such as refineries, chemical processing industries, open cast mines and other confined areas, which demands the need for diesel power packs. For achieving this toxic gases are to be reduced to acceptable limits before they are emitted out of this atmosphere, which otherwise will be hazardous and prone to accidents.

The principle involved is by bubbling the exhaust gas through the scrubber tank containing an alkaline solution; here the temperature of the gases is reduced, while most of the oxides of nitrogen in the exhaust are melted down to nontoxic. The highly dangerous carbon monoxide is not such an Endanger in diesel exhaust, as it does not exceed 0.2 percent by volume, whereas in petrol engines the CO content may be as high as 10 percent. A lime water container in the scrubber tank reduces the considerable percentage of sulfur dioxide (SO_2) presents in the exhaust. The provision of suitable baffles in the scrubber tank aids the turbulence so that, thorough scrubbing take place. The bell mouth solution, while reducing the back pressure. Four measuring the contents of the exhaust gas, provisions are made to take samples between engine outlet and scrubber inlet and after the scrubber outlet before the gases are let out to the atmosphere. These sampling points enable us to measure the exhaust gas content before and after scrubbing. The difference is evaluated and effective control is

initiated. Before saying more about the study, let's say something about the existing sound eliminating machine components which can be called silencer.

Classifications of silencers

Mufflers are installed within the exhaust system of most internal combustion engines, although the muffler is not designed to serve any primary exhaust function. The muffler is engineered as an acoustic sound proofing device designed to reduce the loudness of the sound pressure created by the engine by way of acoustic quieting. The majority of the sound pressure produced by the engine is emanated out of the vehicle using the same piping used by the silent exhaust gases absorbed by a series of passages and chambers lined with roving fiberglass insulation and/or resonating chambers harmonically tuned to cause destructive interference where in opposite sound waves cancel each other out. An unavoidable side effect of muffler use is an increase of back pressure which decreases engine efficiency. This is because the engine exhaust must share the same complex exit pathway built inside the muffler as the sound pressure that the muffler is designed to mitigate. Some vehicle owners remove or install an aftermarket muffler when engine tuning in order to increase power output or reduce fuel consumption because of economic or environmental concerns, recreational pursuits such as motorsport and hyper milling and/or for personal aesthetic acoustical preferences. Although the legality of altering a motor vehicle's OEM exhaust system varies by jurisdiction, in many developed parts of the world, modification of a vehicle's exhaust system is usually highly regulated if not strictly prohibited.

So the silencer type can be:

1. Baffle type
2. Wave cancellation type
3. Resonance type
4. Absorber type
5. Combined resonance & absorber type.

Each of them is explained with their application and differences on vehicles. [16]

Baffle Silencer

It is generally cylindrical in shape with a number of baffles spot welded inside. There are many designs of baffles, but the principle in all cases is the same that is, closing in any direct passage for the gas. Major drawback of this type muffler is their low efficiency. Because of the restrictions provided to the flow by the baffles, the back pressure is increased, thus causing loss in engine power.

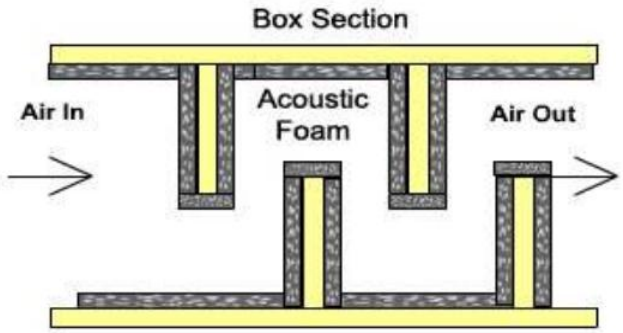


Figure: Baffle type silencer

Wave Cancellation Silencer

In this type, exhaust gases are divided into two parts. The lengths of these paths are so adjusted that after they come out of the muffler, the crests of one wave coincide with the troughs of the second wave, thus the cancelling each other and reducing the noise to zero theoretically. This is achieved if the lengths of the two passages differ by half the wave length. In practice this type of muffler does not eliminate noise completely, because this is possible only at one frequency for which muffler is designed, whereas the noise is a combination of different frequencies. However, appreciable noise reduction is achieved. In this the resistance to the main gas flow is very small as compared to the baffle type.

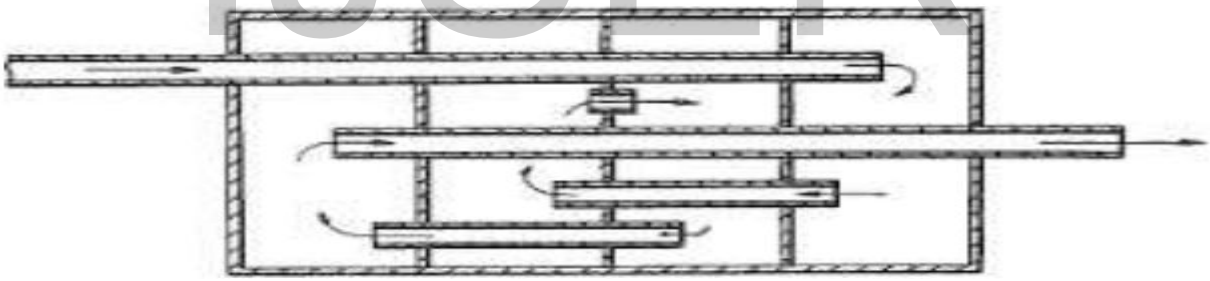


Figure Wave cancellation type silencer

Resonance silencer

These are also called Helmholtz type, after the person who originated the idea. It consists of a number of Helmholtz resonators in series, through which a pipe containing access ports passes. The exhaust gases flow through this type and thus experience no resistance. Series of resonators eliminate the fundamental and higher harmonics of the engine noise.

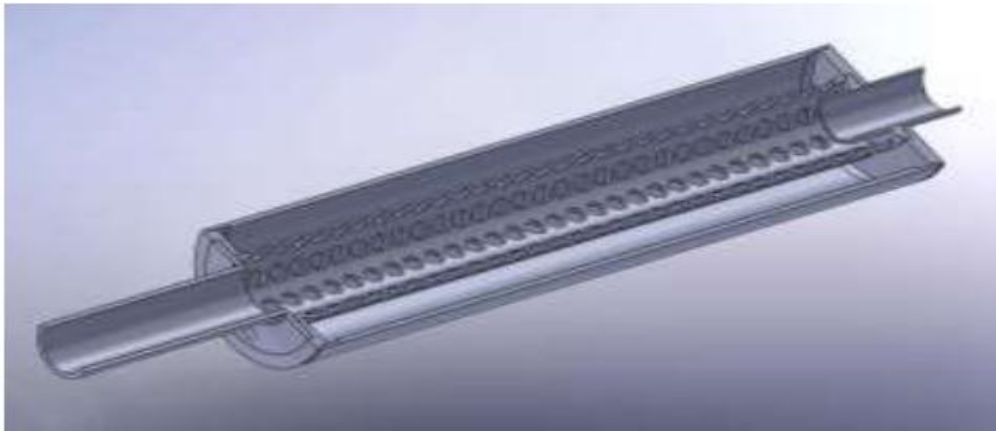


Figure: Resonator type silencer

Absorber Silencer

The sound absorbing material, usually fiber glasses, is placed in this case around the perforated tube through which the exhaust gases pass. The sound is reduced by conversion into heat by the sound absorbing material. Such mufflers are commonly known as glass-packs and are quite common in performance and raising cars due to their little resistance to flow. These essentially attenuate at higher frequency sounds and produce the deep, throaty sound usually associated with a high performance engine. A common design is a cylindrical can with a perforated tube which is surrounded by packing material.

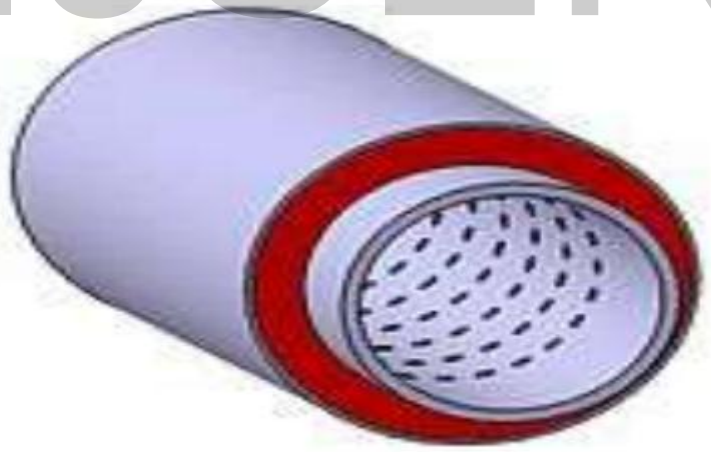


Figure: Absorber type silencer

Combined Resonance and Absorber type:

It is seen that the absorber type muffler, has a drawback in that it is not efficient in reducing noise of low frequency. To obviate this defect, this is combined with a resonant chamber. It has been found that this type is more efficient than either the simple resonance or the absorber types.

In general, here what have been discussed above are the types of silencer that can be used before for sound emission reduction only. (i.e. to eliminate the sound frequency as much as possible depending on the engine types used for purpose.) Then after saying this about the existing sound emission reducing mechanisms, let's see those systems used before for air emission reduction in both petrol and diesel engine vehicles for specific vehicles.

The catalytic converter systems:

As the internal combustion engine utilizes the exhaust stroke to discharge the 'spent' gases via the exhaust system, the harmful emissions are passed through exhaust manifold then to a special muffler type looking device called a catalytic converter. After the emissions have passed through the converter they are passed through the rest of the exhaust system in the conventional manner and finally to atmosphere. The catalytic converter's purpose is to reduce the original harmful emissions to negligible levels by means of catalyst controlled chemical reactions. Within the structure of the catalytic converter is a form utilizing a catalyst.

Figure: Catalytic converter components

Components of the catalytic converter:

There are three main components of the Catalytic Converter:

First, the Monolith (also known as the substrate), a ceramic or metal structure constructed like a honeycomb, through which exhaust gases pass. Second, Wash coat, porous ceramic sponge like coatings applied in a thin layer to the monolith that multiplies the surface area to that of approximately two football pitches, over which the catalytic metals can be deposited. Third will be, the Catalyst, normally consisting of a mixture of Platinum and Rhodium although Palladium is also used. They carry out the chemical reactions that purify the exhaust.

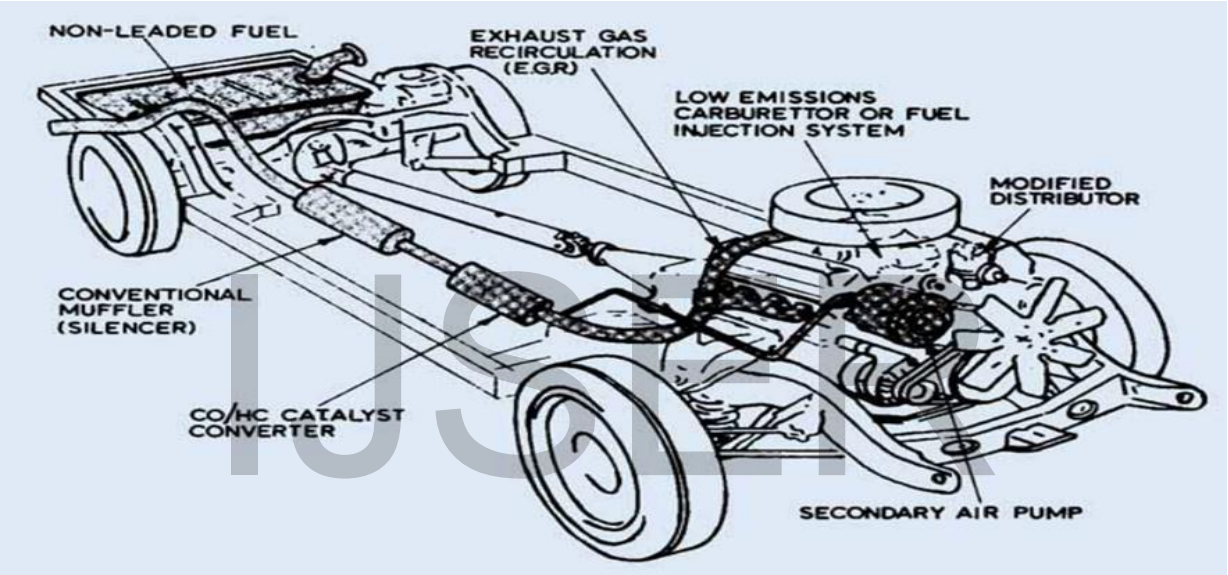


Fig. Johnson Matthew exhausts emission control system for 1975 model vehicles. [22]

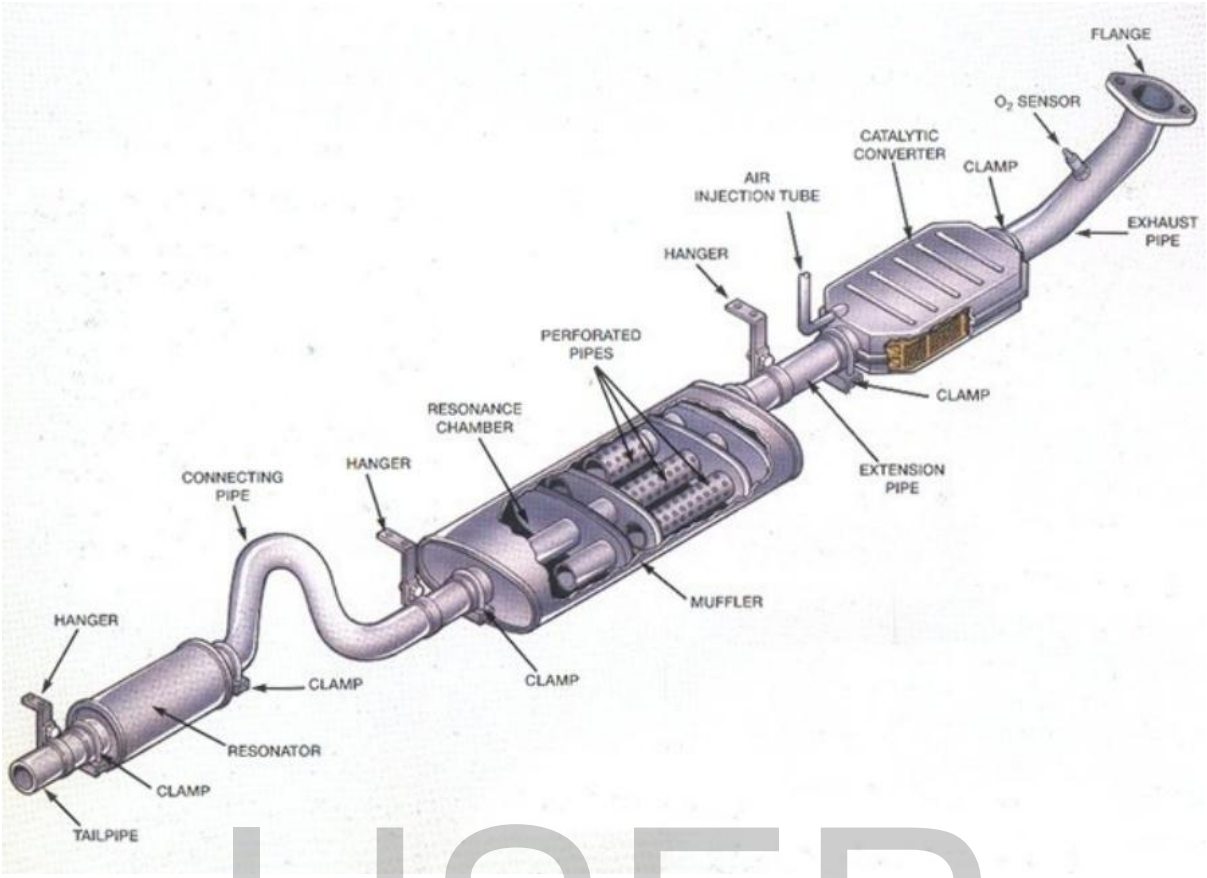


Figure. Combination of silencer and catalytic converter

The catalytic converter operates under some comfortable conditions depending on their design for functionality:

a. Working Temperature:

The catalyst starts operating once the monolith/substrate has attained a temperature of 250-270 °C, the temperature (commonly known as light-off) which a car will normally reach from cold start within a few seconds. Under normal operating conditions the catalyst maintains a temperature of between 400-600 °C. To work most effectively, a catalytic converter needs to reach an optimum temperature. It may not reach this in a short journey. Devises to pre-warm the catalyst are being developed which improve the overall performance of catalytic converters.

b. Stoichiometric Ratio:

For the catalyst to function properly, the engine must be idle stage at an ideal mixture of air and fuel (about 14.7:1 depending on the quality of the fuel). There is a control system mounted upstream of the catalytic converter, meaning it is closer to the engine than the converter. It monitors the exhaust stream. It has a sensor that tells the engine computer how

much oxygen is in the exhaust. The engine computer can increase or decrease the amount of oxygen in the exhaust by adjusting the air to fuel ratio. This control scheme allows the engine computer to make sure that the engine is running at close to the stoichiometric point 14.7:1, and also to make sure that there is enough oxygen in the exhaust to allow the oxidization catalyst to bum the unburned hydrocarbons and CO.

c. Amount of catalysts used:

Platinum or Palladium accelerate the oxidation of hydrocarbons and carbon monoxide, while Rhodium reduces the oxides of nitrogen. As a general rule there are only between 1-2 grams of precious metals in every catalytic converter. The idea is to create a structure that exposes the maximum surface area of catalyst to the exhaust stream, while also minimizing the amount of catalyst required since they are very expensive.

d. Reactions in a Catalytic Converter:

It is not precisely understood how platinum and rhodium work as catalysts but technically, the catalytic converter's action involves two types of reactions:

- Oxidation Reaction.
- Reduction Reaction.

- Oxidation Reaction: In a Catalytic Converter un-burned hydrocarbons are oxidized to water and carbon dioxide.
- Reduction Reaction: nitrogen oxides are reduced back into nitrogen, the major component of air. The catalyst in this chamber makes this possible. The converter uses two different types of catalysts, a reduction catalyst and an oxidation catalyst.

The Reduction Catalyst:

The reduction catalyst uses Platinum and Rhodium to help reduce the NOx emissions. When an NO or NO_2 molecule contacts the catalyst, the catalyst rips the nitrogen atom out of the molecule and holds on to it, freeing the oxygen in the form of O_2. The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst, forming N_2.

For example: $2NO = N_2 + O_2$ *or* $2NO_2 = N_2 + 2O_2$

The Oxidation Catalyst:

The oxidation catalyst uses Platinum and Palladium to reduce the unburned hydrocarbons and carbon monoxide by burning (oxidizing) them over a catalyst. This catalyst aids the reaction of the CO and hydrocarbons with the remaining oxygen in the exhaust gas.

For example: $2CO + O_2 = 2CO_2$

The Control System:

The control system basically monitors the exhaust stream and takes this information to control the fuel injection system. To do this, the catalytic converter is equipped with an oxygen sensor that tells the engine's computer how much oxygen is in the exhaust. This allows the engine's computer to make sure that there is enough oxygen in the exhaust to allow the oxidization catalyst to burn the unburned hydrocarbons and CO.

In gasoline engines, catalytic converters are reliable and efficient at reducing pollution. They convert an estimated 90% of the hydrocarbons, carbon monoxide, and nitrogen oxides produced into less harmful compounds. However, catalytic converters are less efficient when used with diesel engines, which run colder than gasoline engines. Catalytic converters work best at higher temperatures [26].

Here, in catalytic converter applications, the system by itself is set with the catalyst to neutralize those harm full gases that comes from the engine before it reaches the silencer to be released to the atmosphere. So this component is used only for air emission reduction only than sound reduction.

DESIGN CONSIDERATIONS OF THE STUDY

The exhaust gas contains carbon di oxide, sulphur di oxide, carbon monoxide and other oxides of nitrogen. At full load, the temperature of the exhaust gas will lay anywhere between 500°c to 700°c.

The pressure of the exhaust gas depends upon so many factors:-

The design of exhaust gas manifold, magnitude of valve overlaps, engine speed, number of cylinders, the length of the exhaust gas flow path etc.

The design of exhaust gas manifold is very important in case of high speed diesel engines. In order to maintain the exhaust gas pressure within the required limits, the exhaust gas manifold is designed so that, the gases, which come out of the cylinder flows very smoothly, before it is let out into the atmosphere. This is absolutely essential in order to maintain the back pressure within safe limits, so that the engine can be kept at the optimum operating level. The back pressure, if it is allowed to exceed the pre-determined level, the effort on the part of the piston for scavenge is considerably increased and if so power is lost in performing the above, so, the primary consideration when introducing any modification in exhaust system does not and shall not increase the back pressure which drastically affect the performance characteristics of an engine. To be more precise, the speed of the engine is affected for a given specific fuel consumption rate and so the combustion characteristics of an engine are all affected. As a net result of the combustion is not proper and complete which results in the increased impurities or unburnt gases. This principle against the purpose of

introducing any system whose sole object is reducing the very toxic property of the exhaust gas. So in this study it is implied that the introduction of any system reduces the toxic property of the exhaust gas shall not result in any effects in the opposite direction. So by introducing any component in the system the flow path length and the resistance to flow are indirectly increased. So the increase of back pressure is inevitable unless the increase in magnitude compensated in the design of the component itself. Here in this study the exhaust gas has to pass through the water, which is filled in the scrubber tank. In any case, the outlet from the engine shall be kept below the water level in the scrubber tank for that the gas will pass through the water. The gas has no to push the water, in order to bubble through the water. Due to the high temperature, the exhaust gas is let out from the engine, some of the water particles which come in contact, readily changes its phase from liquid state to gaseous state (i.e. Steam which increases the net mass of the exhaust gas flow per unit time).

While, designing the system, have to be very careful so as not to increase the back pressure unduly which will affect the performance of the engine in the negative direction and so the constant of the exhaust gases. Hence, it is absolutely essential to make a provision for the measurement of back pressure in the system, so, that it can be controlled the same if necessary occurs. This ensures not only the safety, but enhances the performance of the system as a whole.

Back Pressure Limits

All engines have a maximum allowable engine back pressure specified by the engine manufacturer. Operating the engine at excessive back pressure might invalidate the engine life time specified by the manufacturer. To facilitate retrofitting of existing engines with Diesel Particulate Filters, especially using passive filter systems, emission control manufacturers and engine users have been requesting that engine manufacturers increase the maximum allowed back pressure limits on their engines.

Mufflers generally result in maximum back pressures in the range of 6 kPa. In exhaust systems with a DPF, the back pressure can rise to significantly higher levels especially if the filter is heavily loaded with soot. The Swiss VERT program determined maximum back pressure limits in order to allow DPFs to be fitted to a wide variety of equipment. Table below outlines the VERT recommended back pressure limits for a range of engines sizes. The

exhaust pressure for large engines was limited to low values due to valve overlap and high boost pressure considerations.

Table 1

VERT maximum recommended exhaust back pressure [18, 21]

Engine Size	**Back Pressure Limit**
Less than 50 Kw	40 kPa
50-500 Kw	20 kPa
500 kW and above	10 kPa

Engine manufacturers are usually much more conservative on their back pressure limits. For example, diesel generator set engines from Caterpillar, Cummins, John Deere and DDC/MTU ranging in size from 15 to over 1000 kW have back pressure limits ranging from 6.7 to 10.2 kPa.

In setting back pressure limits, many factors must be taken into consideration. These include the effect on turbocharger performance, exhaust emissions, fuel consumption and exhaust temperature. The limit that a particular engine can tolerate will depend on specific design factors and making general recommendations is difficult.

So it should take care while designing the aqua silencer for engine emission reduction purpose.

POLLUTION TYPES

Air pollution:

Air pollution is defined as the presence of one or more contaminants in the atmosphere such as dust, fumes gas, mist, odors, smoke or vapor in quantities, of characteristics, and of duration. So diesel engine, like other internal combustion engines, converts chemical energy contained in the fuel into mechanical power. It's obviously discussed that diesel fuel is a mixture of hydrocarbons which during an ideal combustion process would produce only carbon dioxide (CO_2) and water vapor (H_2O). Indeed, diesel exhaust gases are primarily composed of CO2, H2O and the unused portion of the engine charge air. The volumetric concentrations of these gases in diesel exhaust are typically in the following ranges:

CO2- (2 to 12%), H2O- (2 to 12%), O2- (3 to 17%) and N2 – balance.

In general the concentrations depend on the engine load, with the contents of CO2 and H2O increasing and that of O2 decreasing with the increasing engine load.

None of these principal diesel emissions (with the exception of CO2 for its greenhouse gas properties) have adverse health or environmental effects.

These pollutants are hazardous to human, plant as well as wild life and monuments. The pollutants with their effects on healthy may shortly discussed below.

Table

Adverse health effects of IC engine generated air pollutants.

Pollutants	**Short-term health effects**	**Long-term health effects**
Carbon monoxide CO	Headache, shortness of breath, dizziness, impaired judgment, lack of motor coordination.	Effects on brain and central nervous system, nausea, vomiting, cardiac and pulmonary functional changes, loss of consciousness and death.
Nitrogen dioxide NO_2	Soreness, coughing, chest discomfort, eye irritation.	Development of cyanosis especially at lips, fingers and toes, adverse changes in cell structure of lung wall.
Oxidants	Difficulty in breathing, chest tightness, eye irritation.	Impaired lung function, increased susceptibility to respiratory function.
Ozone O_3	Similar to those of NO_2 but at a lower concentration.	Development of emphysema, pulmonary edema Sulfates Increased asthma attacks reduced lung function when oxidants are present.
Sulfates	Increased asthma attacks	Reduced lung function when

SO_4		oxidants are present.
TSP/Respirable suspended particulate/.	Increased susceptibility to other pollutants.	Many constituents especially poly-organic matter are toxic and carcinogenic, contribute to silicosis, brown lung.

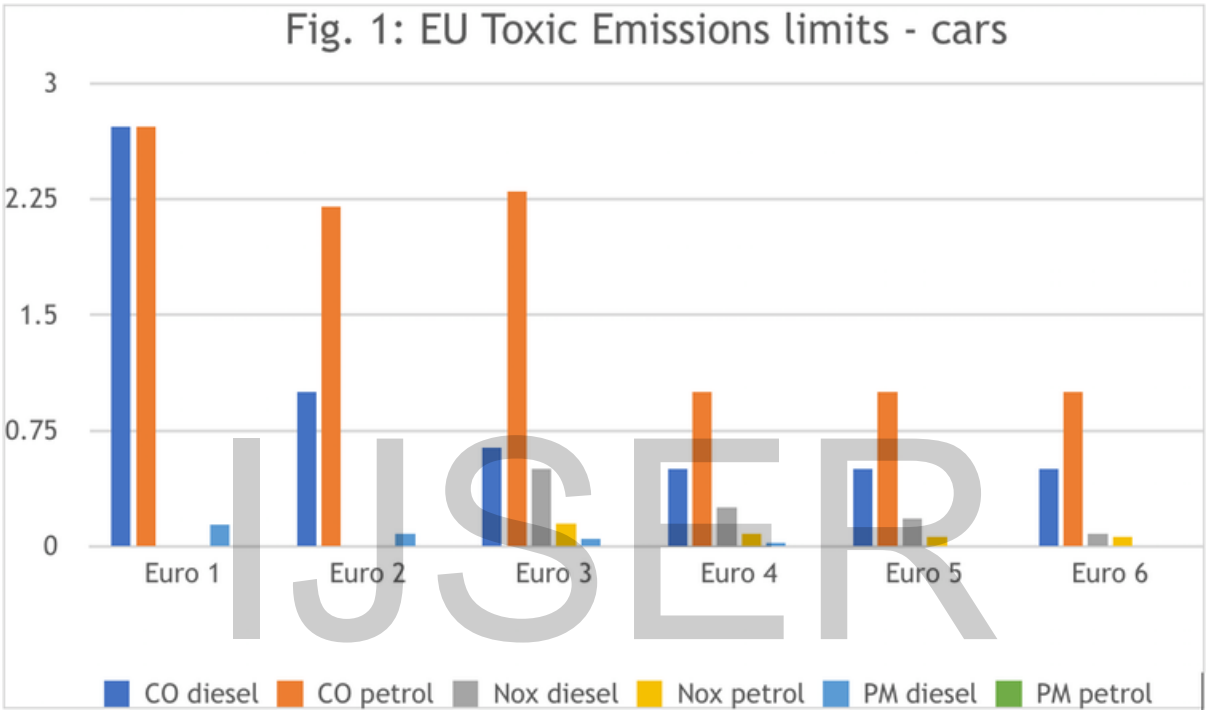


Fig. Comparison of diesel and petrol engine emission [17]

Due to incomplete combustion of the fuel, it produces more hydrocarbons which lead to air pollution. The noise and vibration problem is there in the CI engines. The maintenance cost of the CI engine is more as compared with the SI engines.

Sound pollution:

Noise pollution or noise disturbance is the disturbing or excessive noise that may harm the activity or balance of human or animal life. The source of most outdoor noise worldwide is mainly caused by machines and transportation systems, motor vehicles, aircraft, and trains. Outdoor noise is summarized by the word environmental noise. Poor urban planning may give rise to noise pollution, since side-by-side industrial and residential buildings can result in noise pollution in the residential areas.

MEASUREMENT OF SMOKE

Visual judgments of smoke levels are not possible due to light effects under varying conditions, e.g. the visual assessment depends on gas velocity and background. There are two basic types of smoke meters, which are used to measure smoke density. [19]

1) Filter darkening type,
2) Light extinction type.

The light extinction type of meters can measure both white and black smoke while, the filter paper type meters can give only black smoke readings. The light extinction meter can be used for continuous measurements while, the filter type can be used only under steady state conditions.

i. Bosch smoke meter

Borsch smoke meter is filter darkening type. A measured volume of exhaust gas is drawn through a filter paper, which is blackened, to various degrees depending upon the amount of carbon present in the exhaust. The density of soot is measured by determining the amount of light reflected from the sooted paper the diameter of the filter paper. The diameter of the filter paper, the sample volume, etc. all is well defined.

ii. Van Brand Smoke Meter

Van Brand Smoke Meter is also filter darkening type. The exhaust sample is passed at a constant rate through a strip of filter paper moving at a preset speed. A stain is imparted to the paper. The intensity of the stain is measured by the amount of light, which passes through the filter and is an indication of the smoke of light, which passes through the filter and is an indication of the smoke density of exhaust. Bosch and Van Brand smoke meters differ in the Bosch the amount of light reflected is the measure of smoke level while in the Van brand amount of light passing through the filter to indicate smoke level.

iii. Hartridge smoke meter

This smoke meter works on the light extinction principal. The continuously taken exhaust sample is passed through a tube of about 46cm length which has a light source at one end and photocell or solar cell at the other end. The amount of light passed through this smoke column is used as an indication of smoke level. This smoke density is defined as the ratio of electric output from the photocell or solar cell when sample is passed through the column to the electric output when clean air is passes through it. Smoke meter designed by using a three-way cock is used to pass clean air or exhaust smoke through the smoke meter column. A buffer space is provided so that smoke particles and vapor do not condense on the glass plates used. Instead of a conventional photocell, a number of solar cells are used. This makes

the instrument very sensitive and accurate. The output from the solar cell is fed to a micro voltmeter and light source is provided with control to vary the amount of light, if needed, because of any change in the tube characteristics due to prolonged used of the meter. This type of meter is useful for continuous testing and can be used in vehicle.

iv. UTAC smoke meter

This also works on the light extinction principle, but it differs from the Hartridge meter in that in this meter whole of the exhaust gas is passed through the meter to avoid any sampling error. However, this is not very suitable for large engines due to its prohibitive size. The U.S.A. Public Health Service (PHS) has also developed a similar smoke meter.

CONTROL OF SMOKE MECHANISMS

The above discussions clearly indicate that the only emission measuring method available, to control the smoke level of a diesel engine is as follows:

1. Derating

An engine can be derated by restricting its operation to lower levels of power production than normal for the given application. Derating reduces cylinder pressures and temperatures and thus lowers NOx formation rates. Although NOx exhaust concentrations (i.e., moles of NOx per mole of exhaust) are reduced, it is quite possible for this reduction to be no greater than the power decrease. In such a case, brake specific emissions (i.e. g/hp-hr) are not reduced. This is especially true for four-stroke turbocharged engines. In addition, air/fuel ratios change less with derating for turbocharged engines than for naturally aspirated or blower scavenged units. Thus NOx emissions are less responsive to derating for turbocharged engines. Derating also reduces the engine's operating temperature, which can result in higher CO and HC emissions.

One significant disadvantage of derating is that spare engine capacity may be needed which could require a large capital investment. For new engines, derating can be2-16 applied by designing the engine to operate under derated conditions. This could mean a larger, more expensive engine to do the same job. At lower loads the air fuel ratio obtained will be higher and hence the smoke developed will be less as already discussed. However this means a loss of output.

2. Maintenance

Maintaining the engine in a proper way especially the injection system will not only result in significantly reduced smoke but also keep the performance of the engine at its best. The other

methods are to change in combustion chamber geometry, fumigation, and use of smoke suppressant additives. The amount of equipment required achieving a reduction in some, which will taper off at higher speeds, at which most of the time the engine will run do not make it an attractive methods of smoke control especially when other methods of smoke control, like use of additives, are available. However, the strict air pollution regulations can expedite development in this direction.

3. Smoke Suppressant Additives

Some barium compounds if used in fuel reduce the temperature of combustion, thus avoiding the soot formation, and if formed they break it into fine particles, thus appreciably reducing smoke. However, the use of barium salts increases the deposit formation tendencies of engine and reduces the fuel filter life.

4. Catalytic mufflers

Unlike petrol engine the use of catalytic mufflers are not very effective. There is a very small effect on engine smoke. Such devices need much development before they can be used in practice.

5. Fumigation

Fumigation consists of introducing a small amount of fuel into the intake manifold. This starts pre-combustion reactions before and during the compression stroke resulting in reduced chemical delay because the intermediate products such as peroxides and aldehydes react more rapidly with oxygen than original hydrocarbons. This shortening of the delay period curbs thermal cracking, which is responsible for soot formation. It may even happen that cracking does not occur at all because it requires about 80 kcal/mole to beak a double bond C=C and this energy may not be available due to easy oxidation during pre-combustion reactions. The Fumigation rate of about 11 to 15 percent gives best smoke improvement. However, this improvement varies greatly with engine speed. At low engine speeds 50 to 80 percent smoke reduction is obtained. These decreases as speed increases until a speed at which there is no effect of fumigation.

1.2 Statement of the problem

Today our world is degraded by the environmental pollutions initiated from different factories and vehicles as a main polluting agent. So something what is expected from human being to save this world is creating the solution in whatever good and easy mechanism. Here in this study it’s dialed with emission reduction mechanisms due to the environmental pollution what’s observed around my living area by introducing the machine component

called hybrid aqua silencer. The reason why we go for aqua silencer is, in today life the air pollution causes physical ill effects to the human beings and also to our environment. The main contribution of the air pollution is exhausts from automobile like carbon dioxide, unburnt Hydrocarbon, etc. In order to avoid these types of gases by introducing this aqua silencer is very essential at this moment. An aqua silencer system is designed to replace conventional single unit engine silencers on board structures. With somewhat light weight and slender design, it offers a minimal target point while optimizing the entire exhaust system for low noise and keep back pressure as it is. It is used to control the noise and emission in IC engines. It is fitted to the exhaust pipe of the 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. The emission can be controlled by using the activated charcoal layer and it is highly porous and possesses extra free vacancies so it has high absorption capacity. So that, I will try to reduce the size of silencer as much as possible and not affects the weight of vehicle using some experimental chemicals inside the components.

1.3 Objectives

1.3.1 General Objective

The general objective of this thesis is to design and analyzes the effectiveness Hybrid Aqua Silencer for emission controlling system of vehicles.

1.3.2 Specific Objectives

The specific objectives are:

- To study the existing silencer.
- To design and model the new study.
- To prepare the part and assembly drawing of the system using AutoCAD.
- To prepare the prototype for demonstration.
- To test the functionality of the designed system and
- Compare the effectiveness with the Conventional system.

1.4 Significance of the thesis

The significance of the proposed thesis work will be assumed as the following:

- Reduce the sound emission and the air emission.
- It’s economical compared with the conventional silencer.
- Since it can be made from local material it’s Easy to maintain.

1.5 Beneficiaries

Automotive industries, vehicle owners, researchers, society and country as a whole get benefitted with this work.

1.6 Delimitation (Scope)

It is clear that somewhat the weight of the vehicle slightly increases and it takes more space because of the components than the existing system. So this thesis will be limited in modeling and analysis for FOUR STROKE SINGLE CYLINDER ENGINE AIR EMISSION.

1.7 Structure of the thesis

The scope of the research is confined to develop a machine called aqua silencer for single cylinder diesel engine and check the effects by comparing with the existing silencer. Here the main target is not only the sound problem on the engine rather it concerned with the air emission/depletion/. The thesis will be organized and structured accordingly and it's detailed below:

Chapter -1: Introduces about the silencer and give some hints about the existing material that was used before with their components for more description. Not only this one here also the newly designed machine is also introduces in couple.

Chapter -2: discusses the review of literature in silencer. It deals with the literature related to mechanisms used for emission reduction in simple and locally existing material without affecting the cost and using small amount of chemicals for that purpose. In other way it covers the application of the exhaust emission reduction material called catalytic converter, (i.e. here in hybrid aqua silencer it's tried to eliminate the catalytic converter.)

Chapter -3: discusses on materials and methodologies of the thesis. The overall specifications of the vehicle needed such as weight specifications, engine specifications and silencer specifications with the material properties and reaction takes place in that components is discussed. The CAD model of the hybrid aqua silencer also developed.

Chapter -4: Deals with the theories and design constraint and parameters such as overall size of silencer (i.e. length, width, volume), back pressure, pipe length and diameter). In this chapter the analyses have been done for this thesis will be discussed.

Chapter -5: deals with the conclusion and recommendation depending on the result obtained from the analysis.

CHAPTER TWO

LITERATURE REVIEW

The research over the introduction and development of aqua silencer is very rare. However few researchers have worked over reduction of noise and emission in silencer and catalytic converter respectively. But, the muffler is engineered as an acoustic sound proofing device design to reduce the loudness of the sound and catalytic converter for environmental air emission in respective of the engine type and capacity. Below are some of the reviewed literature has been done by some researchers:

Sarah Raj et al. discussed about silencer types in that the combined resonance and absorber type is the more effective type. In that project they made model and carried out the analysis. The outcome of this experimental analysis was that twin filter silencer is more effective and the water contamination was found to be negligible in aqua silencer [1].

P.Balashunmugam et al the researchers carried out the analysis in which how the lime stones are originally intended to reduce the toxic ingredients of the exhaust, gas through chemical reaction. It is evidently affected the flow of resistance and hence the combustion characteristics of the engine will finally contribute the increased toxic ingredients of the exhaust gas. Because of the introduction of the scrubber, the net length of the exhaust gas flow path is also increased which is again, against the original intention according to the study they conclude that water in scrubber tank can itself play an important role in absorbing the obnoxious products of combustion like the oxides of nitrogen. NO is converted into NO_2 after emission which highly toxic is mainly absorbed in the water scrubber [2].

Rahul.s.padval et al the investigator has found in their experiment of an aqua silencer that water in a silencer reduces the sound. The system is very cheap and is use for four and two wheelers. The performance of twin silencer is almost equivalent to the conventional silencer [3].

Alen.M.A et al the researchers has investigated that how emission can be controlled by the activated charcoal and lime water. They compared the results between simple silencer and silencer with lime water and activated charcoal layer. They conclude that the silencer is more effective in the reduction of emission gases from the engine exhaust using perforated tube, lime water and charcoal layer. By using perforated tube the back pressure will remain

constant and fuel consumption remain constant and sound level is reduced. Also by using activated charcoal in water we can control the exhaust emission to a greater level it is smokeless and pollution free emission equivalent to the conventional silencer [4].

S. Martin et al. the experimenters have designed a muffler for sound attenuation. A passive muffler is categorized as either a reactive or a dissipative muffler dependent on two different mechanisms used to reduce engine noise. A reactive muffler is designed to reflect sound back to the engine compartment by introducing area discontinuities (like expansion or contraction in a duct), branches (like resonator) and flow reversals. This design provides a good sound attenuation for low to moderate frequency bands [5].

Rohit Thakre et al has done the research of Aqua Silencer as it can be said that it is an advanced system which can be used along with or instead of a catalytic converter, using which exhaust emissions at tail pipe of an exhaust system can be easily lowered than specified levels, along with reducing undesirable noise at tail pipe. Also, the use of water decreases overall temperature of exhaust gases coming out via tail pipe, which may add to greenhouse gases. Overall emissions at tail pipe which contains harmful constituents like lead (Pb), carbon monoxide (CO), oxides of nitrogen (NOx) & un-burnt hydrocarbons (UBHC) can be lowered than existing levels using adsorption method, which uses activated charcoal to adsorb these harmful constituents [6].

Dr.P.K.Sharma et al the investigator of An Aqua Silencer said that it is fixed to the exhaust pipe of engine. The noise and smoke level is considerable less than the conventional silencer, it is inexpensive, no need of catalytic converter and easy to install. Air pollution can be defined as addition to our environment of any material, which will have a dexterous effect on life upon our planet. The main pollutants contribute by automobile are carbon monoxide (CO), unburned hydrocarbon, oxides of nitrogen (NOx) and Lead [7].

Santosh Kumar et al here they have done the experiment which basically consists of a perforated tube which is installed at the exit of the exhaust from the engine, which may have holes of variable diameters. This is done to divide the gas molecules of large proportions to form gas molecules of smaller diameter. Theoretically, four or more sets of holes are made on the perforated tube using drilling. The other end of the perforated tube is sealed using a plug. A small coating of activated charcoal is provided all around the perforated tube using inner cylinder which holds the charcoal in place and separates the charcoal and lime water from the

water in the Aqua Silencer. This unit is then placed in a container in which water is filled to a certain level [8].

Keval I. Patel et al the researcher made a complete study of how actually an aqua silencer works and made conclusions accordingly. The use of aqua silencer in reduction of toxic gases and noise versus the benefits that this silencer can give by their use is explained in this extract. The system under study consists of three units: a perforated tube, a charcoal layer, water. The procedure they follow may be first a perforated tube is installed at the end of the exhaust pipe. That perforated tube consists of number of holes of different diameters 8 mm, 4 mm and 2 mm. The water inlet, outlet and exhaust tube was provided in the shell. Using Adsorption method the Result have gotten were sound is reduced, CO is reduced 60 to 70 % compared to ordinary silencer, Engine efficiency increases with increase in flow rate of fluid, and it has Low cost. It gives smokeless and pollution free emission [9].

Akhil Anil Kumar et al The researchers did a complete investigation and analysis of how Aqua Silencer can affect the noise and toxic emission reducing capacity of an engines and explained the applications of engines with aqua silencer. A complete study of aqua silencer was made which included analysis of their work, structure and also their toxic emission and noise reduction capacities. Performance comparison of simple silencer, silencer with activated charcoal and silencer with activated charcoal and lime water was made. Aqua silencer is thermally effective and technically feasible for use as reduction noise and toxic emission of engine but certain improvements in the working of aqua silencer to fit in the application with the engine exhausting unit is essential. Lime water plays crucial role. Materials used for operations are, Perforated tube with activated charcoal, Aqua silencer (box type), and they have done analysis engine exhaust first with aqua silencer and second without aqua silencer. Increase in less toxic emission and noise reduction capacity and efficiency by the use of aqua silencer. [10].

Parikshit K. Patel et al here the investigators have prepare the experimental setup and study was been carried out in order to check the systems performance with the use of perforated tube in aqua silencer. The study aimed at bringing in ideas to reduce toxic emission and noise. The experimenter integrated an aqua silencer directly to exhaust of engine and studied the effect of such an alignment of aqua silencer on this operating constant exhaust system. For this study charcoal layer which was directly wrapped around the perforated tube were selected and tested. The effects of the charcoal layer for absorbing toxic gases and dissolving in water were checked. Also description about the mesh characteristics of this type of

applications with the use of perforated tube in aqua silencer is given. Use of perforated tube's enhanced the systems performance. More the perforated tube diameters lesser the turbulence and contour. Study on the aqua silencer's shows that the use of perforated tube with charcoal layer proved to be more beneficial. Use of perforated tube in aqua silencer has a great effect on the system. Perforated tube reduces the sound and kept the constant back pressure [11].

Maruthi Prasad Yadav et al the researchers made a complete study on performance of different types of silencers and analysis of how aqua silencer can work also explained the some applications with aqua silencers. A complete study of aqua silencer (box type) was made which included analysis of their characteristics, performances and also their emission tests. Performance comparison of diesel engine with and without aqua silencer was made. Aqua silencer is thermally effective and technically feasible for use as noise and toxic gases reduction. Tests were performed to investigate the effect of black smoke and NOx emissions and sound from exhaust gases. It was found that after implementing the aqua silencer engine tended to eliminate NOx emissions and sound completely. [12].

P K Pavan Kumar et al they investigated that, the exhaust pipe coated with 20% activated carbon and refractory with baffles shows least HC emissions. When compared with the conventional exhaust pipe 66% of HC emissions are reduced due to the chemical adsorption of HC by the activated carbon. The chemical reaction oxidizes the hydrocarbon to carbon dioxide and water. There is also importance for the baffles as there is more surface area for adsorption of HC. Different chemical compounds can be used in various design of exhaust pipe to reduce the emissions from the exhaust gases by the works carried out in this regard. Work on an exhaust pipe coated with refractory and activated carbon is carried out and emission tests on the two stroke engine are carried out, results showed that the composition of 20% activated carbon and 80% refractory reduced the CO and HC emissions considerably. [13].

Anubhav Yadav et al have done the experiment on charcoal based exhaust systems. The main pollutants emitted by the vehicles are CO, HC, NOx and sox. Automobiles are responsible for 80% of total co emissions, 36% of HCS, 44% of NOx, 4% of SOx and 18% of particulate matter. They have used activated charcoal and silica gel as it has a property of adsorption. This property is very useful as when various carbon and nitrogen content passes through it, it sticks to its surface, reacts with it and results in release of non-pollutant gases. According to our theoretical analysis and practical approach we found that our system efficiently reduced the percentage of harmful content from the automobile exhaust system.

Testing of their project at PUC centre on Honda Shine 125cc Engine on 13 October 2017 PUC Report shows that the System successfully reduces the cox and HC at the respective rates. [14].

Vijayabalan P et al In this experiment they have successfully controlled emission of carbon dioxide from the diesel operated engines, which is about 9.266% of the overall emission from a vehicle. AVG gas analyzer is used to measure the content of gases and their percentage. Through this other gases has also been controlled like hydro carbon, nitrogen, carbon monoxide and particulate matter. [15]

Ali Azam et al the researcher explains about diesel engines, like their low-operating cost, have high efficiency; reliability and durability because of this type of engines are especially used for heavy duty vehicles. The diesel motors are considered as the principle donor to ecological contamination these days. They are the main cause of several health problems. They contribute to global warming through Particulate Matter, Hydrocarbons (HC), Nitrogen Oxides (NOx) and Carbon Oxides (COx) emissions. Their presence causes a number of respiratory diseases. Various effective techniques are currently available for reducing PM, HC, COx and NOx. [20]

Figure: (a) and (b) exhaust smoke.

Rashid Ali et al He investigated the contents of diesel engine emissions and dialed with particulate matters by saying, PM 2.5 are a mixture of solid particles and liquid droplets in the air. Because of its small size, fine particulate matter can be deposited deep in the lungs where it can cause health problems. Studies have shown an association between particulate matter and premature mortality from respiratory and cardiovascular disease and increased incidence of respiratory illness particularly in children and the elderly. For adults with heart or lung conditions, exposure to fine particulate matter can cause more illness and in some cases premature death. More than 90% of the particulates found in diesel exhaust are fine particles. [16]

Nikolas Hagemann et al they validated that Activated charcoal was initially "any form of carbon capable of adsorption". Lastly they generalize from their review historically used activated charcoal functions, it began with the use of charcoal as a sorbent being traced back to both the Roman and Chinese Empire, and potentially even further. From that the researcher validates how Romans realized that charcoal can purify water; a property we still utilize. However, despite this long history of charcoal's use for purification, it took humans over 3000 years to optimize charcoal for the removal of specific contaminants [27].

In general from those reviews I have observed that, the researchers only concerned with emission parts, they do not concerned that much on the size. So as much as possible I will try to diminish the size what they are using before. Additionally since this technology is not developed in our country, I am the first to transfer this technology here.

CHAPTER THREE

MATERIAL AND METHODS

3.1 Materials

S NO.	COMPONENTS	MATERIALS
1.	Outer shell/cover/	Stainless steel
2.	Lime water	Water and lime powder
3.	Perforated tube	Stainless steel
4.	Non return valve	Steel
5.	Pipe	Stainless steel
6.	Activated carbon	Charcoal
7.		

STAINLESS STEEL

The materials used for this project is corrosion resistant and machinable. The same material of stainless steel is used in the project for all project components. The projects were subjected to drilling, grinding and welding so the material is selected by considering following aspects. Corrosion Resistance: stainless steel is alloy having chromium content in it which is corrosion resistive in nature. Hence the stainless steel is used for aqua silencer.

Electrical And Thermal Conductivity: Stainless steel is an excellent heat and electricity conductor and in relation to its weight is almost twice as good as copper. This has made stainless steel the most commonly used material to make for implementation of practical use.

Reflectivity: Stainless steel is a good reflector of noticeable light as well as heat, and that together with its low weight makes it an ideal material for reflectors in, for example, light fittings or rescue blankets.

Ductility: Stainless steel is ductile and has a low melting point and density. In a liquid condition it can be processed in a number of ways. Its ductility allows products of Stainless steel to be basically formed close to the end of the product's design.

Odorless: Stainless steel is the metal itself is non-toxic and releases no odours or taste substances which make it ideal for packing sensitive product's design.

Recyclability: Stainless steel is 100 % recyclable with no downgrading of its qualities. The re-dissolving or re-melting of Stainless steel requires little energy only about 4 percent of the energy required to produce the primary metal initially is needed in the reprocessing process.

Weld ability: Stainless steel has high degree of weld ability. Hence it is used in many industrial applications. The above main properties of stainless steel make it more crucial material. So as a general stainless steel has a good property to attain for the expected components of aqua silencer [7].

ACTIVATED CARBON/charcoal/

Activated carbon, also called activated charcoal, or activated coal, is a form of carbon processed to have small, low-volume pores that increase the surface area presented for adsorption or chemical reactions; activated is sometimes substituted with active.

Due to its high degree of micro porosity, just one gram of activated carbon has a surface area in excess of 450 m^2, as determined by gas adsorption. An activation level sufficient for useful application may be attained solely from high surface area; however, further chemical action often enhances adsorption properties. Activated carbon is usually derived from charcoal and is sometimes utilized as bio char.

Activated carbon: It is material of very high surface area made up of millions of pores and is well known as "molecular sponge."

Properties of activated carbon:

- High surface area,
- Very low density and
- High adsorbing capacity (especially hydrocarbons) [23].

The AQUA SILENCER is fully based on use of water in it, here the exhaust gases get dissolved in water and the remained gases get accumulate in Activated carbon and finally we got processed gasses.

THERMAL PROPERTIES OF WATER:

Maximum density - 1000 kg/m3

Specific weight - 9.80 KN/m3

Freezing point - 0 ^{0}C

Boiling point - 100 ^{0}C

Latent heat of melting - 334 KJ/Kg

Latent heat of evaporation – 2.270 X 103 KJ/Kg

Specific heat - 4.187 KJ/Kg °K

Thermal expansion – 4 ^{0}C to 100 ^{0}C

Perforated tube /plate/

The perforated tube consists of number of holes of different diameters. It is used to convert high mass bubbles to low mass bubbles. The charcoal layer is pasted over the perforated tube. Perforated tube is tube generally made up of stainless steel and have holes punched or drilled around its periphery. These tubes are provided to guide the flow and hence their main function is to reduce the backpressure of the engine. However, with the appropriate design of perforated tube it is possible to increase the transmission loss of the muffler.

Backpressure is essential for the performance of a silencer. Pressure drop of exhaust system includes losses due to piping, silencer, and termination. The most critical component regarding backpressure of any commercial muffler is cross flow perforated tube in which the diameter of the perforated tube hole and porosity of the perforations are most critical. If the diameter of the hole increases the backpressure decreases sharply by 40%. The change in diameter of holes has remarkable effect on back pressure.

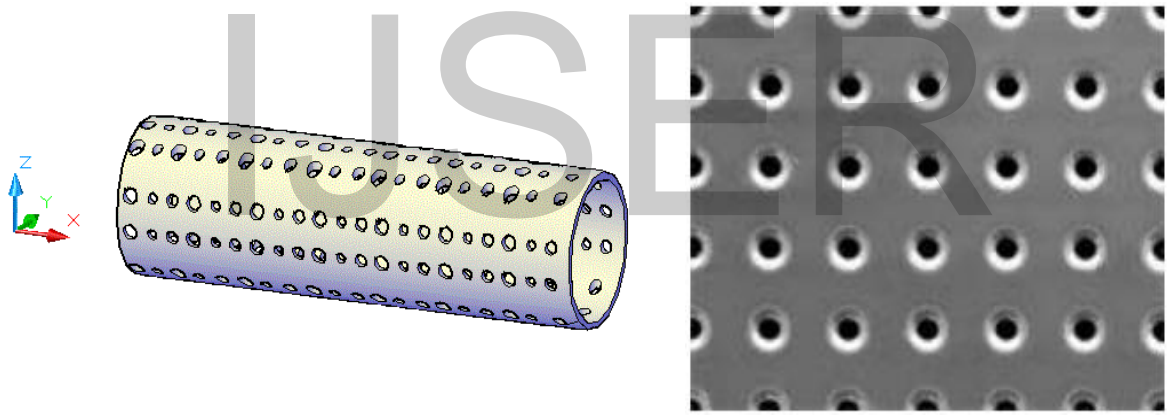


Fig. perforated tube and plate

Charcoal Layer:

The charcoal layer has more absorbing capacity because it has more surface area. This charcoal is called as activated charcoal. It is produced by heating the charcoal above 1500 ^{0}c for several hours in a burner. Its surface area gets increased. Charcoal may be activated to increase its effectiveness as a filter. Activated charcoal readily adsorbs a wide range of organic compounds dissolved or suspended in gases and liquids. In certain industrial processes, such as the purification of sucrose from cane sugar, impurities cause an undesirable colour, which can be removed with activated charcoal. It is also used to absorb odours and toxins in gases, such as air.

Fig. charcoal layer

Lime powder:

Saturated solution of calcium hydroxide is known as Lime water. Some amount of Calcium hydroxide $Ca(OH)_2$ is soluble in water (1.5 g/L at 25 °C). Pure limewater is crystalline, odorless and colorless. Limewater is prepared by stirring allowable calcium hydroxide in pure water, and filtering off the allowable insoluble $Ca(OH)_2$. When calcium hydroxide particles dissolve in pure water then it looks like milky, hence its name known as milk of lime. It is an alkaline solution (with a pH of 12.3).

Fig. Lime powder

Outer Shell

The whole setup was kept inside the outer shell. It is made up of iron or steel. The water inlet, outlet and exhaust tube was provided in the shell itself. Material selection of the outer shell is the crucial parameter because of the consideration of heat conductivity, corrosiveness and cost.

Requirement of good shell material:

1. It should be heat conductive.
2. The thermal conductivity of material must not be high enough so that it will liberate all of its heat and will cause less effective temperature for necessary reactions.
3. The material should have good resistance to corrosiveness and erosion.

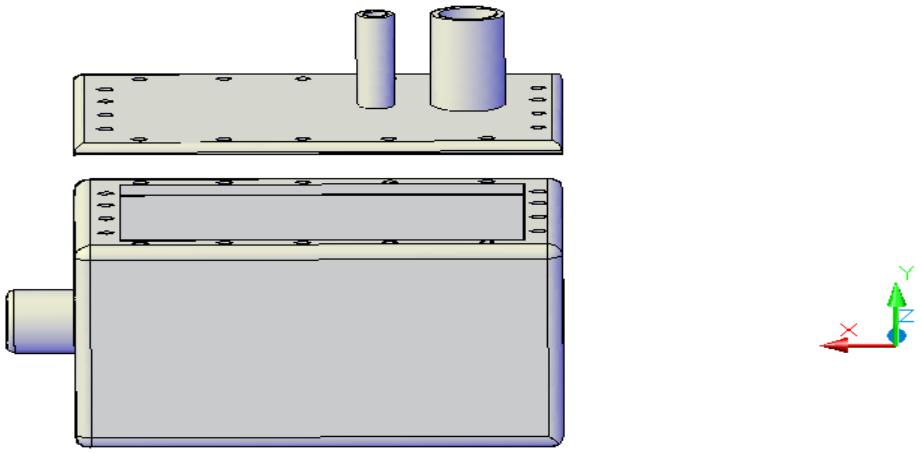


Fig. Outer shell

Non return valve:

The non-return valve is a mechanical device a valve, which normally allows fluid (liquid or gas) to flow through it in only one direction.

They have two ports, one as an inlet for the media and one as the output for the media. Since they only allow media flow in one direction, they are commonly referred to as ‘one way valves’ or ‘non return valves.’ The main purpose of a check valve is to prevent backflow in the system. Figure 1 shows an example of a check valve.

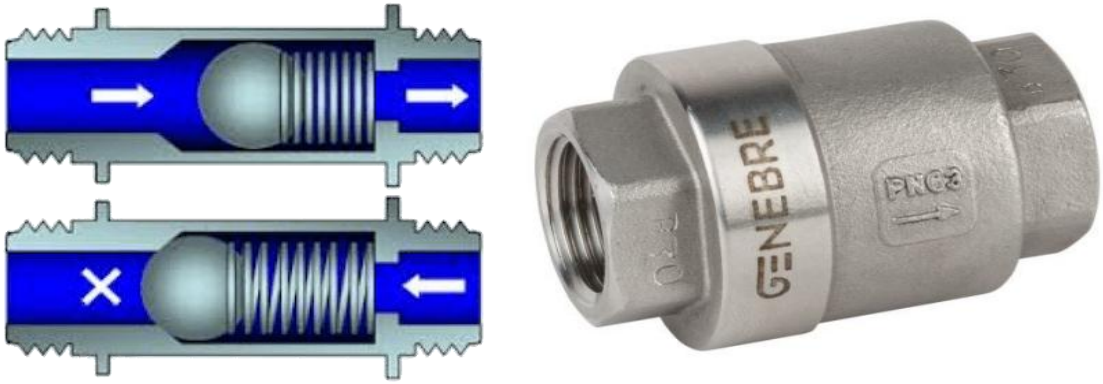


Fig. Non return valve

Here in other way it is check valve relies on a pressure differential to work. They require a higher pressure on the input side of the valve than the output side to open the valve for operation of the needed capacity and direction. When the pressure is higher on the outlet side (or the input side pressure is not high enough), the valve will close. Depending on the valve type, the closure mechanism is different. Unlike other valves, they do not need a handle, lever, actuator, or human to correctly work. They are commonly installed in applications that where backflow would cause an effective issue. However, since they are non-return valves, they are a cheap, effective, and easy solution to solve a potential issue. Backflow can cause an issue if the backflow is contaminated, and therefore, contaminates the media upstream. For example, in this study inlet of the exhaust to the outer shell of aqua silencer it will have a non-return valve to ensure that waste can leave but not re-enter to the pipe from the exhaust manifold. They are also used if backflow will cause damage to equipment upstream that can only allow media to flow in one direction. There are various sizes, designs, and material to ensure there is a check valve for every application. An important concept in check valves is the cracking pressure which is the minimum upstream pressure at which the valve will operate. Typically the check valve is designed for and can therefore be specified for a specific cracking pressure.

The Aqua silencer was filled with water and it is directly connected to the exhaust pipe of the engine. There is a chance for the water to get enter into the engine cylinder through the exhaust manifold pipe. To avoid this, Non return valve is used. It allows the flow of fluid in one direction only.

METHODS

In this Pollution Control Aqua Silencer when the exhaust gases enter into the Pollution Control Aqua Silencer, the perforated tube converts high mass bubbles after that they pass through a charcoal layer which again purifies the gases. It is highly porous and possesses extra free valences so it has high absorption capacity. After passing through the charcoal layer some of the gases may dissolve into the water and finally the exhaust gases escape through the opening into the atmosphere.

Methods to Avoid Water Pollution in Aqua Silencer:

a) Lime Water Wash Method:

The water is treated with the calculated quantities of slaked lime. Lime can neutralize any acid present in the water, SO_2 gases are removed from the flue gases forming calcium sulphite $CaSo_2$. The precipitates dissolved carbon dioxide as calcium carbonate and converts bicarbonate ions into carbonates

Effects of dissolved gases on water:

The water is a best absorbing medium to use in silencer for dissolve toxic gases in water and reduce it completely. After these gases dissolved in water they form acids, carbonates, bicarbonates etc.

 Action of dissolved SO_2:

When SOx is mixed in water, it form SO_2, SO_3, SO_4, H_2SO_4 i.e. sulfur Acid (H_2SO_3), it forms Hydrogen Sulphide which causes carious egg smell, acidify and corrosion of metals.

 Action of dissolved CO_2:

The dissolved carbon dioxide forms Carbonates and Bicarbonates at lower and higher pH. This levels in between 40-400 mg/lit. When carbon dioxide mixes with water it form Carbonic acid and it is corrosive to metals and also causes greenhouse effect.

 Effect of dissolved NOx:

The NOx in exhaust gas under goes Oxidation to form Nitrate, Nitrite, Nitric acid, ammonia. This synthesis of protein and amino acids is affected by Nitrogen. Nitrate usually occurs in trace quantities in exhaust gas. [10]

ADSORPTION PROCESS:

Adsorption is the adhesion of atoms, ions or molecules from a gas, liquid or dissolved solid to a surface. This process creates a film of the adsorbate on the surface of the adsorbent. This process differs from absorption, in which a fluid (the absorbate) is dissolved by or permeates a liquid or solid (the absorbent), respectively. Adsorption is a surface phenomenon, while absorption involves the whole volume of the material. The term sorption encompasses both processes, while desorption is the reverse of it.

Similar to surface tension, adsorption is a consequence of surface energy. In a bulk material, all the bonding requirements (be they ionic, covalent or metallic) of the constituent atoms of the material are filled by other atoms in the material. However, atoms on the surface of the adsorbent are not wholly surrounded by other adsorbent atoms and therefore can attract adsorbates. The exact nature of the bonding depends on the details of the species involved, but the adsorption process is generally classified as physisorption (characteristic of weak van der Waals forces) or chemisorption (characteristic of covalent bonding). It may also occur due to electrostatic attraction.

Adsorption is present in many natural, physical, biological and chemical systems and is widely used in industrial applications such as heterogeneous catalysts, activated charcoal, capturing and using waste heat to provide cold water for air conditioning and other process requirements (adsorption chillers), synthetic resins, increasing storage capacity of carbide-derived carbons and water purification. Adsorption, ion exchange and chromatography are sorption processes in which certain adsorbates are selectively transferred from the fluid phase to the surface of insoluble, rigid particles suspended in a vessel or packed in a column. Pharmaceutical industry applications, which use adsorption as a means to prolong neurological exposure to specific drugs or parts thereof are lesser known.

Activated carbon is used for adsorption of organic substances and non-polar adsorbates and it is also usually used for waste gas (and waste water) treatment. It is the most widely used adsorbent since most of its chemical (e.g. surface groups) and physical properties (e.g. pore size distribution and surface area) can be tuned according to what is needed. Its usefulness also derives from its large micropore (and sometimes mesopore) volume and the resulting high surface area.

Activated charcoal possesses high adsorption capacity because of its granular or powdered form. As it is highly porous and possess free valances. Activated carbon is mainly used for

the removal of taste and odorous from the public water supplies. Because it has excellent properties of attracting toxic gases, finely divided solid particles and phenol type impurities, the activated carbon, usually in the powdered form is added to the water either before or after the coagulation with sedimentation. Hence,

Pollution Control Aqua Silencer reduces noise and pollution. In these chemical reaction involved is as follows:

Reaction: 1

The obnoxious product of combustion is NOx – the oxides of Nitrogen. Water will absorb the oxides of Nitrogen to a larger extent.

The following chemical reaction will enhance the proof, for the above statement.

$$NO + 2HO_2 \rightarrow 2HNO_2 + 2HNO_3 \text{ (Diluted)}\ldots\ldots\ldots\ldots\ldots I$$

Reaction: 2

If a small amount of lime water is added to scrubber tank, the further reaction takes place as follows:

$$Ca\ (OH)_2 + 2HNO_3 \rightarrow Ca\ (NO_3)_2 = 2H_2O$$

$$Ca\ (OH)_2 + 2HNO_3 \rightarrow Ca\ (NO_2)_2 + 2H_2O\ldots\ldots\ldots\ldots\ldots II$$

Reaction: 3

When the carbon dioxide present in the exhaust gas comes in contact with the limewater, calcium carbonate will precipitate. The calcium carbonate when further exposed to carbon dioxide, calcium-bi-carbonate will be precipitated. The following is the chemical reaction [1].

$$Ca\ (OH) + CO_2 \rightarrow CaCO_3 = H_2O$$

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca\ (HCO_3)_2\ldots\ldots\ldots\ldots\ldots III$$

Reaction: 4

The sulphur dioxide present in the diesel exhaust also reacts with the limewater. But the small trace of sulphur dioxide makes it little difficult to measure the magnitude of the chemical reaction, accurately. The following equation gives the chemical reaction and calcium sulphate will precipitate.

$$Ca\ (OH)_2 + SO_2 \rightarrow CaSO_3 + H_2O\ldots\ldots\ldots\ldots\ldots IV$$

Reaction: 5

$$CaCO_3 + SO_2 + H_2O \rightarrow CaSO_3 + CO_2 + H_2O\ldots\ldots\ldots\ldots\ldots V$$

From calcium carbonate, calcium sulphate will precipitate and CO_2 will be a by-product. Because of the small percentage and SO_2 presence, the liberation of Carbon dioxide is very less. But the liberated CO_2 will again combine with $CaCO_3$ to form calcium bicarbonate as mentioned in equation 5.

DESIGN CALCULATIONS

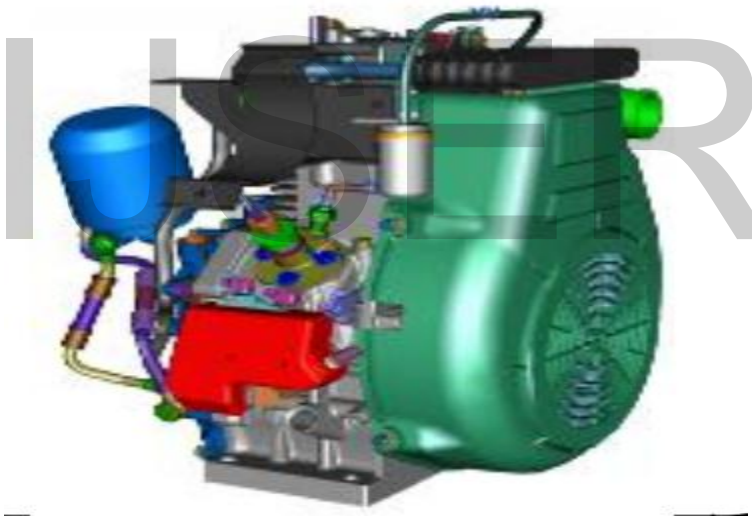
Technical specifications: vehicle

S. NO	DESCRIPTION	VALUE (Unit)
1.	Length	3230 mm
2.	Width	1493 mm
3.	Height	1818 mm
4.	Wheel base	2125 mm
5.	Rear track	1250 mm
6.	Minimum ground clearance	193 mm
7.	Max. grade ability in 1st gear	18% (10.2deg.)
8.	Vehicle kerb weight	518 kg
9.	Maximum gross vehicle weight in kg	990 kg
10.	Tray size (L*W*H)	1650*1425*275 mm
11.	Fuel capacity	8 litres

Fig. Three wheeler bajaj maxima

ENGINE: 4 Stroke, Forced Air & Oil cooled CI engine with 5 Speed transmissions.

S. NO	Description	Value
1.	Engine type	4stroke forced air & oil cooled C.I Engine
2.	No of cylinders	One
3.	Bore	86 mm
4.	Stroke	77 mm
5.	Engine displacement	447.3cc
6.	Compression ratio	24+/-1:1
7.	Max. Engine power	6.62kw at 3400 engine rpm
8.	Max. Torque	23N.m at 2000 engine rpm
9.	Idling speed	1250+/-150rpm



To find fundamental frequency,

Cylinder firing rate:

$$CFR = \frac{RPM}{60}$$ – For two stroke engine.

$$CFR = \frac{RPM}{2\times60}$$ – For four stroke engine.

So using for four stroke single cylinder Engine:

$$\text{CFR} = \frac{\text{RPM}}{120} = \frac{3400}{120} = 28.33$$

Engine firing rate (EFR):

$$EFR = Number\ of\ cylinder \times CFR$$

$$\text{EFR} = 1 \times 28.33 = 28.33$$

Muffler volume calculations:-

Swept volume (Vs):

$$Vs = \frac{\pi}{4} \times D^2 \times L$$

$$\text{Vs} = \frac{\pi}{4} \times 8.6^2 \times 7.7 = \underline{0.44705}\ \text{litre}$$

Volume to be consider for calculations,

$$Volume = Number\ of\ cylinder\ \times \frac{Vs}{2}$$

$$\text{Volume} = 11 \times \frac{0.44705}{2} = 0.2235\ litre$$

Silencer volume (Vm):

$$Vm = Factor\ \times Considered\ volume$$

$$\text{Vm} = 25 \times 0.2235\ ltr = 5.59\ ltr.$$

i.e. Volume can be changed on the space constraints.

Diameter of muffler calculated as:

$Vm = \frac{\pi}{4} \times d^2 \times l$ from this equation,

$$d = \sqrt{(Vm \times 4)/(\pi \times l)}$$

$$d^2 = \frac{5588140.25\ \times 4}{\pi \times 500} = 14237.3mm^2$$

$$\text{d= } \underline{119.32\text{mm}}$$

Here '*l*' can be determined from different research and as per the size. So that, in this study it is 500mm.

The time necessary to process one reactor volume of gases is as follows:

Calculation for determination of diameter and length:

$$Space\ velocity = \frac{Volume\ of\ flow\ rate}{Catalysts\ volume}$$

Space Velocity: The space time necessary to process one reactor volume of fluid.

Assuming space velocity for single cylinder engine =2000/hr.

Volume flow rate = Swept volume × Number of intake stroke per hour

$$Volume\ flow\ rate = \frac{\pi}{4} \times d^2 \times l \times \frac{rpm}{2} \times 60$$

$$\text{VFR= (0.44705 ltr)} \times (3400/2) \times 60$$

Volume of Catalyst:

$$Catalysts\ volume = \frac{Volume\ flow\ rate}{Space\ velocity}$$

Space velocity = Volume flow rate/Catalyst volume

……. **Calculation continues**….

Thermodynamic properties

Thermodynamic properties of diesel fuel combustion in the cylinder and the output exhaust chemistry may be expressed as follow. The chemical formula for diesel fuel can be shown as $C_{12}H_{24\ OR\ 23}$. So when this fuel combusted in the engine it produces power for vehicles to run the piston.

Combustion of diesel fuel can be:

$$4C_{12}H_{24} + 36O_2 = 12CO_2 + 12H_2O + ENERGY$$

Diesel + oxygen = carbon dioxide +water + energy

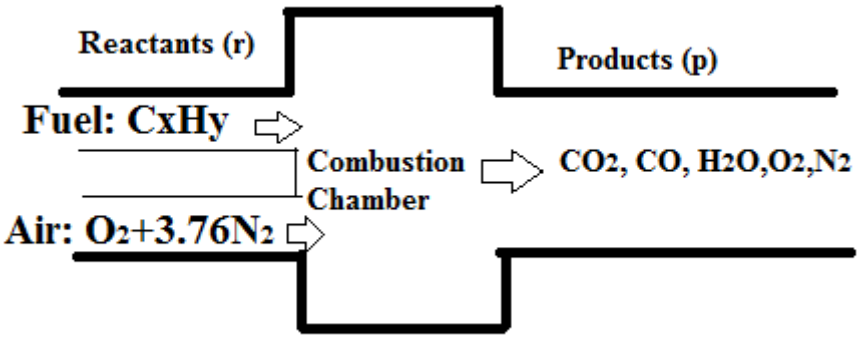
Combustion reactions are spontaneous yielding a -ΔG which can be called as Gibbs free energy. It is defined in terms of a system's enthalpy and entropy as the following:

$$G = H - TS$$

Whereas: H is enthalpy, T is temperature and S is entropy.

The reaction goes from 71 moles of O_2 gas to 48 moles of CO_2 yielding a -ΔS. Combustion reactions break bonds between the molecules signaling an exothermic reaction or -ΔH.

From first laws analysis of combustion, the main purpose of combustion is to produce heat through a change of enthalpy from the reactants to the products. This first law equation in a control volume, ignoring kinetic and potential energy change and assuming no work is done, we have:



The energy released by combustion

Various laboratory experiments have accurately measured the exact amount of energy released by the burning of simple bodies.

So, burning one kilogram of carbon releases energy of about 33 million joules; burning one kilogram of hydrogen releases energy of about 120 million joules.

Knowing the mass composition of a hydrocarbon, it is then easy to deduce the total energy that it can release during its combustion in an engine:

The combustion of one kilogram of diesel fuel of formula C_6H_{12} releases a net energy of about 41.7 million joules; taking into account the density of the product (845 $kg.m^{-3}$), that means about 35.2 million joules per liter;

The combustion of one kilogram of gasoline of formula C_7H_{16} releases a net energy of about 43.7 million joules; taking into account the density of the product (760 $kg.m^{-3}$), that means about 33.2 million joules per liter [29]

The combustion of one kilogram of LPG of formula C3.5H9 releases a net energy of about 45.1 million joules; taking into account the density of the product (550 $kg.m^{-3}$), that means about 24.8 millions of joules per liter.

REFERENCES

[1]. Sarath Raj , Ajbin K Aniyan , Akshai Aji , Anandhu Raj , Anandu Mohan , Sharon T R, October 2015 - March 2016. "Fabrication and Testing of Portable Twin Filter Aqua Silencer", International Journal of Mechanical and Industrial Technology, Vol. 3, Issue: 2, ISSN 2348-7593.

[2]. P.Balashanmugam, G.Balasubramanian, 2014, "Developments of Emission and Noise Control Device (Aqua Silencer)", International Journal of Modern Trends in Engineering and Research, ISSN: 2349-9745, p-ISSN: 2393-8161.

[3]. Rahul S. Padval, Nitin V. Patil, Mahendra.P. Pachare, March 2016, Aqua silencer, International Journal of science Technology and Management, Vol. 5, Issue: 3, ISSN: 2394-1537.

[4]. Alen.M.A, Akshay.M, Prem Sankar.R, Mohammed Shafeeque.M., Aug-2015, "Fabrication and Testing of Aqua Silencer", International Research Journal of Engineering and Technology (IRJET), Vol. 2, Issue: 5, e-ISSN: 2395-0056, p-ISSN: 2395-0072.

[5]. 5th International Conference of Materials Processing and Characterization (ICMPC 2016) "Experimental Investigation on Innovative Modification of Aqua Silencer" Mehta Nirava, Sachindra Doshia Mechanical Engineering Department, Government Engineering College, Bhavnagar, Gujarat 364002, India.

[6]. Rohit Thakre, Ajit Khushwah, Oct-2017, "Review Paper on Design and Development of Aqua Silencer." International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 04 Issue: 10 ISSN: 2395-0072.

[7]. Dr. P.K.Sharma, Swap nil V. Kasar, March -2017, "Design and Manufacturing of Aqua Silencer for Two Stroke Petrol engine". International Journal of Advance Engineering and Research Development Volume 4, Issue 3.

[8]. Santosh Kumar, Richard Brinton, Oct-2017,"Design and Fabrication of Eco-Friendly Aqua Silencer". International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2349-784X Volume: 03 Issue: 10.

[9]. Keval I. Patel, Mr. Swastik R. Gajjar, June 2014, "Design and development of aqua silencer for two stroke petrol engine" IJIRST-International Journal of Innovative Research in Science and Technology, Vol.1, Issue 1.

[10]. Akhil Anil Kumar, Anoop N, Aquib Jawed P.P, Bijoy E, Midhun T.V, Mohammed Shiyas N. P, Ranjith Krishna P.T, May 2016, "Design and Development of Aqua Silencer" International Journal of Engineering and Innovative Technology (IJEIT) Vol. 5, Issue 11.

[11]. Parikshit K. Patel, Keval I. Patel, Ravi Engineer, May 2015, "Analysis of Perforated Tube of Aqua Silencer" Indian journal of research, paripex Volume: 4, Issue: 5. ISSN - 2250-1991.

[12]. G Maruthi Prasad Yadav, K.Nagaraju, H.Raghavendra, B. Malli Karjuna Reddy, G.Narayana Reddy, J.Bharat Kumar, K.Srikanth, K.Jagadesh, Vol. 3 Issue 5, May 2015, "Modeling and Experimental Investigations of the Sound and Emissions performance for 4-stroke Multi Cylinder diesel Engine with an Aqua Silencer" International Journal for Research in Applied Science & Engineering Technology (IJRASET) , IC Value: 13.98 ISSN: 2321-9653.

[13]. P K Pavan Kumar, Dr. K. Rajagopal, Dr. Hiregoudara Yerrennagoudaru, Kalburgi Bharath, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) Volume 13, Issue 5 Ver. II (Sep. - Oct. 2016), "An Investigation to reduce emissions from IC Engines" e-ISSN: 2278-1684, p-ISSN: 2320-334X, PP 115-118.

[14]. Anubhav Yadav, Sandeep Garg, IJARIIE-ISSN (O)-2395-4396 Vol-4 Issue-3, 2018, "Charcoal Based Exhaust System".

[15]. Advanced Automobile Engg. ISSN: 2167-7670 AAE, an open access journal, Volume 5 • Issue 2, 2016. "Control of Carbon Dioxide and other Emissions from Diesel Operated Engines using Activated Charcoal".

[16]. Shaik Sameer, Vijayabalan P and Rajadurai MS, International Journal of Applied Engineering Research ISSN 0973-4562 Volume 6, Number 11 (2011). "Effect of Diesel Emissions on Human Health": A Review, Rashid Ali. pp. 1333-1342.

[17]. Paul Nieuwenhuis Senior Lecturer and Co-Director, Electric Vehicle Centre of Excellence (EVCE), Cardiff University, http://theconversation.com/fact-check-are-diesel-cars-really-more-pollu... May 2, 2017 2.27pm SAST.

[18]. Hannu Jääskeläine, Hannu Jääskeläine, Revision 2007.03a. ttps://www.dieselnet.com/tech/diesel_exh_pres.phpX, selNet.com. Copyright © Ecopoint Inc.

[19]. International Journal of Modern Trends in Engineering and Research, "Developments of Emission and Noise Control Device (Aqua Silencer)", Volume 02, Issue 01, [January - 2015] e-ISSN: 2349-9745, p-ISSN: 2393-8161.

[20]. Ali Azama, Shoukat Al, Adnan Iqbal, 4th International Conference on Energy, Environment and Sustainable Development 2016 (EESD 2016). "Emissions from Diesel Engine and Exhaust after Treatment Technologies".

[21]. Altair technology conference, "Backpressure Study in Exhaust Muffler of Single Cylinder Diesel Engine using CFD Analysis" 2015 India.

[22]. Automobile emission control systems platinum catalysts for exhaust purification by g. J. I. Acres and b. J. Cooper, Johnson Matthey & co limited.

[23]. Protsahan Pradhan, thesis 2013, National institute of technology, Rourkela, "comparative study of different adsorbent materials in a charcoal canister", "Non-return valves, requirements and test methods", Vds guidelines for water extinguishing systems. Publishing house: Vds Schadenverhutung GmbH, Amsterdamer Str. 172-174, Germany. VdS2100-09en: 2011-05(01).

[24]. Vds Guidelines for water extinguishing system, Non-return valves. Vds 2100-09en: 2011-05(01).

[25]. "Conex Banninger Valves, an IBP GROUP Company. Manufacturer specifications.

[26]. S.Prakash, M. Prabhahar, M.SaravanaKumar, Mubasheer, Muhamed Shahabaz.M, Muhammed Lijas.B. Volume 118, no.5 2018, Cfd analysis on silencer modified with baffle plates and insulation of lcv diesel engine, international journal of pure and applied mathematics.

[27]. Nikolas Hagemann, Kurt Spokas, Hans-Peter Schmidt, Ralf Kägi, Marc Anton Böhler and Thomas D. Bucheli, "Activated Carbon, Biochar and Charcoal" Linkages and Synergies across Pyrogenic Carbon's ABCs, Water 2018, 10, 182; doi:10.3390/w10020182.

[28]. Rishikesh Acharekar, Digvijay Bhujbal, Omkar Bhingole, Nitin Sherkar, Prof. Argade R.R., Volume: 03 Issue: 04 Apr-2016 "Design, Development and Experimentation of Aqua-Silencer for Four Stroke Petrol Engine", International Research Journal of Engineering and Technology (IRJET), P62-66.

[29]. Association andilca, www.andilka.com/ fuel-combustion. automobiles and the laws of physics.

[30]. What does Smoke Coming Out of Your Exhaust Mean?, https://www.buyautoparts.com/howto/exhaust-smoke.htm, Copyright © 2019 Buy Auto Parts. All rights reserved.

APPENDIX A- DIMENSIONS FOR GROOVE CONNECTIONS OF NON RETURN VALVE

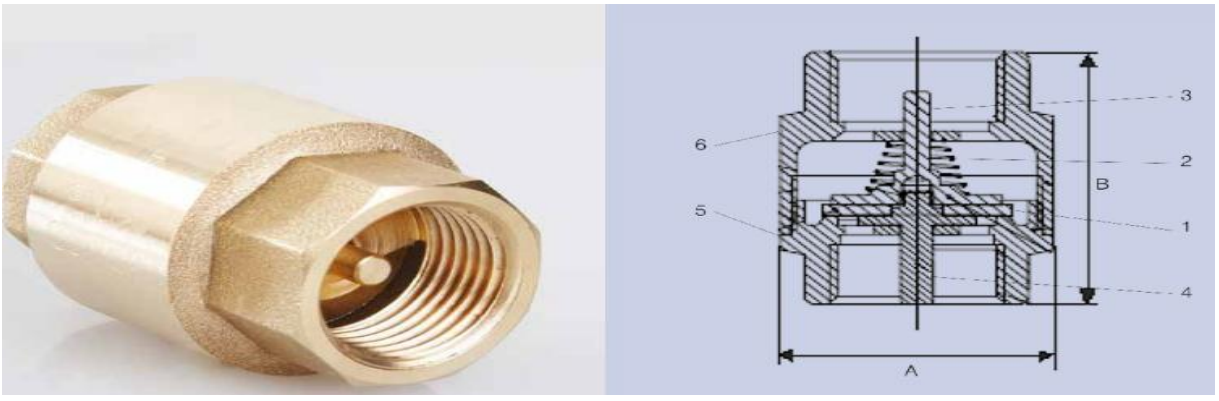
This annex contains the dimensions of valve connections for use with pipe couplings.

Valid for cutting machined connections of malleable iron, cast ductile iron, steel or cast steel with 350 N/mm^2 minimum tensile strength [24].

Nominal size		Nominal outer diameter in mm	Nominal outer diameter in mm		Pipe length up to groove in mm	Groove width in mm	Diameter at groove ground in mm	
			max.	min.	± 0,76	± 0,76	max.	min.
DN	25	33.7	33.73	33.07	15.87	7.92	30.23	29.85
DN	32	42.4	42.57	41.76	15.87	7.92	38.99	38.61
DN	40	48.3	48.74	47.78	15.87	7.92	45.09	44.70
DN	50	60.3	60.94	59.72	15.87	7.92	57.15	56.77
DN	65	76.1	76.85	75.35	15.87	7.92	72.26	71.80
DN	80	88.9	89.79	88.11	15.87	7.92	84.94	84.48
DN	100	114.3	115.44	113.51	15.87	9.52	110.08	109.58
DN	125	139.7	141.10	138.91	15.87	9.52	135.48	134.97
DN	150	168.3	169.85	167.49	15.87	9.52	163.95	163.40
DN	200	219.1	220.65	218.29	19.05	11.13	214.40	213.77
DN	250	273	274.62	272.26	19.05	12.70	268.27	267.59
DN	300	323.9	325.42	323.06	19.05	12.70	318.29	317.53

Remark 1: Groove shoulder flash-free with cutting up to max. 0.3 mm x 45°.
Remark 2: Groove ground with radius up to max. 0.8 mm.

Material specifications



No.	Component	Material	Specification
1.	Seat	EPDM	EN 2430:1995
2.	Spring	Stainless Steel	ISO.15510
3.	Spindle core (Upstream)	Brass	EN 12165 CW617N-DW
4.	Spindle core (Downstream)	Brass	EN 12165 CW617N-DW
5.	Bonnet	Brass	EN 12165 CW617N-DW
6.	Body	Brass	EN 12165 CW617N-DW