THE PERFORMANCE ANALYSIS AND EMISSIONS ANALYSIS OFAN SI ENGINE WITH VARIOUS BLENDS OF ETHANOL- GASOLINE

A major thesis
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of the requirement for the award of the Degree of

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Submitted By:-

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CERTIFICATE

This is to certify that the minor project report entitled **"THE PERFORMANCE AND EMISSIONS ANALYSIS OF AN SI ENGINE WITH VARIOUS BLENDS OF ETHANOL- GASOLINE"** which is being submitted by **VIRENDRA SINGH,** is a bonafide record of student's own work carried by him under our guidance and supervision in partial fulfillment of requirement for the award of the Degree of **Master of Engineering** in Thermal Engineering, Mechanical Engineering Department, Delhi College of Engineering, University of Delhi.

The matter embodied in this project has not been submitted for the award of any Other degree.

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ABSTRACT

As energy crunch loom large. Fossil fuel stocks are falling. Oil price have broken the $70barrier par gallon. Many countries are switching to bio-fuels. The EU has decided to use 5.75% bio fuels like ethanol for motor-cars by 2010.China plans to use 10% bio-fuels by 2010.The US already produces about 10 million tones Ethanol. Interestingly, Henry Ford, the father of modern automobile was an ardent advocate of ethanol as a fuel for motor cars. He was a great believer in recycling. Presently we are using 5% ethanol blend with petrol which can be increased to 10%. Brazil is already using 10% ethanol blended with petrol in motor cars which can be increased to 100% ethanol dedicated vehicle. Research has shown that the use of high ethanol content fuels can result in up to a 66% reduction of hydrocarbon emissions. Hydrocarbons typically represent 80% of total vehicle emissions. Current vehicles are capable of using E10, a blend of 90% gasoline and 10% ethanol. The production and research on ethanol compatible vehicles has increased in recent years with a focus on six areas of importance: the engine, engine control system, cold starting strategy, emissions control, compatible materials, and safety. This major project report is concentrated on high energy content of different ethanol-Gasoline Blends E5, E10, E15, E20 and an effort to cover all the other important areas of concern.

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INTRODUCTION

i. Project Background

The global fuel crises in the 1970 have triggered awareness amongst many countries of their vulnerability to oil embargoes and shortages. Considerable attention was focused on the development of alternative fuel sources, with particular reference to the alcohols. A blend of 10% dry ethanol and unleaded gasoline (E10) was commercially introduced into the USA and is still marketed in the Midwest. More recently, the oxygenated and octane enhancing benefits of ethanol have been highlighted as a potential substitute for Methyl Tertiary Butyl Ether (MTBE), an oxygenated additive used to enhance octane and also reduce CO emissions. MTBE has been shown to be highly toxic even in small quantities when it contaminates groundwater. Flexible fuel vehicles introduced in the early 1990's can be operated on up to 85% ethanol, straight unleaded gasoline or any mixture of the two fuels. The use of ethanol blended with gasoline was a subject of research in the 1970's and it was shown that ethanol- gasoline blends were technically acceptable for existing gasoline engines. The relatively high cost of ethanol production at that time meant that the fuel could only be considered in cases of fuel shortages. Today the economics are much more favorable in the production of ethanol and it is able to compete fairly well with standard gasoline. Hence there has been renewed interest in the ethanol-gasoline blends with particular emphasis on emissions reductions. In the last two decades of the 20th century, major advances in engine technology have occurred, leading to greater fuel economy in vehicles. The reduction of emissions from engines has become a major factor in the development of new engines and manufacturers are trying to meet the requirements specified by Environmental Protection Agency (EPA). As a result the use of non-conventional fuels as a means of meeting these requirements has generated much attention. When considering an alternative fuel for use in gasoline engines, a number of issues are important. These issues include supply and distribution, integrity of the fuel being delivered to the engine, emissions and engine durability. An additional factor that makes ethanol attractive as a fuel extender or substitute is that it is a renewable resource.

Environmental issues regarding the emission of conventional fuels such as -gasoline and diesel are of serious concern worldwide. The standard emission from conventional fuel vehicles are Unburnt hydrocarbon (HC), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NOx) and particulate matter (PM) etc. These emissions are harmful gases which can have adverse impact on human body and destroy the environment by playing an important role in formation of the greenhouse effect, acid rain and global warming. Therefore, alternative fuels such as Ethanol are being considered to replace the role of conventional fuels in order to reduce these harmful emissions from being released to the atmosphere. These alternative fuels may possibly contribute to a significant reduction in vehicular emission worldwide**.**

ii. Objectives

The main aim of this research project is to analyze the various performance parameters and emissions using various Gasoline-Ethanol Blends in spark ignition engine. This research can be further divided into the sub-objectives listed below:

- Conduct a detailed study on the history, properties and usage of Ethanol as an alternate fuel for SI engines.
- Measure the performance parameters of a four-stroke engine using both the gasoline and Ethanol as the main fuel.
- Measure the concentration of emission gases such as NOx, CO, and. Hydrocarbons from the four-stroke engine using both the gasoline and Ethanol as the main fuel.
- Evaluate the data collected from the experiment conducted for both gasoline and Ethanol in the four-stroke engine for different set of load conditions and engine speeds.
- Comparative study of the use of Ethanol and gasoline in term of performance, pollutants and feasibility of using Ethanol fuel as a suitable alternative in S.I engines.

iii. Methodology

First, a literature review of different S.I engine alternative fuels particularly Ethanol was performed. The literature survey was undertaken from various resources such as journals, conference articles, online sources, and reference books. All relevant information were analyzed to construct a precise summary of background information which included the history of Ethanol, advantages and limitations of Ethanol, physical and chemical properties of Ethanol and safety issues of Ethanol. At the same time, comparisons between gasoline and Ethanol were also noted.

Next, a review of the crucial engine performances such as engine efficiency, brake power and specific fuel consumption was done. The emission from the tailpipe of the engine such as hydrocarbon (HC), carbon dioxide (C02), carbon monoxide (CO), oxides of nitrogen (NOx) and particulate matter (PM) was also studied.

Experiments were conducted on a four-stroke gasoline engine in Automobile Engineering laboratory, DCE to collect engine performance data and emissions data from the exhaust of the engine. The experiments were conducted using different Power to collect the data. All the data was analyzed to make comparisons between gasoline and Ethanol opporation. A conclusion was made after analyzing the data collected from the experiments.

LITERATURE OVERVIEW

2.1 Internal Combustion Engine: An Overview

The internal combustion engine converts chemical energy into useful mechanical energy by burning fuel. Chemical energy is released when the spark in the combustion chamber ignites the fuel mixture. The gas produced in this reaction rapidly expands forcing the piston down the cylinder on the power.

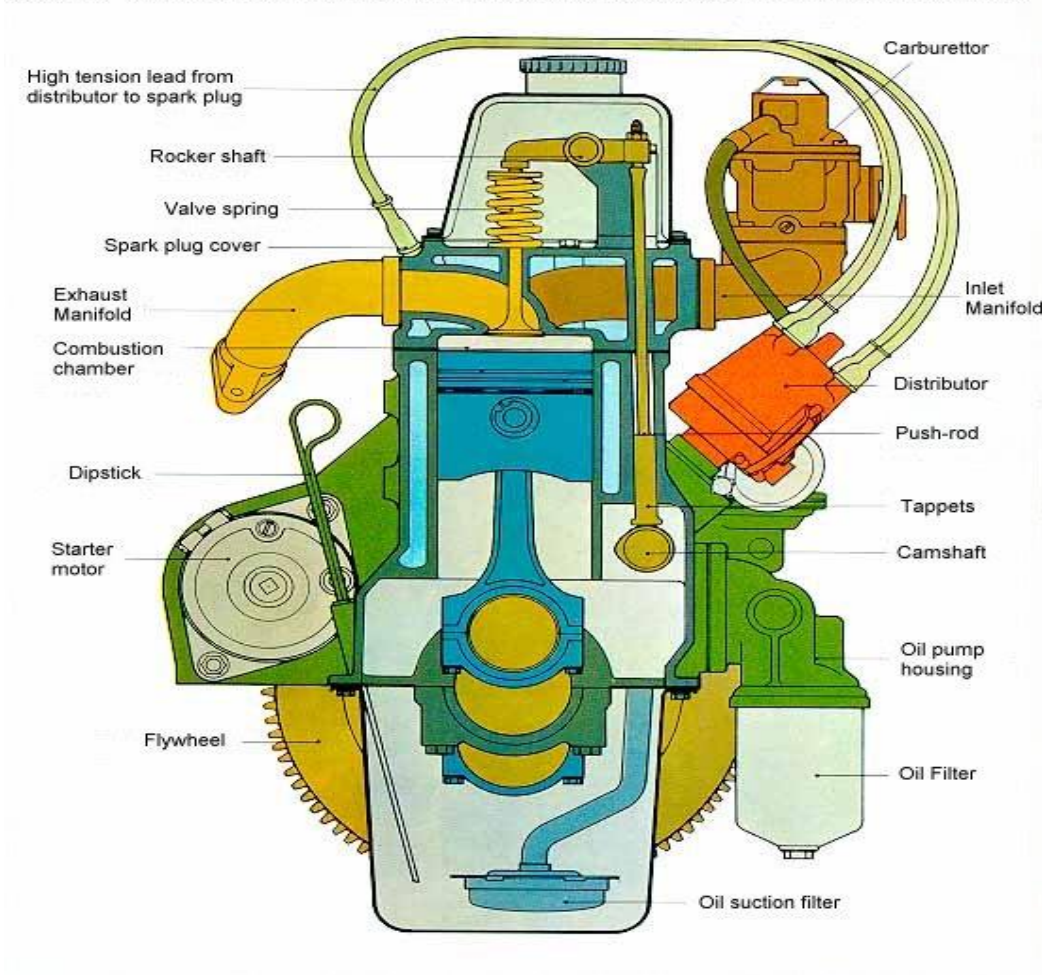FRONT SECTION OF A 4-CYLINDER INTERNAL COMBUSTION ENGINE

Figure 2.1: A 4 - Cylinder Internal Combustion Engine

The basic components for a combustion cycle in a four-stroke engine are combustion chamber (cylinder), piston, intake port and outlet or exhaust port. The pistons reciprocate inside the cylinder, exhaust and intake ports open and close during various stages of the cycle. The movement of the piston up or down the cylinder makes up one stroke of the four-stroke cycle (Otto cycle). The linear motion is then converted to rotary motion by the crankshaft. The crankshaft is shaped to balance the pistons, which are fired in a particular order to reduce the vibration (typically for a 4-cylinder engine, 1-2-4-3 or 1-3-4-2). The flywheel then helps smoothen out the linear movement of the pistons.

ii. The Otto Cycle

Each movement of the cylinder up or down the cylinder is one stroke of the four-stroke combustion cycle or Otto cycle. Most modern internal combustion engines use the four-stroke cycle. The four stroke cycle consists of an induction stroke where air and fuel are taken into the cylinder as the piston moves downwards, a compression stroke where the air and fuel are compressed by the upstroke of the cylinder, the ignition or power stroke where the compressed mixture is ignited and the expansion forces the cylinder downwards, and an exhaust stroke where the waste gases are forced out of the cylinder. The intake and outlet ports open and close to allow air to be drawn into the cylinder and exhaust gases to be expelled.

During the intake stroke the inlet valve opens at the top of the cylinder, as the piston moves down air and fuel are drawn into the cylinder. As the piston reaches its lowest position the inlet valve closes and the piston travels upwards compressing the air-fuel mixture. As the piston reaches its highest position at maximum compression a spark ignites the mixture causing a rapid expansion of gas raising the pressure in the cylinder and forcing the piston downwards. Once the cylinder has reached its lowest position the outlet port opens and as the piston rises up the cylinder the exhaust gases are forced out. The valves, which open and close the port are sprung to make them naturally close. The valves are opened by a system of rotating cams and pushrods driven by a camshaft, which in turn is timed and driven from the crankshaft. The valve timings vary between engines depending on the setup; generally there is some overlap to speed the flow of gases as

shown below, Named after Nikolaus Otto (1832-1891), the Otto cycle used as an ideal approximation for the spark-ignition engine. The Otto cycle consists of four idealized processes:

The Otto cycle's thermal efficiency η_{otto} is given by:

$$\eta_{otto} = Wnet\ /Q23 \qquad\qquad (2.1)$$

From the 1st Law of thermodynamics for a complete cycle

$$\Delta U=Q-W=0$$

$$Wnet = Qnet = Q23 - Q41 \qquad\qquad (2.2)$$

Substituting (2.2) into (2.1) we have

$$\eta_{otto} = Q23 - Q41$$

$$Q23 = 1- Q41\ /Q23 \qquad\qquad (2.\ 3)$$

Assuming air to be a perfect gas we have constant specific heat capacities; thus, for a fixed mass of air we have

$$Q23 = mCv\ (T3-T2)$$

$$Q41 = mCv\ (T4 -T1)$$

Thus

$$\eta_{otto} = 1 -(T4 - Tl)/\ (T3 - T2) \qquad\qquad (2.4)$$

The heat addition and rejection processes are both isentropic, PV is a constant.
Thus:

$$T3 = T4\ (V1/\ V2)^{y-1}$$

$$T2 = T1\ (V1/V2)^{Y-1}$$

Where

Y is the ratio of gas specific heats

V1 /V2 are the compression ratio, r of the engine.

Substituting into equation (2.4) we have

$$\eta_{otto} = 1 - (1/r-1)$$

2.2 Engine Performance Parameters

Engine performance is a major concern in this research project alongside the main aim of analyzing the reduction in the emission of nitrogen oxides using liquefied petroleum gas in spark ignition engine. Some indicators of engine performance such as input power; brake power, specific fuel consumption and engine efficiency are calculated to compare the engine performance between gasoline and Ethanol.

i. Input Power:

The input power of an engine refers to the maximum energy that can be put into the engine, and is given by:

$$IP = Q_{HV} \times \dot{m}_f$$

Where:

IP = Input power (kW)

Q_{HV} = Lower calorific value of fuel (MJ/kg)

$\dot{m}_f$ = Mass flow rate of fuel (kg/s)

Q_{HV} (Gasoline) = 44.5 MJ/kg

ii. Brake Power:

Brake power refers to the power delivered by the engine. During internal combustion, chemical energy from the fuel is converted to generate heat to do work. However, the heat generated cannot be fully converted to work, and some of that are lost to the exhaust flow and to the surroundings by heat transfer. Indicated power (IP), which is used to push the piston to do the work, is used to subtract the friction power to obtain the brake power of an engine. Increasing displacement and speed can generate greater power.

Brake power is given by

$$BP= IP-FP$$

$$BP = 2\pi NT/60*10^3$$

Where:

BP = Brake power (kW)

N = Engine speed (rpm)

T= Torque (N.m)

Torque is usually used as a measure of an engine's ability to do useful work, and it has the unit of Nm or Ibs-ft. Apart from that, torque also refers to the measure of the work done per unit rotation (radians) of crank. The magnitude of the torque acting on a body is equal to the product of the force acting on the body and the distance from its point of application to the axis around which the body is free to rotate. It should be noted that only the force component that lies on the rotation plane and perpendicular to the radius from the axis of rotation to the point of application contributes to the value of torque. Torque is given by:

$$T=60P/2\Pi N$$

Where:

T= Torque (Nm)

P=Power Developed by the Engine (W)

N = Engine speed (rpm)

In this research project, the brake power generated is converted to electrical power (EP), which is used to supply electricity to light the electric bulbs. Therefore, the brake power is measured as follows:

iii. Specific Fuel Consumption (sfc):

Specific fuel consumption measures the amount of fuel needed to provide a given power to an engine for a given period. It is an important parameter to compare gasoline and Ethanol in terms of economic aspect. sfc is largely dependent on engine design, for example, a typical gasoline engine has a sfc of about 0.3 kg/kWh. However, sfc is inversely related with engine efficiency - a lower value of sfc shows better engine performance. The sfc is defined as:

$$sfc = \frac{m_f}{P}$$

Where:

sfc = Specific fuel consumption (kg/kWh)

m_f = Mass flow rate of fuel (kg/h)

P = Power output (kW)

And Brake specific fuel consumption (bsfc) is given by:

$$bsfc = \frac{\dot{m}_f}{BP}$$

Where:

bsfc = Brake specific fuel consumption (kg/kWh)

m_f = Mass flow rate of fuel (kg/h)

BP=Brake Power (kW)

There are several factors, which affect the value of bsfc. For instance, higher compression ratio delivers a greater bsfc as it extracts more power from the fuel. On the other hand, the value of bsfc will decrease if the combustion occurs with a fuel with equivalence ratio near to unity ($\Phi = 1$). Bsfc will be of greater value at high speed as the friction losses are increased.

iv. Engine Efficiency:

Engine efficiency is defined as the ratio of the effective or useful output to the total input in an engine. It also accounts for the fraction of fuel that burns during combustion. For any engine:

For one engine cycle in a single cylinder, the fuel conversion efficiency η_f is given by:

$$\eta_f = \frac{W_c}{m_f Q_{HV}}$$

$$= \frac{\dfrac{P}{\dot{m}_f Q_{HV}}}{}$$

And it can be presented in the form

$$\eta_f = \frac{3.6}{(sfc)Q_{HV}}$$

Where:

η_f = Engine efficiency

P = Output power produced per cycle (kW)

m_f = Mass flow rate of fuel per cycle (kg/s)

Q_{HV} = Lower calorific value of fuel (MJ/kg)

Engine Emissions

The fuel used in spark ignition engines is gasoline consisting of compounds of carbon and hydrogen called hydrocarbons (HC). The chemical composition of gasoline is 45-60% saturated hydrocarbon, 30-50% aromatic hydrocarbon and 5-10% olefin

hydrocarbon. The fuel is vaporized in the carburetor or by EFI, mixed with air and combusted within the spark ignition engine. A major portion is converted to carbon dioxide (CO_2) and water (H_2O). But, in addition to oxygen, air consists of 79% of nitrogen (N_2). So, at high temperature, nitrogen oxides (NO_x such as NO, NO_2 etc) are also formed. Due to incomplete combustion regulated pollutants like unburned hydrocarbons and carbon monoxide are produced. The carbon monoxide (CO) in the exhaust gas is due to the incomplete combustion of carbon in the fuel, which if it gets further oxidized becomes carbon dioxide (CO_2). The hydrocarbons (HC) in the exhaust gas may be due to incomplete combustion or due to fuel escape.

i. Carbon monoxide

The toxicity of CO is well Know. It is mortal above one thousand pips it can also act in much lower concentrations, due to its affinity for blood hemoglobin that is 240 times greater than of oxygen. With cardiovascular problems carbon monoxide may also display long-term toxicity such as headache dizziness and nausea, which occur when CO blocks 25%of the hemoglobin. Loss of consciousness, which is dangerous for drivers, can occur if the CO rate reaches 50% and death occurs when the rate reaches 70%. Affects the cardio vascular system, exacerbating cardiovascular disease symptoms, particularly angina; may also particularly affect fetuses, sick, anemic and young children, affects nervous system impairing physical coordination, vision and judgments, creating nausea and headaches, reducing productivity and increasing personal discomfort.

The carbon dioxide (CO_2) is final product of complete combustion of fuel composed exclusively of carbon and hydrogen. An essential step in such hydrocarbon oxidation process is CO formation.

Even at maximum power output, there is as much as 38% of excess air in the combustion chamber. However, although carbon monoxide (CO) should not be formed, it may in fact be found in small quantities in the exhaust. The reason is partly that, in local areas of the combustion chamber, most of the oxygen has been consumed before injection ceases and therefore fuel injected into these cannot burn completely to CO_2.

Regulations define particulates as anything that is retained, at an exhaust gas temperature of 52%, by a filter having certain specified properties. They therefore include liquids as

well as solids. Particle sizes from 0.01 to 10μm, the majority being well under 1.0μm. While black smoke comprises mainly carbon, the heavier particulates comprise ash and other substances, some combined with carbon. The proportions however depend on type of engine, fuel and lubricant.

The equilibrium concentration of carbon monoxide (CO) in exhaust gas (concentration in the composition of exhaust gas kept for a sufficiently long time under constant temperature and pressure) not only decreases sharply with increase of air- fuel ratio, it also decreases considerably with a reduction in the exhaust gas temperature. If chemical equilibrium is maintained, at any exhaust temperature, the concentration of CO is extremely low when O_2 is plentiful as in lean vapor.

The concentration of CO in exhaust gas has an almost fixed relation to the air-fuel ratio. Below an A/F ratio of 16 it increases rapidly. Also, if the quality of vapor is inconsistent, extreme cases of localized deprivation of oxygen may cause flame to be put out due to cooling and the concentration of CO increases beyond the CO levels, associated with a constant air-fuel ratio.

ii. Nitrogen Oxides (NO$_x$)

The nitric oxides NO is by itself nontoxic. The suspected effects concern its fixation to hemoglobin. The essential affect of NO stems form its role as Nitrogen peroxide is in soluble and can penetrate deeply in to the pulmonary system. It acts on pulmonary alveoli and impairs their structures, inhibits the pulmonary defenses, and has a catatonic effect on the alveolar macrophages, increased susceptibility to infections, pulmonary diseases, impairment of lung function and eye, nose and throat irritations.

The nitrogen oxide formed by the combining of N_2 and O_2 in the vapor, during combustion in the spark ignition engine. Nitric oxide (NO) is mostly formed with a small volume of nitrogen dioxide (NO_2). The emitted NO gets oxidized in the atmosphere and turns to NO_2. Usually NO and NO_2 are together referred to as NO_x.

The concentration of NO in the exhaust is strongly related to the maximum combustion temperature and the air-fuel ratio. Under constant volume combustion of the vapor, the equilibrium concentration level of NO in the combusted gas, in the case of no heat loss is

maximum, when air-fuel ratio is 18. As the concentration of the vapor increases and the air-fuel ratio decreases NO level decreases rapidly. On the other side, as the concentration of vapor decreases, NO level also gradually decreases. However, as in the case of CO, the actual concentration of NO in the exhaust is much higher because the formation and decomposition speed of NO is much slower than the main speed of combustion.

Under theoretical calculations, because the initially combusted portion is at higher temperature for longer time, the formation of NO should progress in the combusted gas. Concentration of NO decreases as decomposition progresses with the expansion of the combusted gas above the optimum air/fuel ratio (i.e. lower concentration of vapor). However, the speed of decomposition is slow and the NO level does not reduce to the level expected with the decrease in temperature resulting in concentration level of NO emitted higher with the exhaust.

In lean vapor concentration NO formation is slow and does not reach the equilibrium level associated with the flame temperature. But because decomposition is also slow NO is emitted in the exhaust at an almost fixed concentration.

On the other hand, the later the combustion takes place, the lower the combustion temperature and the lesser the time spent in the combustion chamber. So, the NO formation is much less compared to the equilibrium level of the corresponding flame temperature. The NO emission gets fixed at this concentration and the NO contribution to the exhaust is small.

iii. Hydrocarbons

Human health in mainly affected by unstructured hydrocarbon. The olefins are liable to undergo partial metabolic conversion, converting them to geotaxis epoxides. Benzene is well Know haematotoxic and occupational exposure to it can cause Leukemia. However this Leukemia only occurs with concentrations over 40 ppm. They affect the bone marrow by inhibiting the formation red blood corpuscles. The WBC is also destroyed as well as the blood platelets.

Total hydrocarbon (THC) is used to measure the level of formation of unburnt hydrocarbons caused by incomplete combustion in the engine. The hydrocarbons emitted

may be inert such as methane gas or reactive to the environment by playing a major role in the formation of smog. The types hydrocarbons emitted from the exhaust greatly depend on the type and composition of fuel used. Heywood (1988) added that fuels with a greater concentration of aromatics and olefins compounds will result in a higher percentage of reactive hydrocarbons.

iv. Formation of HC Emissions

HC emissions rise rapidly as the mixture becomes substantially richer than stoichiometric. When combustion quality deteriorates, e.g., with very lean mixtures, HC emissions can rise rapidly due to incomplete combustion or misfire in a fraction of the engine's operating cycles.

The possible HC emission formation mechanisms for spark-ignition engines (where fuel-air mixture is essentially premixed) have been proposed:

- Crevice flows: The crevice mechanism where crevices in the combustion chamber are filled with a mixture of fuel and air. This mixture remains unburned after flame passage since the flame cannot propagate into the crevices. When the exhaust valve opens and the pressure drops in the combustion chamber the fuel in crevices is driven out in hot bulk gasses and are being partly oxidized. The UHC emissions from SI engines will normally increase with increasing compression ratio.

- Flame quenching: As the flame approaches the combustion walls it is extinguished (due to Heat Transfer to walls). Thus, leaving a layer of unburned fuel-air mixture adjacent to the wall.

- Absorption/desorption in oil films: Hydrocarbons can be absorbed into the oil film on the cylinder bore during compression. These hydrocarbons are released again during expansion and often escape oxidation as a result. Absorption/desorption from in-cylinder deposits may also be considered as a reason for the UHC.

- Incomplete combustion: Incomplete combustion in a fraction of the engine's operating cycle (either partial burning or complete misfire), occurring when

combustion quality is poor (e.g. during engine transients when A/F, EGR, and spark timing may not be adequately controlled).
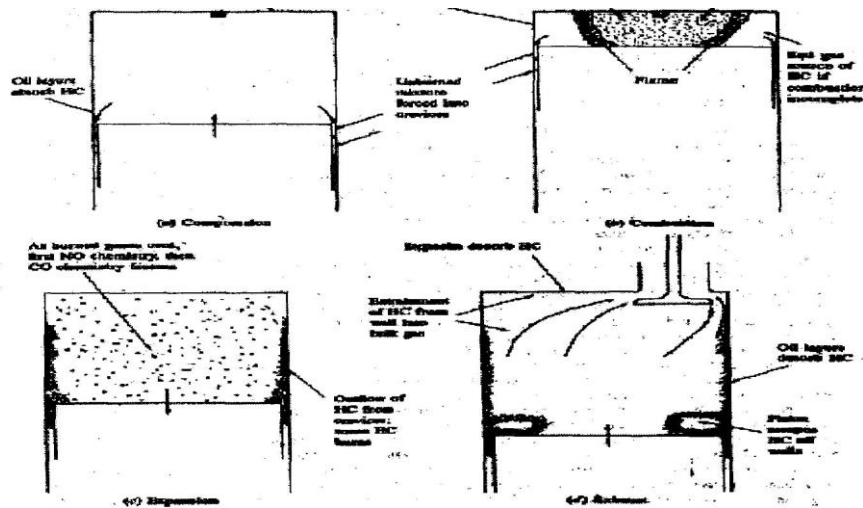

Figure 3.1: Summary of HC, CO and NO pollutant formation mechanisms in SI engine

Hydrocarbons from LPG emission contain only short chain hydrocarbons and are not likely to consist of toxic components, which can be found in gasoline hydrocarbons emissions. However, LPG hydrocarbons emissions often causes nuisance when LPG engines operate indoors (Nett Technologies, undated).

v. Sulpher dioxide (SO$_2$)

Sulpher in fuel is emitted as Sculpture Dioxide in the exhaust gases. High concentration of SO2 can give rise to human health effect, which are respiratory in nature and aggravate bronchitis. Environment affects include toxicity to plants either by direct gaseous toxicity or by acid deposition.

Sulpher dioxides generally emitted from diesel vehicles, is another respiratory irritant. Sulpher in fuel is emitted as SO$_2$ in the exhaust gases. Sulpher is not only a direct threat to human health but also increase the emission particulates. Sulpher compound contribute to the volume of particulate matter, which is one of major concerns. Particulate Sulpher i.e. sulphuric acid (H$_2$SO$_4$) particles may act as condensation nuclei or cause visibility

degradation. High concentration of SO_2 can give rise to human health effect, which are respiratory in nature and aggravate bronchitis and can impair lungs function by constricting airways and damaging the tissues. SO_2 can cause severe damage to lung tissues following chronic exposure, accentuating pulmonary diseases and cardiac disorders. Very young and old people are most susceptible to these effects.

Environment affects include toxicity to plants either by direct gaseous toxicity or by acid deposition. The latter can make water system acidic damaging aqueous life. Corrosion of buildings, stone works and metals increases in presence of SO_2.

Although the emission of particulate matter is usually associated with the diesel engine, there is increasing evidence to suggest that PM emissions from SI engines pose a significant threat to health. In particular, PM emissions pose a significant problem for Stratified Charge, Direct- Injection Gasoline engines. In order to understand the reasons for this concern, we must first consider the formation and composition of PM.

• Particulates are principally SOOT which has absorbed other organic compounds i.e. hydrocarbon compounds.

• Soot is describes as a carbonaceous material not just carbon

• PM is formed in fuel-rich regions of flames (both pre-mixed and diffusion flames)

With respect to the Direct-Injection Spark-Ignition (DISI) engine, particularly in stratified charge mode, it is extremely difficult to achieve good charge homogeneity. Accordingly, there are proportionally a larger number of fuel-rich regions within the cylinder of a DISI engine, which provide potential sites for PM formation, than is the case for a similar Port-Fuel-Injected (PFI) engine. The literature suggests that PM emissions from DISI engines are an order of magnitude greater than an equivalent PFI engine.

3.1 Health effects of Vehicle exhaust emissions

The complete combustion of fuel composed exclusively of carbon and hydrogen, would only generate carbon dioxide and water, to the exclusion of any other harmful product. However the very short time allowed for chemical oxidation processes to take place in combustion chambers, the lack of homogeneity in the carbureted mixture, and the

heterogeneity and rapid variations in temperature never allow the state of ideal thermodynamic equilibrium to be reached. This means that products of incomplete combustion are present in the exhaust, as well as sulfur compounds from sulfur bearing residues, the remaining in the fuel, where as nitrogen oxides gases are formed by high temperatures oxidation of the inert nitrogen present as a diluents in the air. The difference between emissions of gasoline and diesel fuelled engine is that the diesel engine, which operate by compression ignition, emits carbonaceous particulates that are absent in exhaust of gasoline fuelled engines. The other pollutant other than hydrocarbon, carbon monoxide and nitrogen oxides is sulfur dioxide, which varies directly with sulfur content of fuel. Pollutants like aldehydes results from combustion of alcohol fuel.

The process of formation of various products of incomplete combustion and their health effects to human health are included in this report as follows.

i. Carbon monoxide and its effects on health

Carbon monoxide formed during the combustion of fuel in the vehicles is one of the lethal gases known. This is poisonous gas that is color less and odor less. It affects health by displacing oxygen from hemoglobin and preventing the passage of oxygen from the lungs to the bloodstream thus suffocating the blood tissues. The toxicity of CO is well known. It is mortal above one thousand ppm. It can also act in much lower concentrations, due to its affinity for blood hemoglobin that is 240 times greater than that of oxygen. This blocking of hemoglobin reduces the oxygen supply to the tissues; this situation is aggravated when combined with cardiovascular problems. Carbon monoxide may also display long term toxicity such as headache, dizziness and nausea, which occurs when CO blocks 25% of the hemoglobin. Loss of consciousness, which is dangerous for drivers, can occur if the CO rate reaches 50% and death occurs when the rate reaches 70%.

ii. Effect of nitrogen oxides on health

Nitrogen oxides produced during the combustion of fuel in the automobiles cause respiratory problems. The nitric oxides NO is by itself nontoxic. The suspected effects concern its fixation to hemoglobin. The essential effect of NO stems from its role as a NO_2 precursor. Like carbon monoxide, nitrogen dioxide (NO_2) is also toxic and it binds

to hemoglobin and decreases oxygen transport efficiency of blood and hence can cause lung disorders. It is insoluble and can penetrate deeply in to the pulmonary system. It acts on pulmonary alveoli and impairs their structures, inhibits the pulmonary defenses, and has a cytotoxic (any substance which is toxic to cells) effect on the alveolar macrophages. It stimulates their activity in low doses and then weakens the defenses of the body, thus causing other complications. Nitrogen peroxide can thus cause the death of specific cells in the lungs and impair the regulation of the pulmonary function. The symptoms of the toxic action of NO_2 are insomnia, coughing, panting, and impairment of the mucous membranes. Nitrogen dioxide (NO_2), which is more hazardous among the several forms of nitrogen oxides, causes one to exert greater efforts in breathing. It penetrates deep into human lungs causing edema. . Human mucus membranes may feel irritation due to NO_x.

iii. Effect of Ozone on health

Ozone is the lower stability and greater solubility limits its depth of penetration. The human body reacts by shrinkage of the respiratory passages as soon as the O_3 concentration exceeds 0.1 ppm. Physical activity also diminishes tolerance to these pollutants. Other symptoms are irritation of the eyes and mucous membranes, headaches with coughing and reflexive inhabitation of breathing, as well as reduced lung capacity. O_3 can trigger attacks of asthma, followed by acute inflammation and pulmonary edema. Ozone strongly affects the pulmonary functions of asthmatics. Ozone causes oxidation of proteins and per oxidation of fatty acids, specially unstructured fatty acids.

iv. Effect of Hydrocarbons on health

Volatile organic compounds which are emitted from vehicles cause eye and respiratory irritation. Human heath is mainly affected by unstructured hydrocarbon. The olefins are liable to undergo partial metabolic conversion, converting them to geotaxis epoxies.

Benzene is well known haematoxic (casing blood poisoning) and occupational exposure to it can cause Leukemia. However this Leukemia only occurs with concentrations over 40 ppm. They affect the bone marrow by inhibiting the formation of red blood corpuscles. The WBC is also destroyed as well as the blood platelets. Benzene is a suspect in other hematological disorders such as Hodgkin's disease and lymphoma, and may cause chromosomal anomalies. The metabolites of benzene responsible for these biological effects are still poorly known, although phenols and epoxies are often mentioned as resulting from the enzymatic oxidation of benzenes
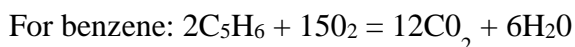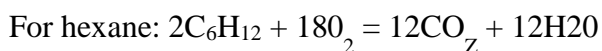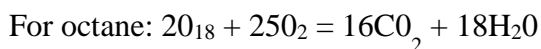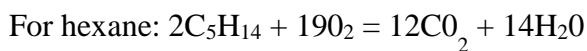
Fuels used in S.I. Engine

i. Gasoline

Early refineries used a simple distillation process to separate crude oil into its components according to their boiling points. The gasoline produced by this method was only that naturally occurring in the crude oil. As demand for motor spirit grew, engineers and chemists found that more severe heating of the higher boiling points hydrocarbons broke them down, or 'cracked' them, into smaller, lower boiling hydrocarbons more suitable for gasoline production. From 1913, thermal cracking was used to increase gasoline production. Substances known as 'catalysts' were later found to do a better job of cracking hydrocarbons than heat alone, by speeding up the reaction and producing a greater yield of higher octane petrol. Chemistry

Gasoline is a derivative of petroleum refining. It is essentially a complex mixture of hydrocarbons that boils below 180^0C. The hydrocarbon constituents are those that have 4 - 12 carbon atoms in their structure and fall into three general types:

• Paraffin's, such as hexane (C_6H1_4), and octane (C_8H_{18})

• Olefins, such as hexane (C_6H_{12})

•Aromatics such as benzene (CH) and toluene

Gasoline consists of a blend of more than 200 such hydrocarbons either occurring naturally in petroleum or manufactured from it. Gasoline can vary considerably in composition, depending upon the source of the original crude oil, and the processes used in production. When there is enough oxygen, hydrocarbons can be burnt to form CO_2 and water vapor, releasing heat.

The equation for the complete combustion of hexane is:

For hexane: $2C_5H_{14} + 19O_2 = 12CO_2 + 14H_2O$

For octane: $2O_{18} + 25O_2 = 16CO_2 + 18H_2O$

For hexane: $2C_6H_{12} + 18O_2 = 12CO_Z + 12H2O$

For benzene: $2C_5H_6 + 15O_2 = 12CO_2 + 6H_2O$

If insufficient oxygen is available, incomplete combustion occurs, forming carbon monoxide CO, nitrogen oxides and carbon, as well as carbon dioxide and water.

a. Environmental considerations:

Exhaust emissions from petrol-driven cars include, in addition to CO_2 and water vapor, hydrocarbons, nitrogen oxides and CO. Fitting a three-way catalytic converter that converts these three types of exhaust components into less reactive substances may effectively reduce these latter emissions.

Volatile organic compounds are also emitted into the atmosphere through evaporation from fuel tanks, carburetors and refueling stations. Using carbon canisters containing activated charcoal, which absorbs these vapors, can reduce these emissions.

Evaporation can also be controlled during manufacturing and distribution with double tank roofs, improved tank seals and vapor recovery units.

An important element in the efficiency of gasoline combustion is the octane number. This indicates the ability of the fuel to resist detonation, which is referred to as engine pinging or knocking. The spontaneous igniting of the fuel and air in the engine cylinders before the spark is fired causes such detonation. Higher-octane fuels are less susceptible to detonation and thus prevent engine knock and in turn maintain engine power.

Lead has traditionally been added to gasoline as an effective and economic method of boosting octane quality. However, concerns have recently arisen about the possible health effects of lead in vehicle exhaust emissions. Concerns also about atmospheric 'smog' pollution have led to the desire to remove up to 90% of the smog precursors present in engine exhaust gases by the use of catalytic converters. This in turn requires that the gasoline be lead free if the catalyst is to function properly. In Australia this resulted in a decision to change to cars, which operate on unleaded gasoline with a lower octane than previously used, so that changes to refinery configurations, to make up for the octane loss upon the removal of the lead, would not be too extensive.

This change is not without its disadvantages, since a lower octane fuel results in a less efficient engine, and an overall increase in carbon dioxide emissions. Some additional CO_2 emissions also arise from the changed refining processes. Thus, although the move to

unleaded gasoline may be successful on a local level from a smog point of view, it is likely to have an increased impact upon global air quality in terms of CO_2.

c. Economic considerations:

Most cars today run on gasoline because it is a relatively cheap, convenient, safe and reliable fuel that yields good vehicle performance complete with a good vehicle range capability. It can also be stored and handled easily.
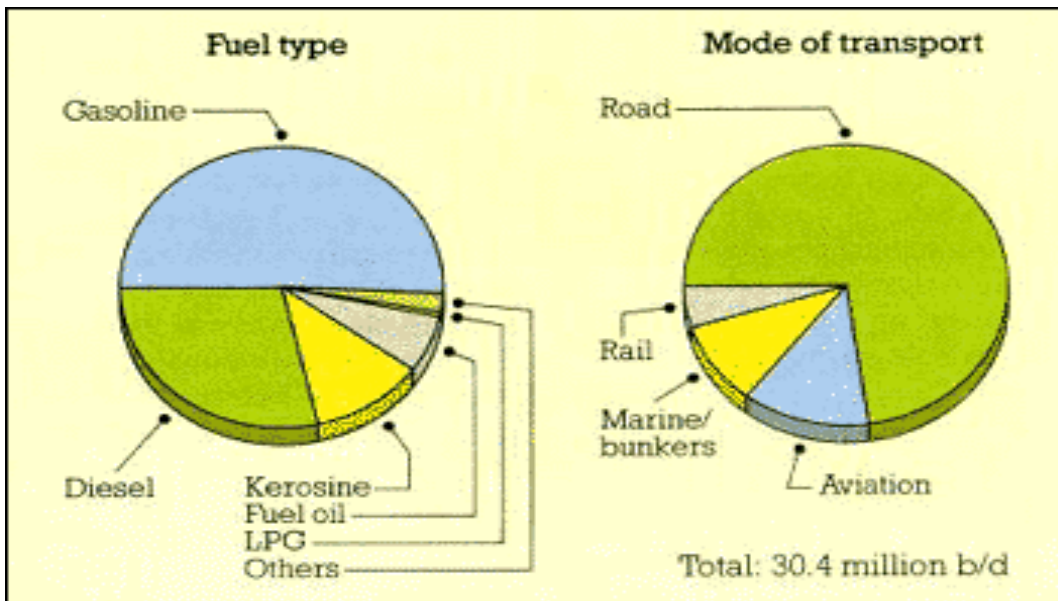

Figure4.1: World Transportation Fuels Demand

ii. Ethanol

Ethanol (ethyl alcohol, grain alcohol, EtOH) is a clear, colorless liquid. In dilute aqueous solution, it has a somewhat sweet flavor, but in more concentrated solutions it has a burning taste. Ethanol (C_2H_5OH) is made up of a group of chemical compounds whose molecules contain a hydroxyl group, -OH, bonded to a carbon atom. Ethanol made from cellulosic biomass materials instead of traditional feedstock (starch crops) is called bio-ethanol.

Ethanol is an alcohol-based alternative fuel produced by fermenting and distilling starch crops that have been converted into simple sugars. Feedstocks for this fuel include corn, barley, and wheat. Ethanol can also be produced from "cellulosic biomass" such as trees and grasses and is called bio-ethanol. Ethanol is most commonly used to increase octane and improve the emissions quality of gasoline.

iii. Methanol

Methanol (CH_3OH), also known as wood alcohol, is an alcohol fuel and it can be used as an alternative fuel in flexible fuel vehicles that run on M85 (a blend of 85% methanol and 15% gasoline). However, it is not commonly used because automakers are no longer supplying methanol-powered vehicles.

Methanol can be used to make methyl tertiary-butyl ether (MTBE), an oxygenate which is blended with gasoline to enhance octane and create cleaner burning fuel. MTBE production and use has declined because it has been found to contaminate ground water. In the future, methanol could possibly be the fuel of choice for providing the hydrogen necessary to power fuel cell vehicles.

iv. Liquid petroleum gas (LPG)

LPG is a by-product of two sources: natural gas processing and crude oil refining. When natural gas is produced, it contains methane and other light hydrocarbons that are separated in a gas processing plant. Because propane boils at -44^0F and ethane boils at -127^0F, separation from methane is accomplished by combining increasing pressure and decreasing temperature. The natural gas liquid components recovered during processing include ethane, propane and butane and other heavier hydrocarbons. Propane and butane along with other gases are also produced during crude refining as a by-product of the process that rearrange or break down the molecular structure to obtain more desirable petroleum compounds.

v. Hydrogen

The simplest and lightest fuel is hydrogen gas (H_2). Hydrogen is in a gaseous state at atmospheric pressure and ambient temperatures. Hydrogen may contain low levels of carbon monoxide and carbon dioxide, depending on the source.

Hydrogen is being explored for use in combustion engines and fuel cell electric vehicles. On a volumetric basis, the energy density of hydrogen is very low under ambient conditions. This presents greater transportation and storage hurdles than for liquid fuels. Storage systems being developed include compressed hydrogen, liquid hydrogen, and physical or chemical bonding between hydrogen and a storage material (for example, metal hydrides).

Widespread use of hydrogen as an energy source could help address concerns about energy security, global climate change, and air quality. Fuel cells are an important enabling technology for the hydrogen future and have the potential to revolutionize the way we power our nation, offering cleaner, more efficient alternatives to the combustion of gasoline and other fossil fuels.

Hydrogen's main benefits are

• Reduced greenhouse gas emissions

• Improved air quality

• Increased energy efficie

4.1. ETHANOL: THE INDIAN SCENARIO

India is the second largest producer of sugarcane in world. India imports nearly 70% of its annual crude petroleum requirement, which is apex. 110 million tons. The prices are in the range of US$ 50-70 per barrel, and the expenditure on crude purchase is in the range of Rs.1600 billion per year, impacting in a big way, the country's foreign exchange reserves.(Oil Prices touched a record high of $70 per barrel).

The Indian petroleum industry now looks very committed to the use of ethanol as fuel, as it is expected to benefit sugarcane farmers as well as the oil industry in the long run. Ethanol (FUEL ETHANOL) can also be produced from wheat, corn, beet, sweet sorghum etc. Ethanol is one of the best tools to fight vehicular pollution, contains 35% oxygen that helps complete combustion of fuel and thus reduces harmful tailpipe emissions. It also reduces particulate emissions that pose a health hazard.

i. Ethanol: -

General Information	Ethanol
Other name	Ethyl alcohol
	Grain alcohol
	Hydroxyethane
Molecular Formula	C_2H_5OH
Molecular mass	46.07 g/mol
Appearance:	Color less liquid
Auto-ignition temperature	363 C
Flash point	13 C(27)

In the first phase (2004) of the project, ethanol- blended gasoline is being supplied through retail outlets in nine States and four Union Territories. These states are Andhra Pradesh, Goa, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Tamil Nadu and Uttar Pradesh. The four Union Territories include Chandigarh, Dadra and Nagar Haveli, Daman and Diu

and Pondicherry. Gasoline blended with 5 per cent ethanol would be supplied by gasoline pumps all over the country under the second phase towards the end of the year. The content of ethanol blending would be increased to 10 per cent in the third phase of the programmed scheduled for 2005.

Most industrial ethanol is denatured to prevent its use as a beverage. Denatured ethanol contains small amounts, 1 to 2 percent of several different unpleasant or poisonous substances. The removal of all these substances would involve a series of treatments more expensive than the federal excise tax on alcoholic beverages. These denaturants render ethanol unfit for some industrial uses. In such industries un-denatured ethanol is used under close federal supervision.

ii. Availability of Ethanol.

In the absence of a well-knit policy in the past for purchasing and blending ethanol, not many distilleries have been producing ethanol. Only three distilleries attached to sugar mills had war years' experience, and were able to gear themselves up to supply ethanol immediately. Now, about 11 factories in Uttar Pradesh will be adding facilities to produce about 75 million liters of anhydrous alcohol by end-September; 7 units in Tamil Nadu (production capacity of 62.5 million liters of anhydrous alcohol); 8 units in Karnataka (anhydrous alcohol production capacity of 66.5 million liters); and 4 units in Andhra Pradesh (capacity of over 40 million liters). The cooperative sector units in Maharashtra, Punjab and UP have also taken up similar steps.

As capacities are built up, the oil sector should also be able to generate that much demand for ethanol to guard against any idling capacity. The Petroleum Ministry may therefore like to look into this matter and ensure that the oil sector speeds up the creation of requisite facilities for blending ethanol with petrol. So far generation of demand for ethanol has been very low and it takes considerable time for IOC's units to finalize purchase of ethanol against offers made by distilleries in response to their tenders.

iii. Production of Ethanol

India is the second largest producer in terms of sugarcane production; India and Brazil are almost equally placed. In Brazil, out of the total cane available for crushing, 45% goes for sugar production and 55% for the production of ethanol directly from sugarcane juice. This gives the sugar industry in Brazil an additional flexibility to adjust its sugar production keeping in view the sugar price in the international market as nearly 40% of the sugar output is exported.

The annual projected growth rate in the area under sugarcane at 1.5% per annum has doubled during the last five years. This is because it is considered to be an assured cash crop with good returns to the farmer's vis-à-vis other competing crops. India is currently passing through a glut situation with closing stocks at the end of the year of over 100 lakh tons since 1999-2000. Correspondingly, molasses production has also increased. The table below gives the production of molasses, alcohol utilization by the alcohol-based chemical industry, potable sector and the surplus at the end of each year. It is therefore evident that along with sugarcane production, phenomenal growth is also taking place in the production of molasses, the basic raw material for the production of ethanol from sugarcane. Of course, there are also other agro routes available to produce ethanol. [12] According to **MoPNG** (MINISTRY OF PETROLEUM AND NATURAL GAS), 5% ethanol blends on an all-India basis would require 500 million liter of ethanol. The current availability of molasses and alcohol would be adequate to meet this requirement after fully meeting the requirement of the chemical industry and potable sectors. In the Indian Sugar Mill

Association, this matter was recently examined and it was concluded that instead of taking up the scheme on a state-wise basis, it would be appropriate to take it up in metropolitan and other cities where environmental pollution is a major concern. The blending should be taken up to 10% and introduced selectively to make a better impact on the environment, as no changes in the engine or carburetor are required, and other countries are already carrying this out successfully.

There is considerable scope for further reduction in the cost of production of both sugarcane and sugar in India with liberalization of controls on the sugar industry. Consolidation of land holdings and corporate farming on the raw material side and expansion of capacity on the unit size are important developments and would lead to substantial improvements in productivity, thereby rendering India a cost-effective producer of sugar in the world.

The area under sugarcane is presently less than 2% of total cultivable area in the country and about 3% of the irrigated area. There is considerable scope for increasing the area under sugarcane considering the fact that it is more profitable compared to other crops. The Planning Commission has visualized a conservative increase in area under sugarcane by 6 lakh hectares during the 10th Plan period, but considering past trends, the area under cane is likely to exceed 5 million hectares.

During the 10th Plan period, the annual incremental growth in consumption has been estimated at 9 lakh tons per annum. For the first time the Indian Government has fixed a target of 15 lakh tons per annum for export for this period. However, the production target was fixed at 21.3 million tons keeping in view the large carry forward stocks at the

Beginning of the period and to correct the demand-supply distortions presently caused. These targets are achievable looking at the performance of the industry in the past with a production of 18.5 million tons achieved in 2000-01.

Such flexibility has become very relevant in the current scenario of economy liberalization and more particularly as a means to correct the aberrations in sugar production.

The task force on the sugar industry for the Tenth Five Year Plan has suggested the evolution of a national policy on alternative fuels, which would include the use of ethanol-blended gasoline.

Until such a policy is evolved, sugar factories and distilleries should be encouraged to produce ethanol from the surplus alcohol available with them, a report of the task force

says. For this, it suggests providing loans from the Sugar Development Fund at 6 per cent per annum for up to 60 per cent of the project cost.

The ministry of petroleum and natural gas and the oil companies, in consultation with the department of food and public distribution, the All-India Distilleries Association and the apex bodies of the sugar industry, can set a reasonable price for ethanol produced by distilleries for the purpose of blending with gasoline.

Considering the environment-friendly characteristics of ethanol-blended gasoline as an automobile fuel, the pricing of ethanol needs to be viewed not only in terms of a financial cost-benefit analysis, but also in terms of an economic cost-benefit analysis, the report adds. There has been a steady increase in the production of alcohol in India, with the estimated production rising from 887.2 million litres in 1992-93 to nearly 1,654 million litres in 1999-2000. Surplus alcohol leads to depressed prices for both alcohol and molasses.

According to the task force, the projected alcohol production in the country will increase from 1869.7 million litres in 2002-03 to 2,300.4 million litres in 2006-07. Thus the surplus alcohol available in the country is expected to go up from 527.7 million litres in 2002-03 to 822.8 million litres in 2006-07.

Utilization of molasses for the production of ethanol in India will not only provide value-addition to the byproduct, it can also ensure better price stability and price realization of molasses for the sugar mills. This will improve the viability of the sugar mills, which will in turn benefit cane growers.

With gasoline demand expected to increase from 7.9 million tones in 2001-02 to 11.6 million tones in 2006-07, the requirement of ethanol at 5 per cent blending is expected to rise from 465 million liters to 682 million liters.

4.2. PROPERTIES OF ETHANOL

Ethanol (ethyl alcohol) is a clear, colorless liquid with a faint odour. It has a high latent heat of vaporization and contains oxygen, characteristics that are relevant to its environmental performance in combustion as a motor fuel, and in its storage and distribution.

There are a number of fuel properties that are essential to the proper operation of a gasoline engine. Materials compatibility and corrosiveness are also important factors that need to be considered. Properties that affect safety should be foremost in any fuel evaluation. These include ash point and flammability. Finally fuel biodegradability has become a significant factor with respect to ground water contamination.

In dilute aqueous solution, ethanol has a somewhat sweet flavor, but in more concentrated solutions it has a burning taste. Ethanol (CH_3CH_2OH) is made up of a group of chemical compounds whose molecules contain a hydroxyl group, -OH, bonded to a carbon atom. Ethanol made from cellulosic biomass materials instead of traditional feedstock (starch crops) is called bio-ethanol.

i. Physical properties

Ethanol's hydroxyl group is able to participate in hydrogen bonding. At the molecular level, liquid ethanol consists of hydrogen-bonded pairs of ethanol molecules; this phenomenon renders ethanol more viscous and less volatile than less polar organic compounds of similar molecular weight. In the vapor phase, there is little hydrogen bonding; ethanol vapor consists of individual ethanol molecules.

Ethanol is a versatile solvent. It is miscible with water and with most organic liquids, including non polar liquids such as aliphatic hydrocarbons. Organic solids of low molecular weight are usually soluble in ethanol. Among ionic compounds, many mono valent salts are at least somewhat soluble in ethanol, with salts of large, polarizable ions being more soluble than salts of smaller ions. Most salts of polyvalent ions are practically insoluble in ethanol.

Several unusual phenomena are associated with mixtures of ethanol and water. Ethanol-water mixtures have less volume than their individual components: a mixture of equal volumes ethanol and water has only 96% of the volume of equal parts ethanol and water, unmixed. The addition of even a few percent ethanols to water sharply reduces the surface tension of water. This property partially explains the tears of wine phenomenon: when wine is swirled inside a glass, ethanol evaporates quickly from the thin film of wine on the wall of the glass. As its ethanol content decreases, its surface tension increases, and the thin film beads up and runs down the glass in channels rather than as a smooth sheet.

Table4.1-Physical properties of ethanol

Boiling point:	**79 °C**
Melting point:	**-117 ° C**
Relative density (water = 1):	**0.8**
Solubility in water:	**miscible**
Vapour pressure, kPa at 20°C:	**5.8**
Relative vapour density (air = 1):	**1.6**
Relative density of the vapour/air-mixture at 20 degree C (air = 1): 1.03	
Flash point:	**13 ° C**
Auto-ignition temperature:	**363 ° C**
Explosive limits, volume % in air:	**3.3-19**

Table 4.2: - Comparison between Diesel, Ethanol, and Gasoline

	Typical Diesel	Ethanol	Typical Gasoline
Vapor pressure@38°C, psi	0.04	2.5	7-9
Flash point, °C	55-65	13	-40
Boiling point (or range), °C	170-340	78	33-213
Autoignition temperature, °C	230	366	300
Flammability limits, vol%	0.6-5.6	3.3-19.0	1.4-7.6
Flammability limits, °C	64-150	13-42	(-40)-(-18)

ii. Vapor Pressure:

The vapor pressure of Ethanol is a very important characteristic property of this fuel. It determines the cold start behavior of an engine. At low temperatures it is very difficult to create vapor. Alcohol has lower vapor pressure than gasoline. As a result, cold starting with E85 is very difficult as compared with conventional gasohol and gasoline engine. The E10 curve demonstrates that the higher level of gasoline (90%) in this blend produces a much higher vapor pressure at temperatures below 30°F, where cold starting is very difficult.

iii. Calorific Value:

In addition to ethanol's poor cold starting characteristics ethanol also has lower energy content than gasoline because of its chemical structure in which alcohol molecules contains fixed oxygen. E85 has 71.6% the energy of E10 as demonstrated in Table 2. This means it will require approximately 28.4% more E85 to produce the same heating value as gasohol. And in comparison to gasoline (43960/26800) =1.64 or approximately 64%more pure alcohol is required.

iv. Octane Number:

Ethanol Blended Gasoline does offer a higher octane number, which allows for use in higher compression engines. This will increase thermal efficiency of engines and result in a slight decrease in fuel consumption.

v. Latent heat of vaporization:
In comparison with gasoline, ethanol has very high latent heat of vaporization. For pure ethanol it is 2.91 times that of gasoline in a stoichiometric mixture. It result in an air temperature reduction of approximately 4.5°C, thus increasing the volumetric efficiency and hence the power output.

vi. Viscosity and lubricity:
Fuel viscosity and lubricity play significant roles in the lubrication of fuel injection systems, particularly those incorporating rotary distributor injection pumps that rely fully on the fuel for lubrication within the high pressure pumping mechanism. In the common

rail accumulator fuel-injection system, the high-pressure pump that delivers fuel to the rail also relies on the fuel for lubrication. In in-line pumps and unit injectors, there is less reliance on the fuel for lubrication; however, there are still some metal interfaces that require lubrication by the fuel such as between plunger and barrel. Injector lubrication also is affected, particularly at the needle guide-nozzle body interface. Lower fuel viscosities lead to greater pump and injector leakage reducing maximum fuel delivery and ultimately power output. Hot restart problems also may be encountered as insufficient fuel may be injected at cranking speed when fuel leakage in the high-pressure pump is amplified because of the reduced viscosity of the hot fuel. The addition of ethanol to diesel lowers fuel viscosity and lubricity. Wrage and Goering (1980) investigated the variation of kinematics viscosity with percentage of ethanol present and generated the graph shown in Fig.3. They concluded that a blend of 18.5% dry ethanol (1.1 mm2/s viscosity) with No. 2 diesel (2.46 mm2/s viscosity) would equal the ASTM minimum viscosity of 2.0 mm2/s at 37.8 _C and would be well above the minimum for No. 1 diesel as shown in Fig. 1. Speidel and Ahmed (1999) reported a viscosity of 2.25 mm2/s for a blend containing 15% dry ethanol, 5% PEC additive and 80% diesel. It should be noted that the final blend viscosity is dependent on the viscosity of the diesel fuel. Blending ethanol with a diesel fuel that has a viscosity close to the minimum is likely to yield an overall viscosity lower than the ASTM minimum.
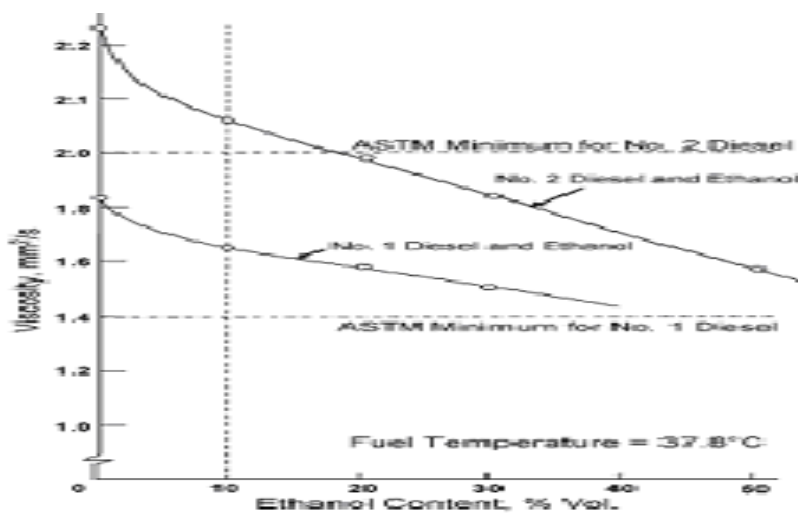
Figure 4.3 ASTM Lubricity Test

Two ASTM lubricity tests are commonly used to characterize the lubricity of fuels, the Sung Load Ballon-Cylinder Lubricity Evaluator (SBOCLE), D6078-99 and the High Frequency Reciprocating Rig (HFRR), D6079-99. Relatively few lubricity tests have been carried out on ethanol–diesel blends. Speidel and Ahmed (1999) reported a SBOCLE test value of 5200 g for the blend containing 15% dry ethanol, 5% PEC additive and 80% diesel, as compared to the minimum of 3100 g specified for No. 2 diesel. Bio-based oils have been effective in increasing fuel lubricity and are commercially available. Hardenberg and Schaefer (1981) included 1% castor oil in a 95% ethanol fuel that was used

Successfully in affect of trucks and buses in Brazil. Minimum specifications for viscosity and lubricity of ethanol–diesel blends are required in order to ensure that fuel injection system durability is not compromised relative to diesel fuel usage and that engines are able to start reliably when hot.

Fuel viscosity also affects the atomization and spray characteristics in the combustion chamber. Lower viscosities typically result in smaller Sauter mean droplet diameters, thereby increasing the surface area of droplets and significantly influencing the evaporation characteristic time (Heywood, 1988; Desantes et al., 1998). The lack of reports of specific measurements to corroborate these trends with ethanol–diesel blends indicates a need to investigate their atomization and spray characteristics, as these parameters have a significant effect on the combustion process.

4.3 Advantages and disadvantages of Ethanol

Ethanol is an attractive alternate liquid fuel source for internal combustion engines. Advantages of ethanol over Fossil Fuels are as follows:

- Ethanol is a much cleaner fuel than fossil petroleum fuels.
- It is a renewable fuel made form plants.
- It is not a fossil fuel: manufacturing it and burning it does not increase the green house effect.

- It provides high octane at low cost as an alternative to harmful fuels additives compared to the gasoline fuels.
- Ethanol blends can be used in all engines with out modifications.
- Ethanol is biodegradable without harmful effects on the environment.
- It is sulfur free, which leads to very low Sulpher dioxide emissions.
- Ethanol' high oxygen content reduces carbon monoxide levels more than any other oxygenates: by 25-30%, according ton the USEPA.
- High-level ethanol blends reduce nitrogen oxides emissions by up to 20%.

High-level ethanol blends can reduces emissions of volatile organic compounds (VOC) by 30% or more VOC are major sources of ground level. As a transportation fuel, ethanol can be used directly or mixed with ignition improvement additive to use in diesel engine specially configured for that purpose.

Relative less work has done on the use of ethanol in compression ignition engine; due to its certain disadvantages some of the disadvantages of Ethanol are as fellow:

- The relatively low boiling points and high vapor pressure of ethanol indicate that vapor lock could be a serious problem, particularly at high altitudes on warm summer days.
- It absorbs water and will cause phase separation in mixtures if water comes into the distribution, storage or vehicle fuel system.
- Ethanol is very difficult to burn by compression-ignition, because of their low ignition quality, usually designated by a low 'certain number'.
- The lubricity of ethanol is unacceptable for high-pressure injection pumps in diesel engines.

4.4 Storage and Safety

There is specific storage and handling procedures for ethanol blends at distribution and service stations, these include requirements for tanks and tank linings, piping and fittings, and pumps and dispensers.70 The Australian Institute of Petroleum is currently developing a code of practice for the storage of ethanol blends. Although some materials used to fabricate storage systems may have evolved over time to accommodate the storage of ethanol and ethanol blends, a recent US study has revealed that some single-walled fiberglass reinforced plastic tanks as well as some gaskets; sealants, adhesives and other component materials may not be compatible with ethanol.
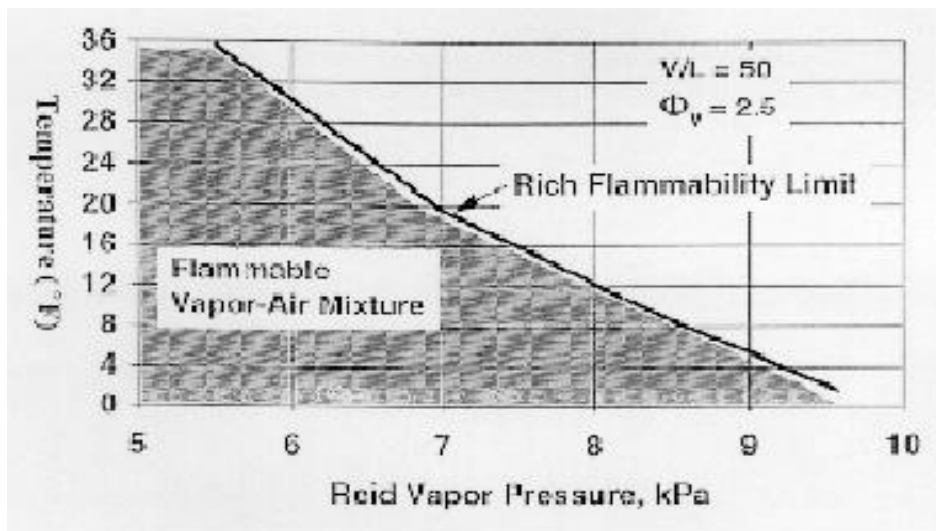
Figure4.4- Effect of RVP on Rich Flammability Limit Temperature

EXPERIMENTAL SETUP

The main objective of the experiment is to investigate the effects on performance of pure Ethanol in S I engine and blending of Ethanol with gasoline fuel in spark ignition engine. A Briggs and Stratton 305cc, 10 hp engine was employed as the test engine in this analysis.
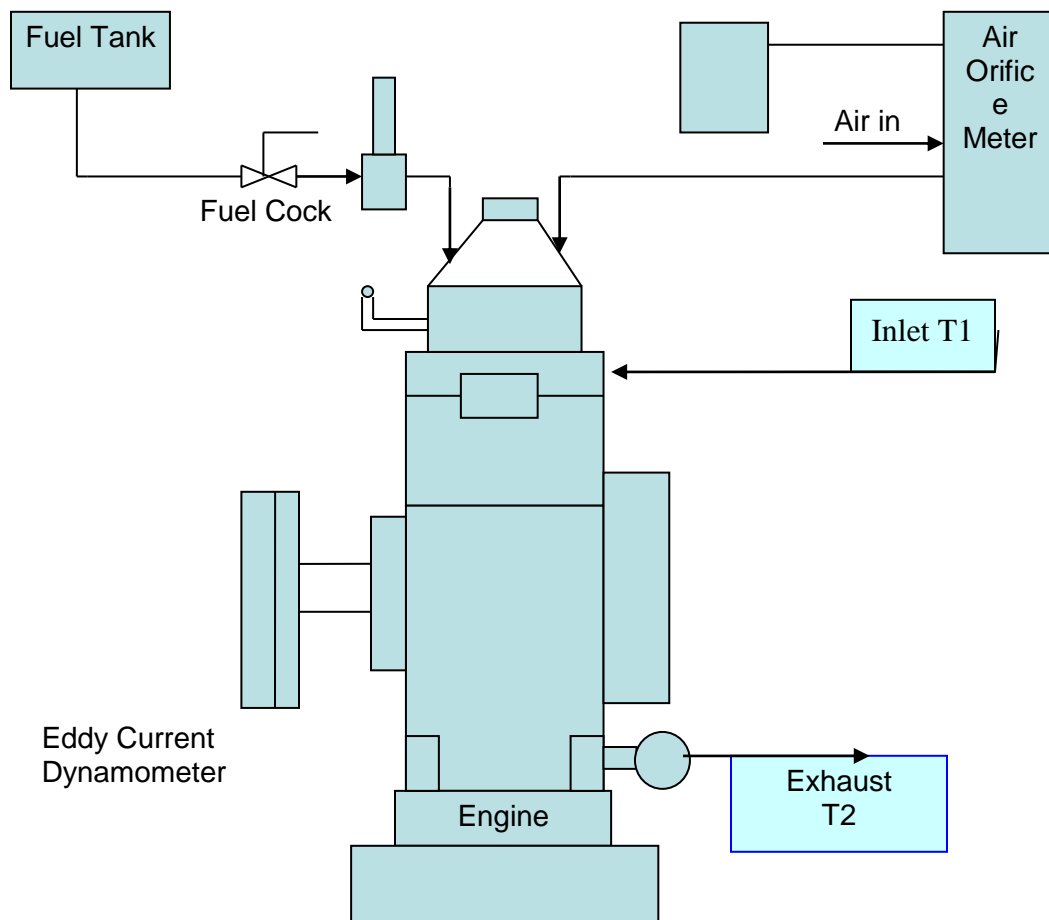
Figure 7.1 Experimental Set Up

ENGINE SPECIFICATIONS: -
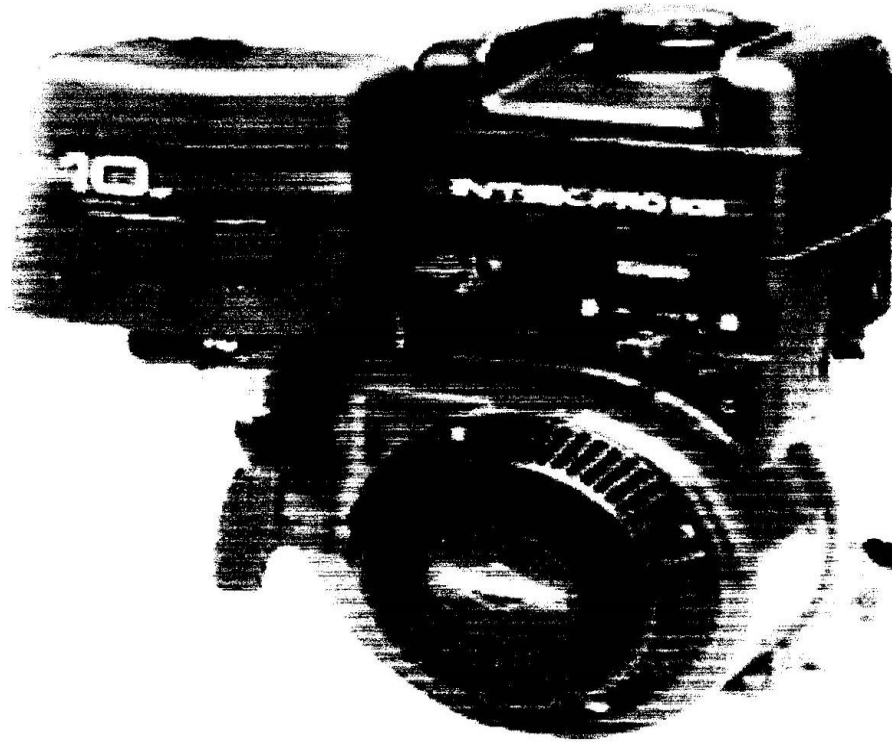
Figure 7.2 Briggs & Stratton Model 20 INTEK

Description	INTEK T"' IIC Model 202400 Model 205400
Displacement	18.6 cu. In. (305cc)
Bore	3.120 in. (79.25mm)
Stroke	243 8in(6167mm)
Compression Ratio	9.0:1
Horsepower	8.0 hp (5.96kW))/ 10.0 hp (7.46 kW)
Torque	14.5 ft. lb. (19.66 Nm) @ 2800 RPM Emissions Certified
Valve Design	Overhead Valve
Cylinder	30-degree slant
Bore Type	Dura-Bore TM, Cast Iron Sleeve
Carburetor	Side-Draft, (19.0 mm)

Ignition	Magnetron®
Low-Mount (Panel)	A/C Dual Element Air Filter (Oval
Air Cleaner	Optional
Lubrication	Dipper/Splash
Bearings	DU Magneto DU PTO (Ball Bearing optional)
Controls	3 in 1, Manual/Fixed Speed
Fuel Tank	(3.785 Liters) Polymer
Fuel rill In Tank	150 Micron (Additional In-Line 75 Micron fuel filter optional)
Muffler	Lo-Tone Small (Super Lo-Tone optional)
Oil Capacity	26 Fl. Oz. (0.7 Liters)
Oil Fill	(High Oil Fill Optional)
Oil Sensor	(Low Oil Sensor, Rocker Stop switch Optional)

Control Panel:

Figure 7.2 Control Panel

A control panel consists of the following components: -

i. Eddy current dynameters

ii. Flow meters

iii. Excitation current ammeter

iv. Air box

i. Eddy-current dynamometer

The working principal of eddy current dynamometer consists of a stator on which are fitted a number of electromagnets and a rotor disc made of copper or steel and coupled to the output shaft of the engine. When the rotor rotates Eddy currents are produced in stator due to magnetic flux set up by the passage of field current in the electromagnets. These eddy currents oppose the rotor motion thus loading the engine. These eddy currents are dissipated in producing heat so that this type of dynamometer also requires some cooling arrangement. The torque is measured exactly as in other types of absorption dynamometer with the help of a moment arm. Regulating the current in the electromagnets controls the load**.**

Eddy-current dynamometer capable of absorbing power includes the eddy- current brake and various mechanical rakes employing dry fraction (Pony brake) and fluid fraction. Tape recordings of engine torque and speed measured under actual driving c0nditions for an automobile are utilized to reproduce these conditions in the laboratory engine test. Two feedback systems control engine speed and torque. A Tachometer generator speed signal from the dynamometer is compared with the desired speed signal form the tape recorder; if the two are different; the dynamometer control is automatically adjusted to change speed until agreement is reached. Actual. Actual engine torque is obtained from a load cell on the dynamometer and compared with the desired torque form the tape recorder. If these do not agree, the error signal actuates the engine throttle control in the proper direction. Other systems operate simultaneously and continuously to the force

engine speed and torque to follow the tape-recorder commands. By adapting recent developments in Variable-frequency ac motor control, becomes a versatile dynamometer for both driving and absorbing applications. Features include fast response, Flexible control, simplified maintenance, and energy conservation, since up to 85 percent of the energy absorbed is returned to the ac power line.

The following are main advantages of eddy current dynamometers:

- High horsepower per unit weight of dynamometer.
- They offer the highest ratio of constant horsepower speed range(up to 5:1).
- Relatively higher torque under low speed conditions.
- No natural limit to size-either small or large.

Figure 7.3 Eddy-current dynamometer

Fig 7.4 Load cell for Eddy-current dynamometer

ii. Flow meters

Flow meter is measure the volume flow in a given time interval and by multiplying it by the specific gravity of the fuel which should be measured occasionally to get an accurate value. Another method is to measure the time required for consumption of a given mass of fuel.

Accurate measurement of fuel consumption is very important in engine testing work though this seems to be a simple matter; it is by no means so as apparent from the occurrence of the following phenomena:

1. Due to engine heat vapour bubbles are formed in the fuel line.
2. If bubbles are formed before or inside the flow meter and flow meter cont then the indicated flow can be much high than actual.
3. If there is any swirl in the fuel flow turbine type flow meters may register a higher flow rate.
4. The density of the fuel is dependent on the temperature.

iii. Excitation current ammeter

Specifications: 0-30 A.C, Least count -1 A

It is used to vary load of the Eddy-current dynamometer

iv. Air box

The orifice method can be used if pressure pulsations could be damped out by some means. The usual method of damping out pulsations is to fit an air box of suitable volume volume (500 to 600 times the swept volume in single cylinder engines and less in the case of multicylinder engines) to the engine with an orifice in the side of the box remote from the engine.

PERFORMANCE EVALUATION TEST

8.1 Gasoline: -

$Q_{LHV}= 44.5$ MJ/kg

Load (Kg)	Mass flow Rate (m_f) (Kg/sec*10^{-6})	Power (watt)	Exhaust. Tem. (°C)	$Q_{cv} = (m_f *_{cv})$ KJ/sec	η_{th}	BSFC (Kg/KWh)	CO (%)	HC (ppm)	NOx (ppm)
0	72.16	0	100	3211.12	-	-	1.8	103	184
2	120.5	675.76	120	5362.25	12.60	.4953	1.2	82	221
4	180.5	1351.52	180	8032.25	16.82	.37098	.87	75	374
6	228.7	2019.53	230	10177.1	19.84	.3145	.40	69	744
8	239.5	2684.08	260	10657.7	25.18	.2478	.28	64	1421
10	245.3	3344.32	268	10915.8	30.6	.2037	.16	45	1663

Table 8.1 Variation in various parameters with the Power for Petrol Mode

i. Performance Curve for Gasoline

Gasoline- Exh. T (C) Vs Power (Watt)
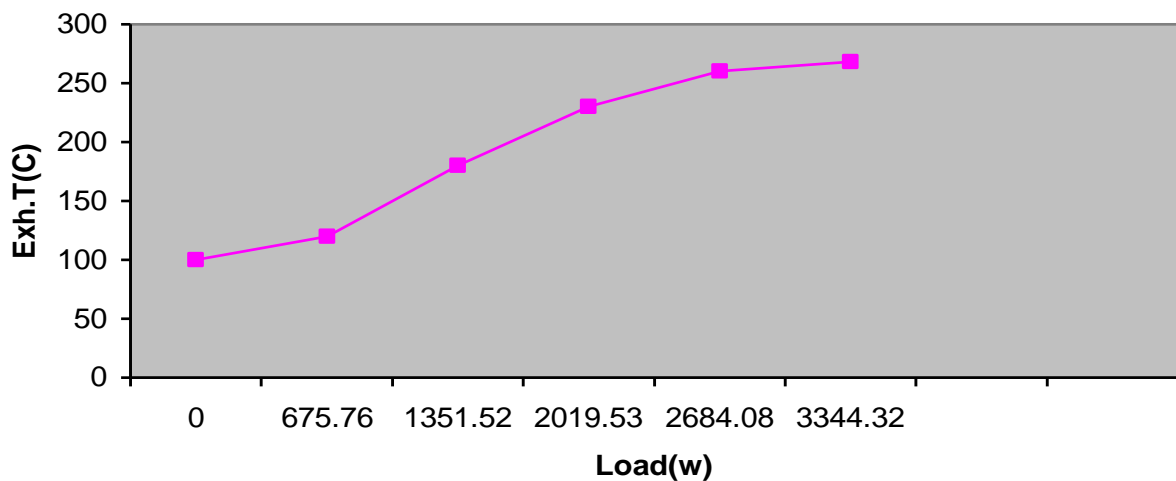
Figure 8.1.a. Curve b/w Exh.Tem. Vs Power (Watt) Gasoline

Gasoline- Thermal efficiency Vs Power (Watt)
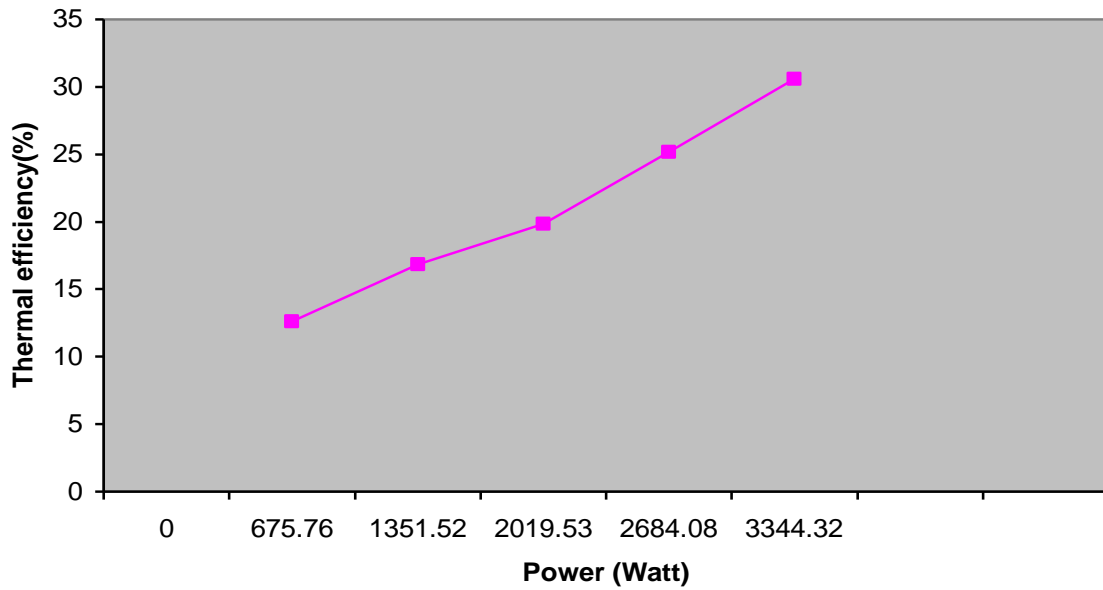
Figure 8.1.b. Curve b/w Thermal efficiency Vs Power (Watt) Gasoline

Gasoline Power Vs Power (Watt)
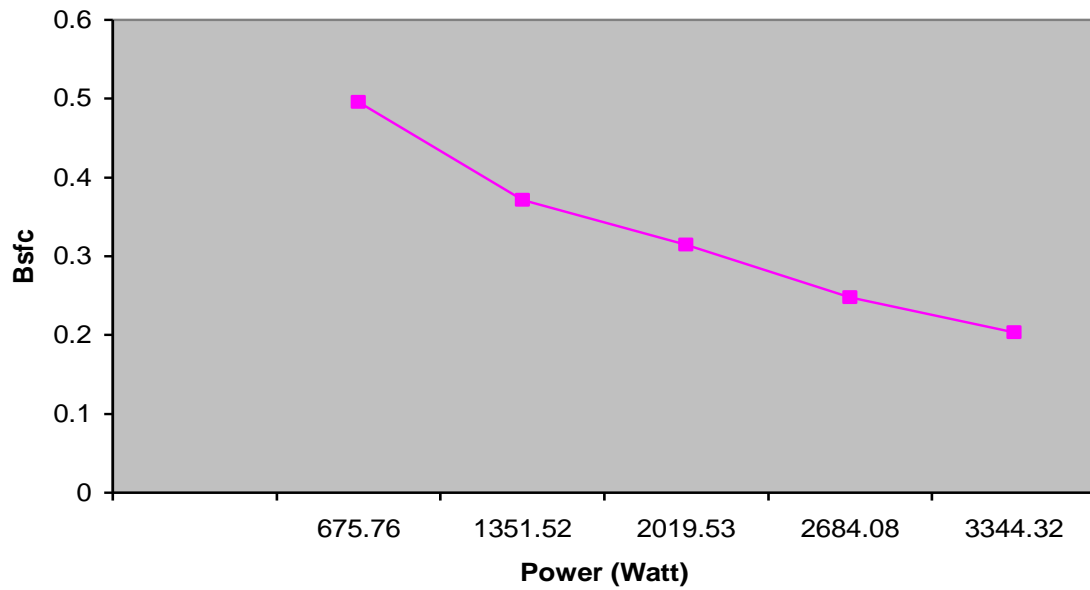
Figure 8.1.c. Curve b/w Bsfc Vs Power (Watt) Gasoline

Gasoline-CO (%) Vs Power (Watt)
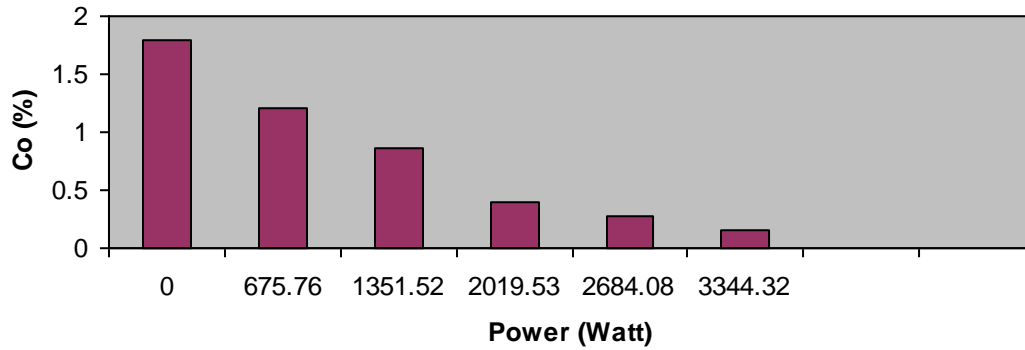
Figure 8.1.d. Curve b/w CO (%) Vs Power (Watt) Gasoline

Gasoline- NOx (ppm) Vs Load
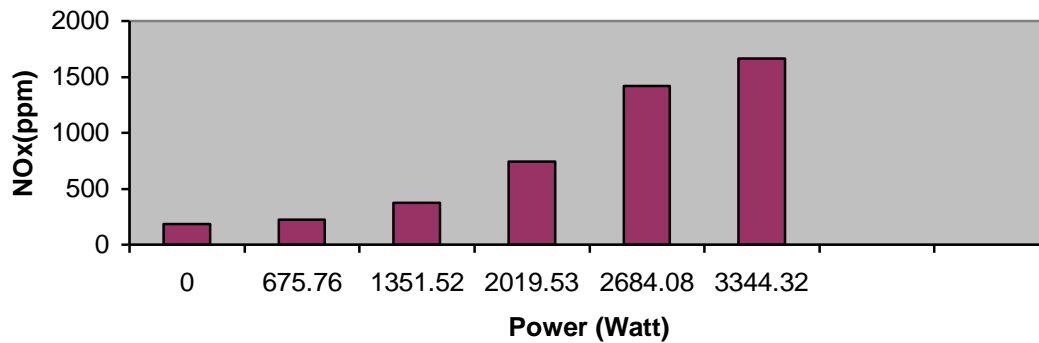
Figure 8.1.e. Curve b/w NOx (ppm) Vs Power (Watt) Gasoline

Gasoline- HC (ppm) Vs Power (Watt)
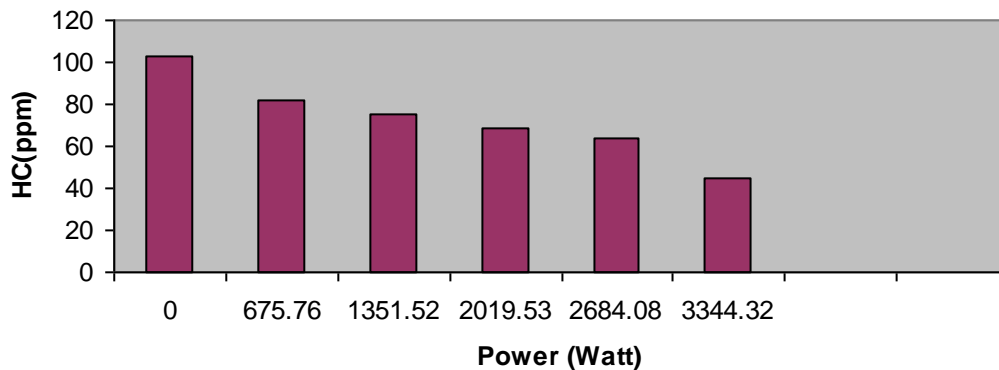
Figure 8.1.f. Curve b/w HC (ppm) Vs Power (Watt) Gasoline

8.2 E-8:- (92% Gasoline +8% Ethanol)
$Q_{LHV=43.1328 \text{ MJ/kg}}$

Load (Kg)	Mass flow Rate (m_f) (Kg/sec*10^{-6})	Power (watt)	Exhaust. Tem. (°C)	$Q_{CV} = (m_f {}^*cv)$ KJ/sec	η_{th}	BSFC (Kg/KWh)	CO (%)	HC (ppm)	NOx (ppm)
0	74.5	0	120	4213.39	-	-	1.21	95	120
2	124.5	681.37	150	5370.33	12.7	0.5592	0.95	73	180
4	186.5	1358.4	244	8044.26	16.9	0.3813	0.47	65	295
6	236	2031.1	254	10179.3	20.0	0.3227	0.20	62	650
8	247.5	2699.6	272	10675.3	25.2	0.2546	0.18	58	1250
10	253.5	3363.7	280	10934.1	31.0	0.2093	0.10	40	1300

Table 8.2 Variation in various parameters with the Power for E-8 Ethanol-gasoline Blendes

i. Performance Curve for E-8
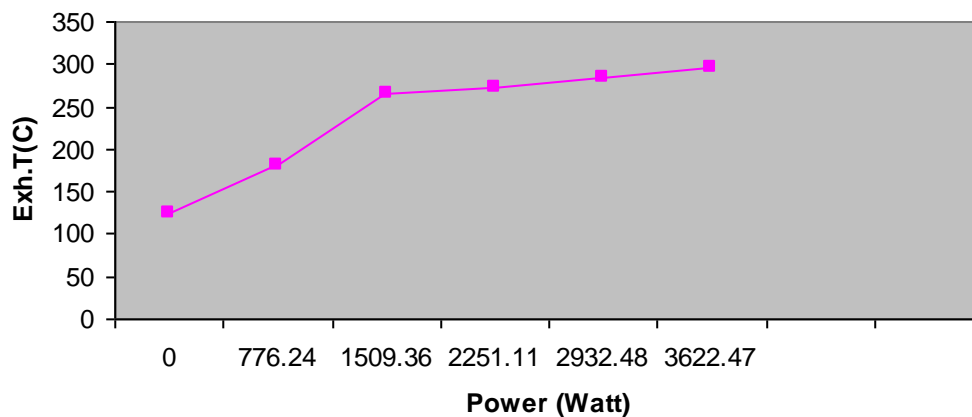
E-8 Exh. T (ppm) Vs Power (W)
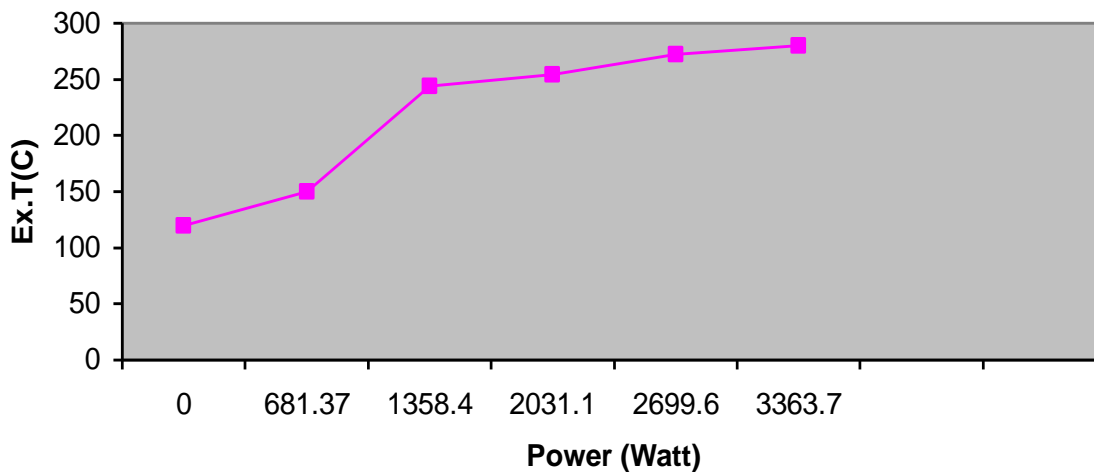
Figure 8.2.a. Curve b/w Exh. Tem.(°C) Vs Power (Watt) E-8

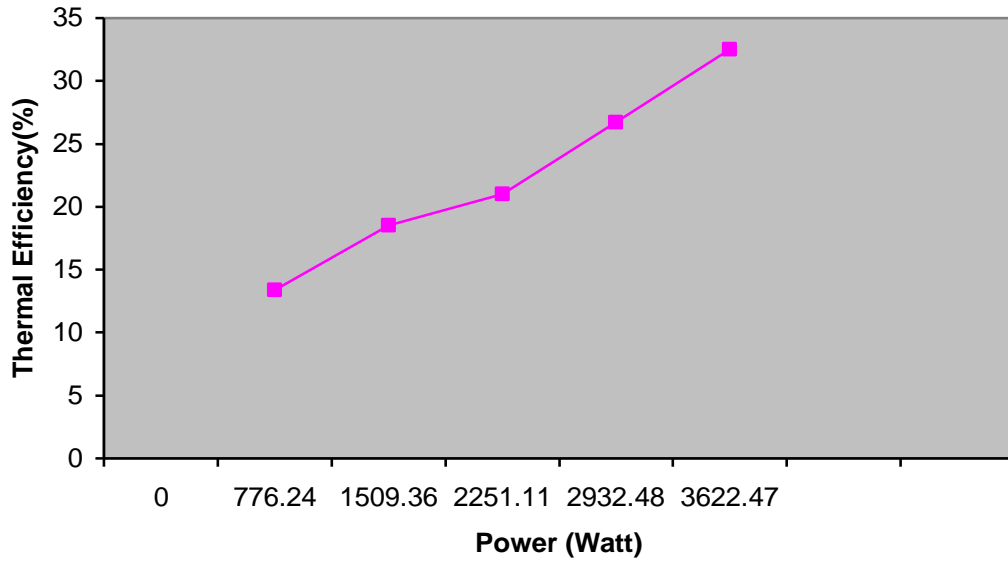**E-8 Thermal Efficiency Vs Power (W)**
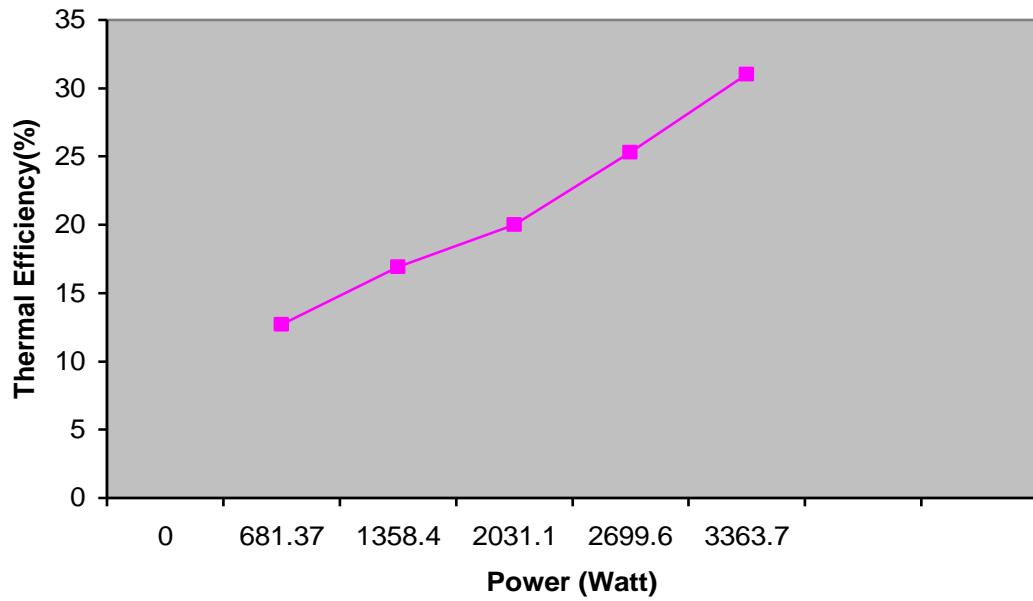
Figure 8.2.b. Curve b/w Thermal Efficiency Vs Power (Watt) E-8
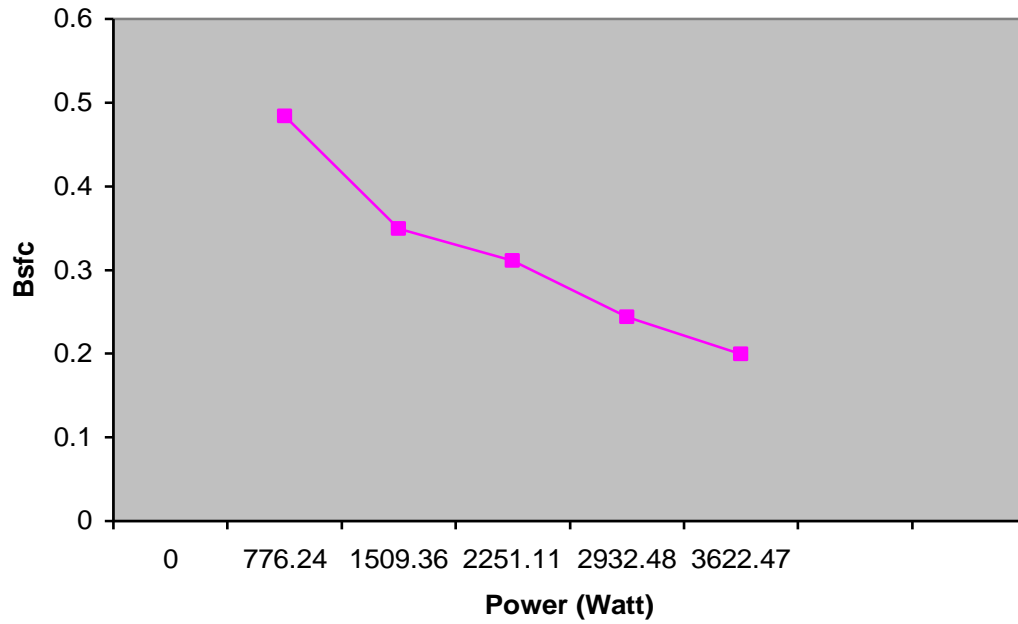
E-8 Bsfc Vs Power (W)
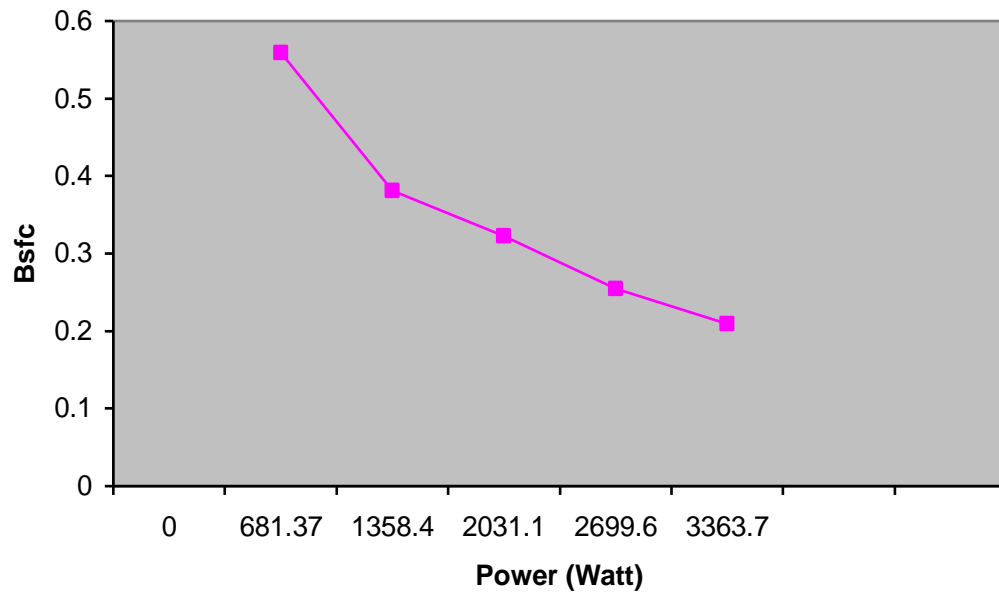
Figure 8.2.c. Curve b/ w Bsfc Vs Power (Watt) E-8

E-8 CO% Vs Power (W)
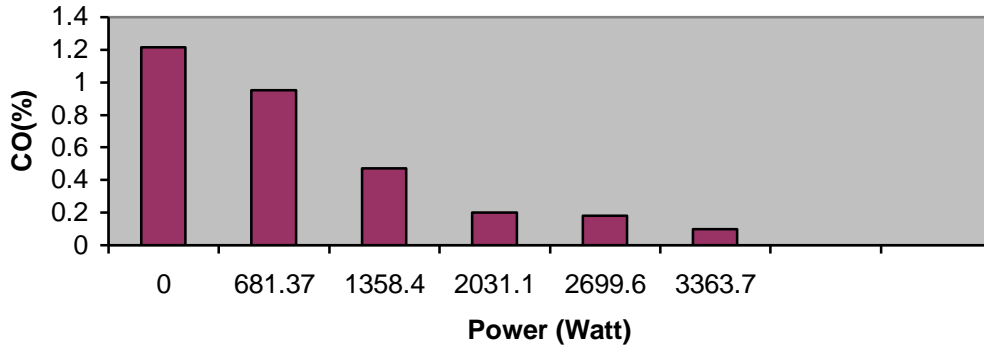
Figure 8.2.d. Curve b/ **w** CO% Vs Power (Watt) E-8
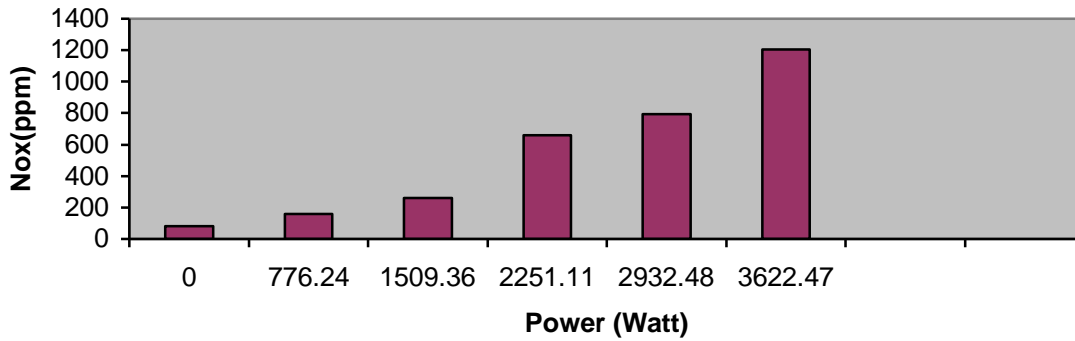
E-8 NOx (ppm) Vs Power (W)
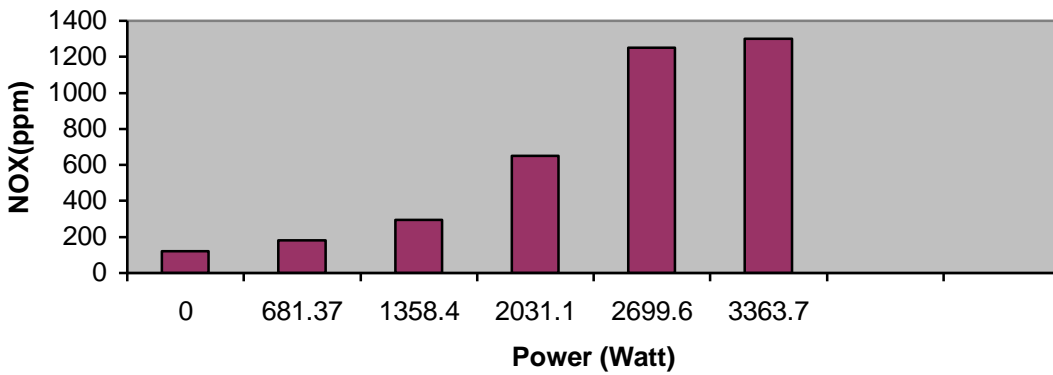
Figure 8.2.e. Curve b/w NOx (ppm) Vs Load E-8
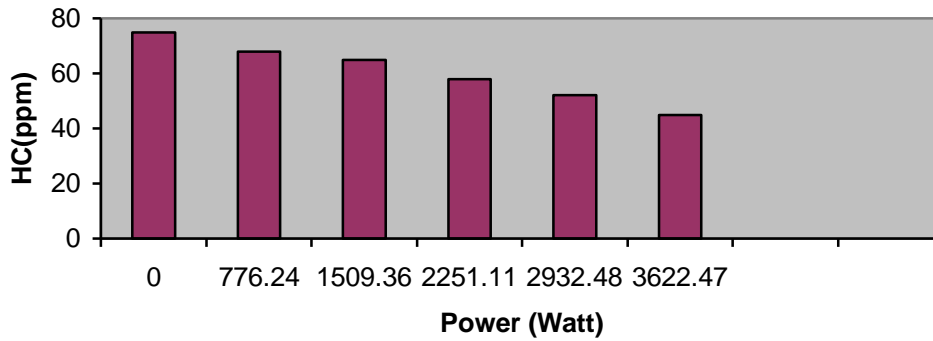
E-8 HC (ppm) Vs Power (W)
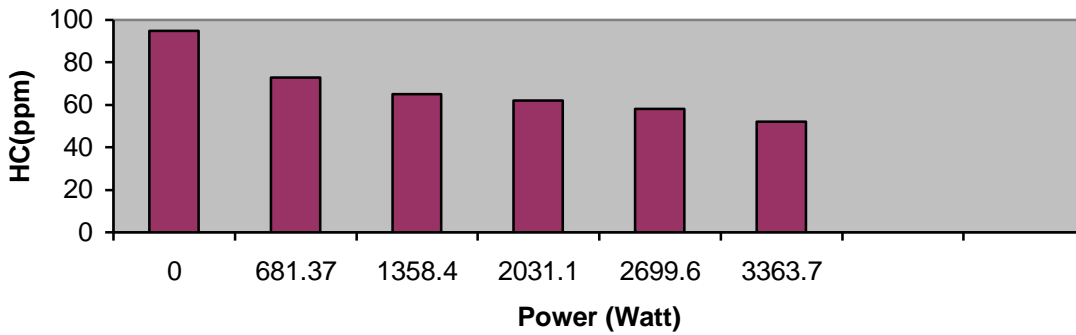
Figure 8.2.f. Curve b/w HC (ppm) Vs Power (Watt) E-8

8.3 E-10:- (90% Gasoline + 10% Ethanol)

$Q_{LHV=42.75 \text{ MJ/kg}}$

Load (kg)	Mass flow Rate (m_f) (Kg/sec*10^{-6})	Power (watt)	Exhaust. Tem.(°C)	$Q_{CV} = (m_f *_{CV})$ KJ/sec	η_{th}	BSFC (Kg/KWh)	CO (%)	HC (ppm)	NOx (ppm)
0	76.0	0	125	9500	-	-	0.812	75	80
2	135.34	776.24	180	5785.78	13.4	.484	0.669	68	160
4	190.0	1509.366	265	8122.5	18.5	.3496	0.357	65	261
6	252.0	2251.11	272	10773	21.0	.31095	0.220	58	638
8	257.6	2932.48	284	10986.7	26.6	.2440	0.173	52	794
10	260	3622.47	295	11115	32.5	.19937	0.09	32	1203

Table 8.3 Variation in various parameters with the Power (Watt) for E-10 Ethanol-gasoline Blendes.

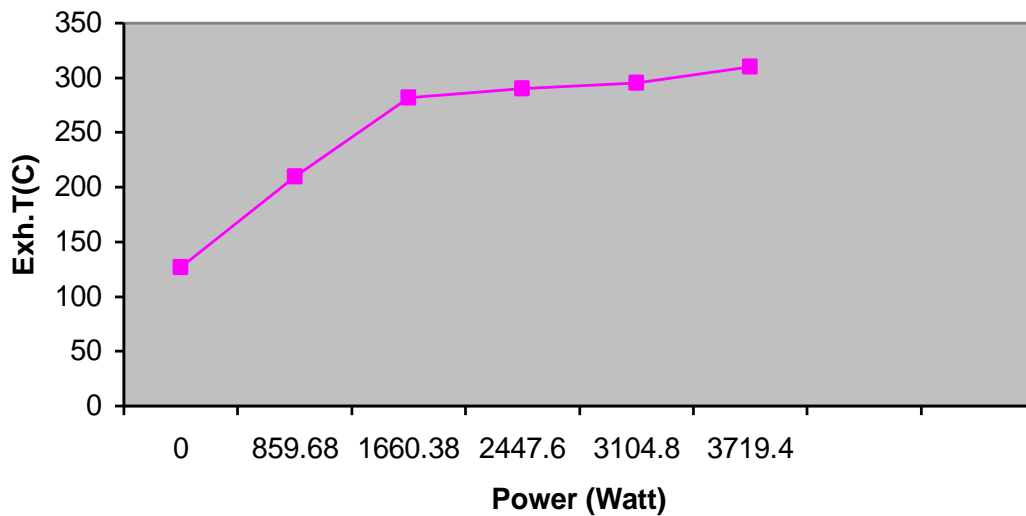### i. Performance Curve for E-10

E-10 Exh.T Vs Power (W)

Figure 8.3.a. Curve b/w Exh. T. (°C) Vs Power E-10
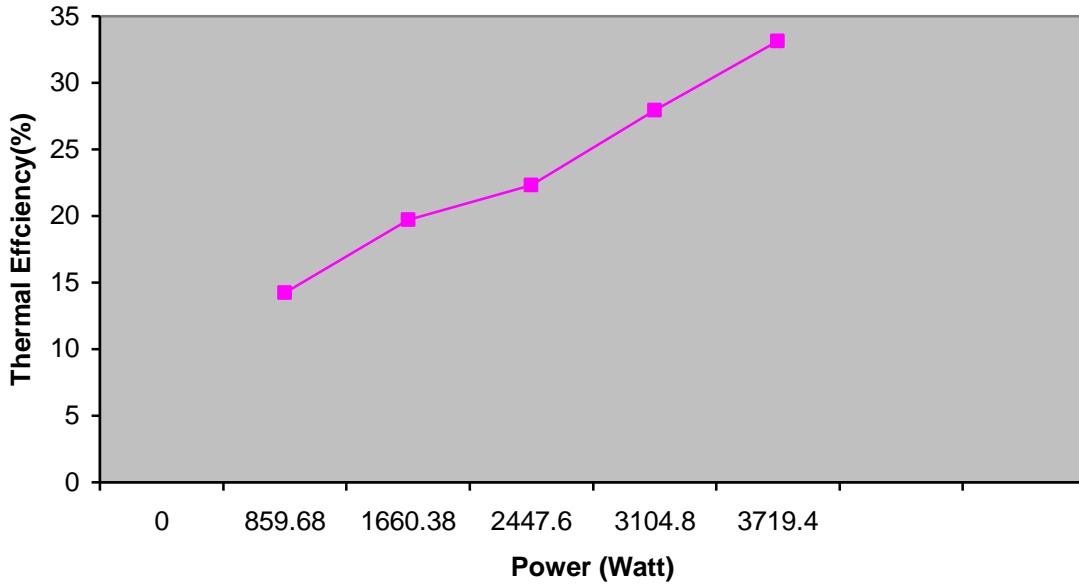
E-10 Thermal Efficiency Vs Power (W)

Figure 8.3.b. Curve b/w Thermal Efficiency Vs Power (Watt) E-10

E-10 Bsfc Vs Power (W)

Figure 8.3.c. Curve b/w Bsfc Vs Power E-10

E-10 CO% Vs Power (W)
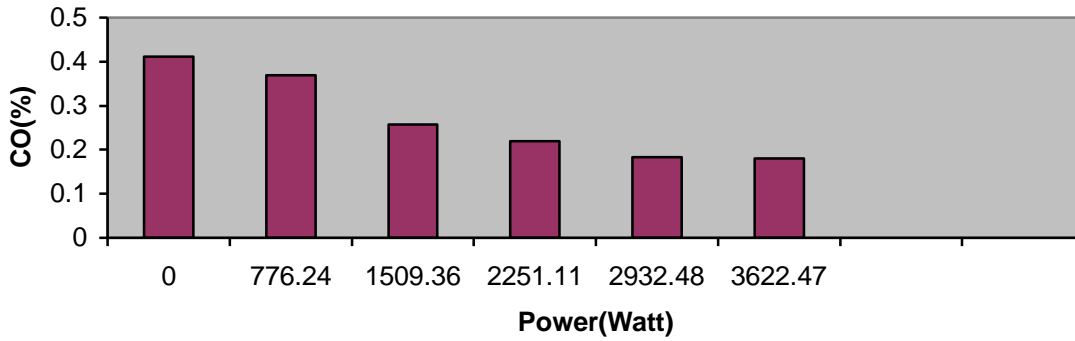
Figure 8.3.d. Curve b/ w CO% Vs Power E-10

E-10 NOx (ppm) Vs Power (W)

Figure 8.3.e. Curve b/w NOx (ppm) Vs Power (Watt) E-10

E-10 HC (ppm) Vs Power (W)

Figure 8.3.f. Curve b/ w HC (ppm) Vs Power (Watt) E-10

8.4 E-12:- (88% Gasoline + 12% Ethanol)

$Q_{LHV=42.3671 MJ/kg}$

Load (Kg)	Mass flow Rate (m_f) (Kg/sec*10^{-6})	Power (watt)	Exhaust. Tem.(°C)	$Q_{CV} = (m_f *cv)$ KJ/sec	η_{th}	BSFC (Kg/KWh)	CO (%)	HC (ppm)	NOx (ppm)
0	78.34	0	127	3319.03	-	-	0.413	57	77
2	142.6	859.68	210	6041.54	14.22	0.4607	0.312	46	150
4	198.7	1660.3	282	8418.34	19.72	0.3324	0.211	32	258
6	258.9	2447.6	290	10968.8	22.3	0.29382	0.109	28	550
8	262.34	3104.8	295	11114.5	27.93	0.2347	0.087	22	687
10	264.87	3719.4	310	11221.7	33.14	0.1978	0.07	20	1150

Table 8.4 Variation in various parameters with the Power (Watt) for E-12 Ethanol-gasoline Blendes

i. Performance Curve for E-12

E-12 Exh.T (C) Vs Power (W)

Figure 8.4.a. Curve b/w Exh.T. (°C) Vs Power (Watt) E-12

E-12 Thermal Efficiency Vs Power (W)

Figure 8.4.b. Curve b/w Thermal Efficiency Vs Power (Watt) E-12

E-12 Bsfc Vs Power (W)
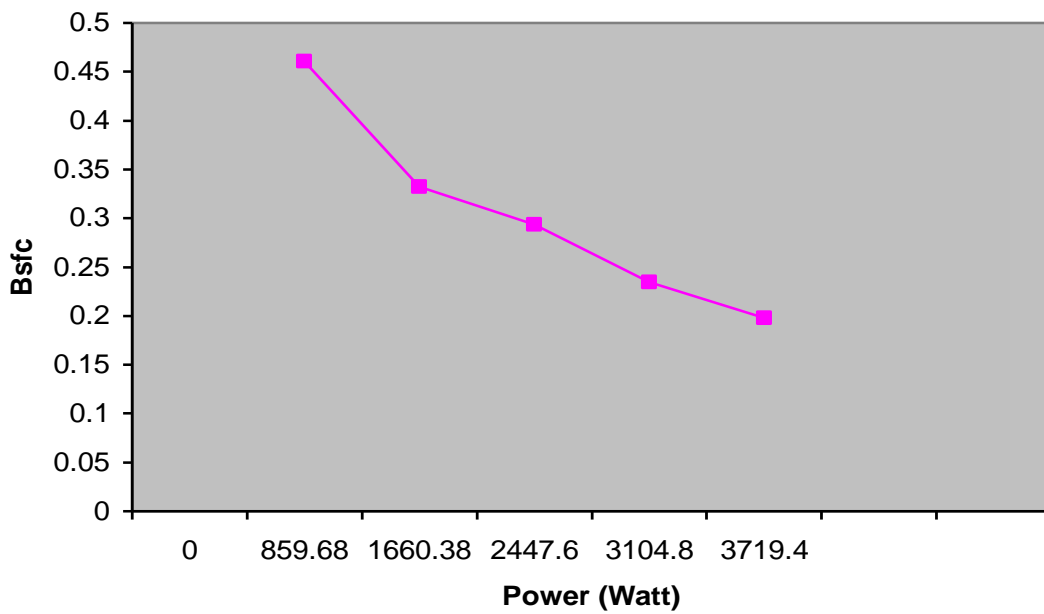
Figure 8.4.c. Curve b/w Bsfc (C) Vs Power (Watt) E-12
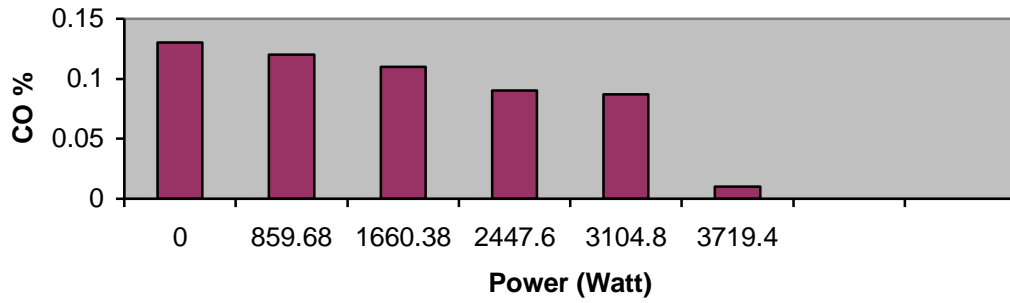
E-12 CO% Vs Power (W)

Fgure 8.4.d. Curve b/w CO % Vs Power (Watt) E-12
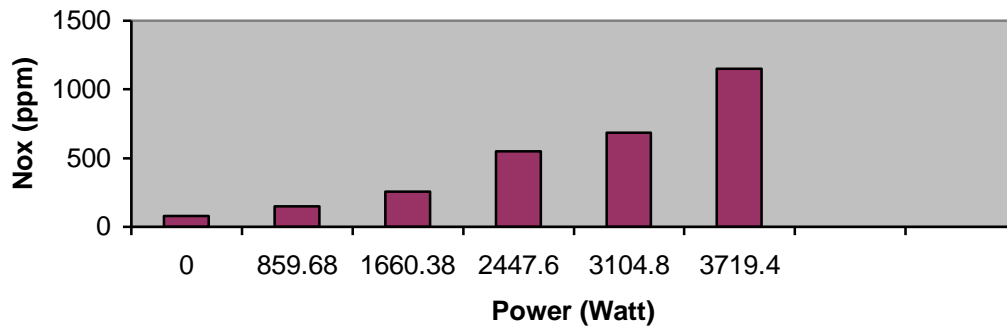
E-12 NOx Vs Power (W)

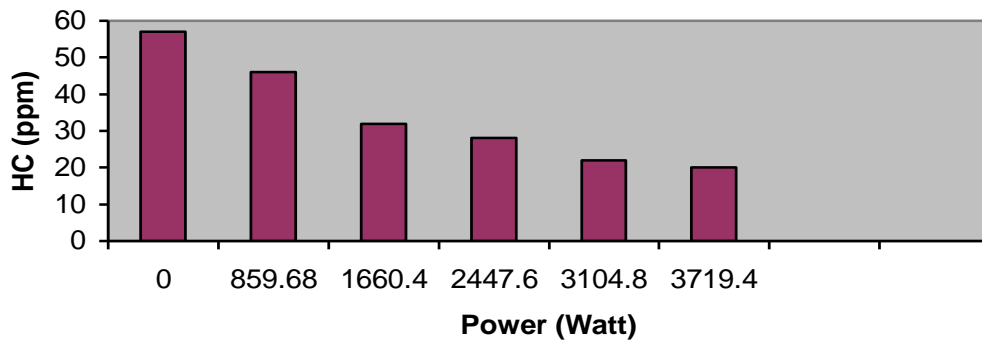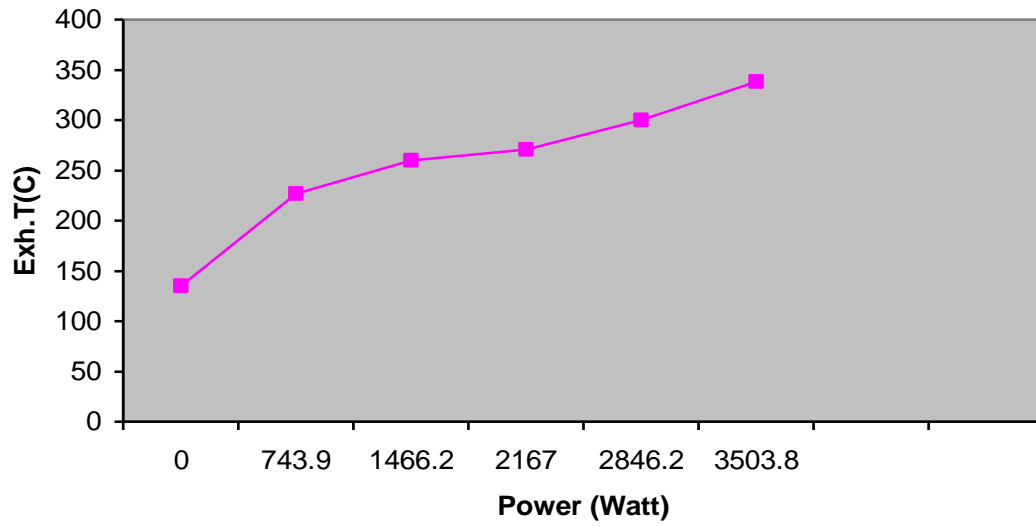Figure 8.4.e. Curve b/w NOx Vs Power (Watt) E-12

E-12 HC Vs Power (W)

Figure 8.4.f. Curve b/w HC Vs Power (Watt) E-12

8.5 E-14 :- (86% Gasoline + 14% Ethanol)

$Q_{LHV=41.9296 \text{ MJ/kg}}$

Load (Kg)	Mass flow Rate (m_f) (Kg/sec*10^{-6})	Power (watt)	Exhaust. Tem. (°C)	$Q_{cv} = (m_f *cv)$ KJ/sec	η_{th}	BSFC (Kg/KWh)	CO (%)	HC (ppm)	NOx (ppm)
0	75.8	0	135	3178.26	-	-	.015	28	53
2	135.5	743.9	227	5681.46	13.04	0.50596	.012	21	85
4	190.56	1466.2	260	7990.10	18.35	0.36102	.009	18	168
6	246.87	2167	271	10351.16	20.93	0.31645	.005	18	223
8	256.65	2846.2	300	10761.23	26.44	0.25048	.005	18	328
10	261.56	3503.8	338	10967.161	31.94	0.20736	.005	17.5	428

Table 8.5 Variation in various parameters with the Power for E-14 Ethanol-gasoline Blendes

i. Performance Curve for E-14

E-14 Exh. (C) Vs Power (W)

Figure 8.5.a. Curve b/w Exh. **Tem. (°C)** Vs Power (Watt.) E-14

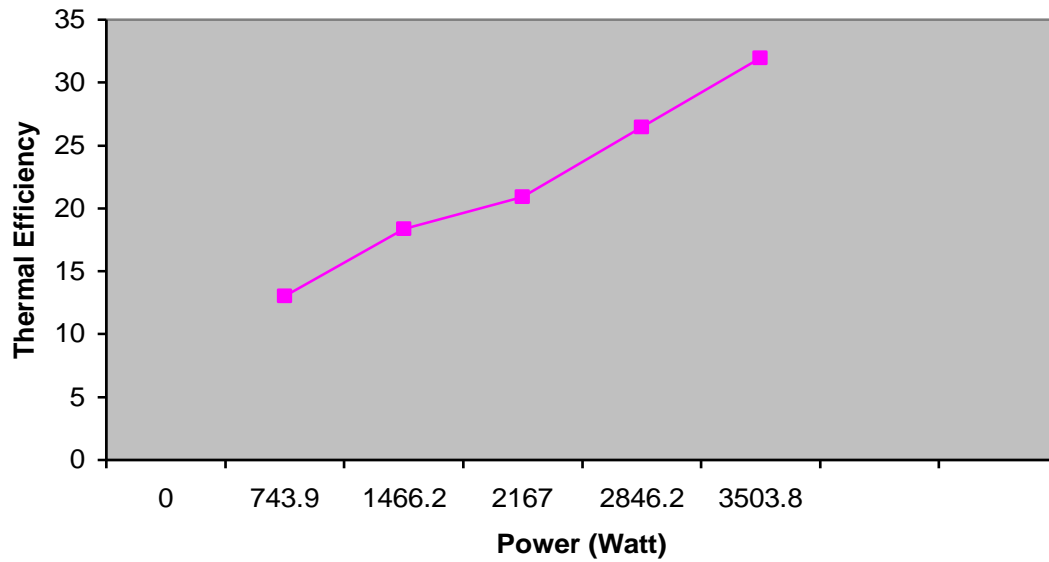**E-14 Thermal Efficiency Vs Power (W)**

Figure 8.5.b. Curve b/w Thermal Efficiency Vs Power E-14
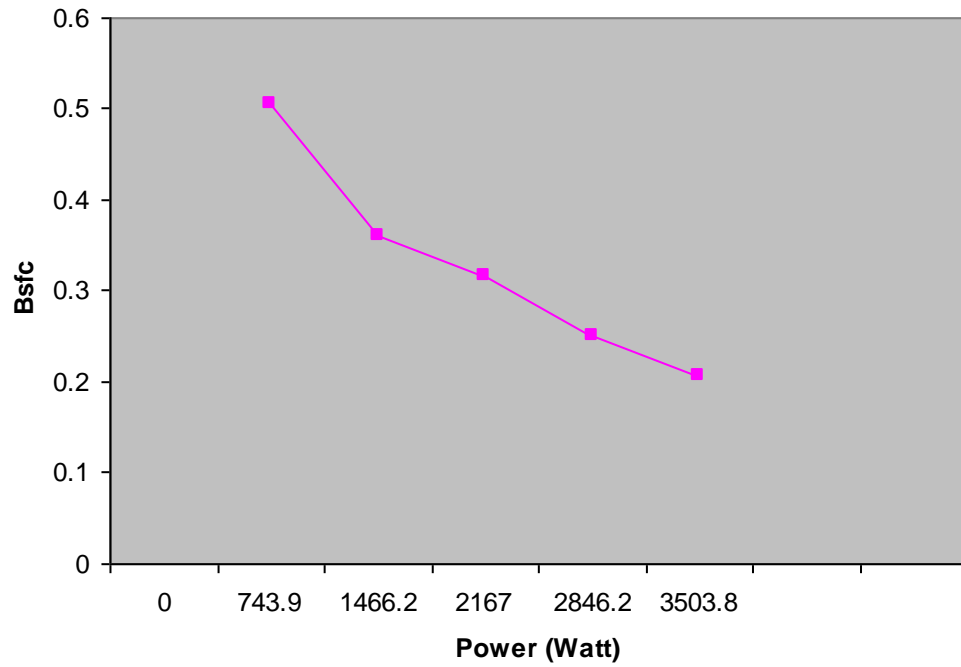
E-14 Bsfc Vs Power (W)

Figure 8.5.c. Curve b/w Bsfc Vs Power (Watt) E-14
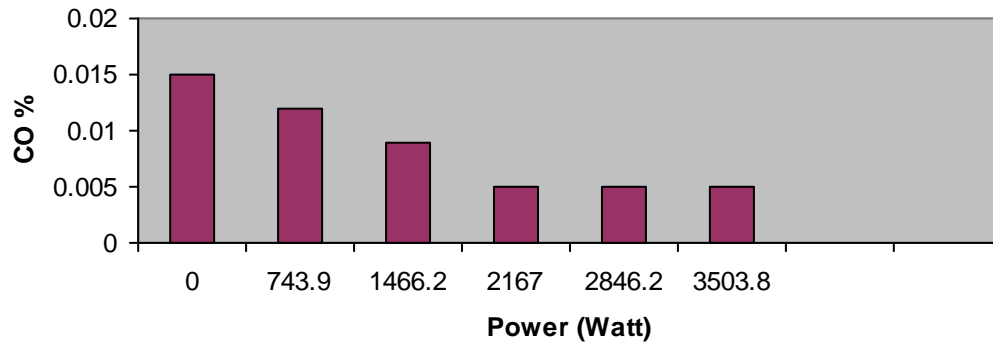
E-14 CO% Vs Power (W)

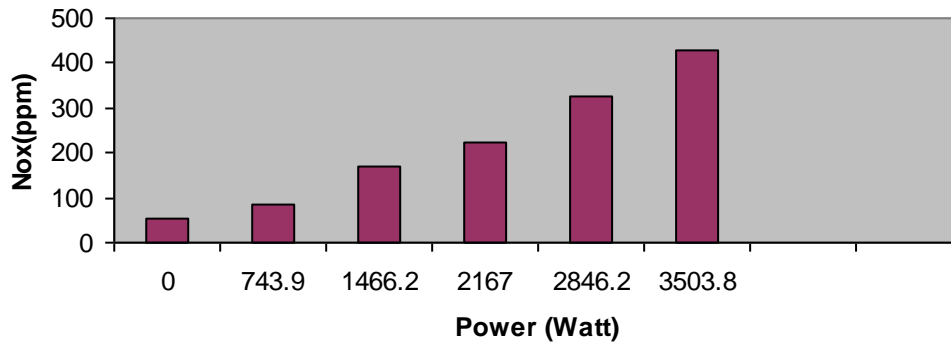Figure 8.5.d. Curve b/w CO% Vs Power (Watt) E-14

E-14 NOx (ppm) Vs Power (W)

Figure 8.5.e. Curve b/w Exh. T(**C**) Vs Power (Watt) E-14
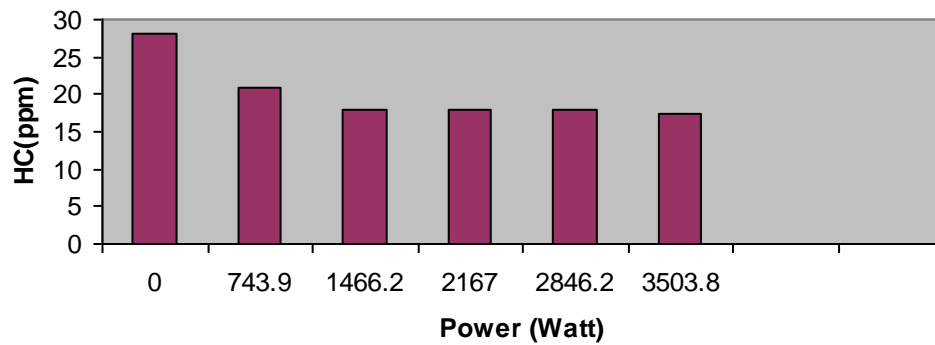
E-14 HC Vs Power (W)

Figure 8.5.f. Curve b/w HC Vs Power (Watt) E-14

9. RESULTS AND DISCUSSION

i. Thermal Efficiency

Thermal efficiency is defined as the ratio of output power to that of the chemical energy input. From the graph it is clear that as the power on the engine increases combustion efficiency increases because at part Power is less with the increase in power on the system.

On comparing the Gasoline with the Pure Ethanol Fuel we find that the Thermal Efficiency of Ethanol is better than that of gasoline because of the following reasons:

1. Higher octane rating of the gaseous fuel allows higher compression ratio in comparison to pure gasoline mode.
2. Since Ethanol enters in a gaseous state it allows more proper mixing of fuel and air. Proper mixing means proper combustion and less fuel goes unburnt into exhaust, giving more thermal efficiency.

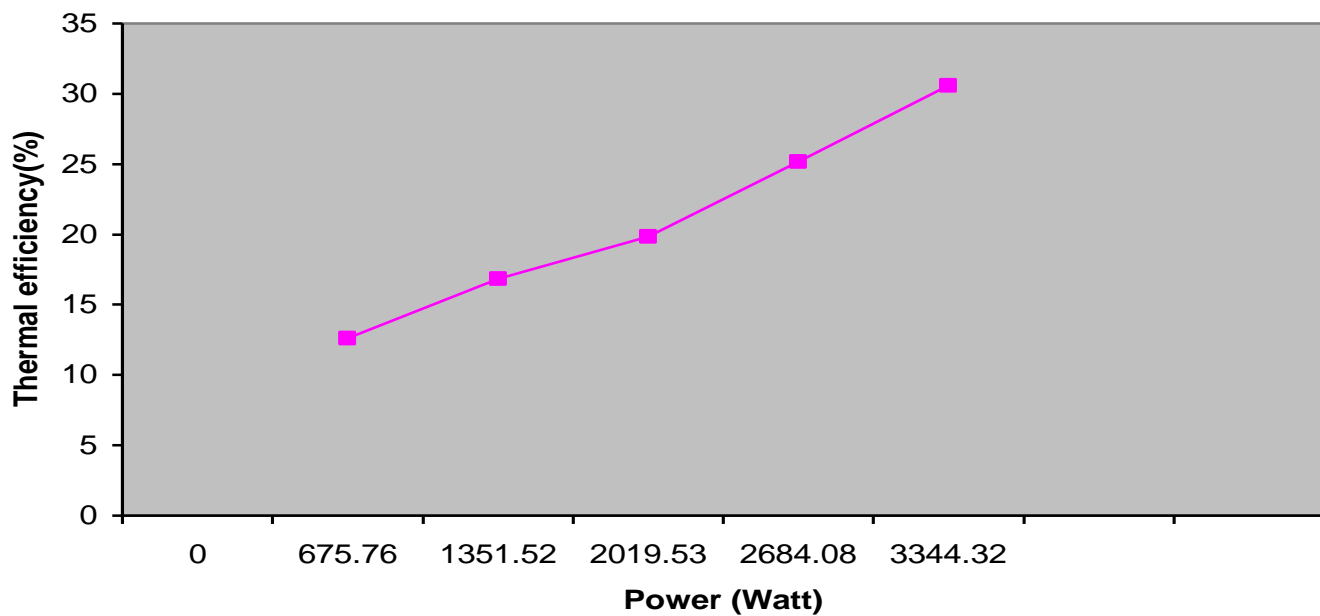## Comparison of Thermal Efficiency between Gasoline v/s Ethanol blends

Figure 9.1Variation of Thermal efficiency with Power at various Ethanol blends flow rate.

It is quite clear now that with Ethanol fuel thermal efficiency increases. When we mix the Ethanol with the Gasoline the thermal efficiency of the mixture always remain more as compared to pure Gasoline mode.

ii. **Brake Specific Fuel Consumption**

Variation of BSFC with the Power is given in the graph. Though the BSFC continuously decreases with the power. Ethanol volume is more thus in the induction stroke less quantity of Ethanol is drawn.

- At full power, increase in ethanol flow rate reduces the bsfc.
- At a particular power, increase in Ethanol leads to decrease in Bsfc.
- At a particular Ethanol flow rate, increase in the applied power decrease Bsfc of engine.

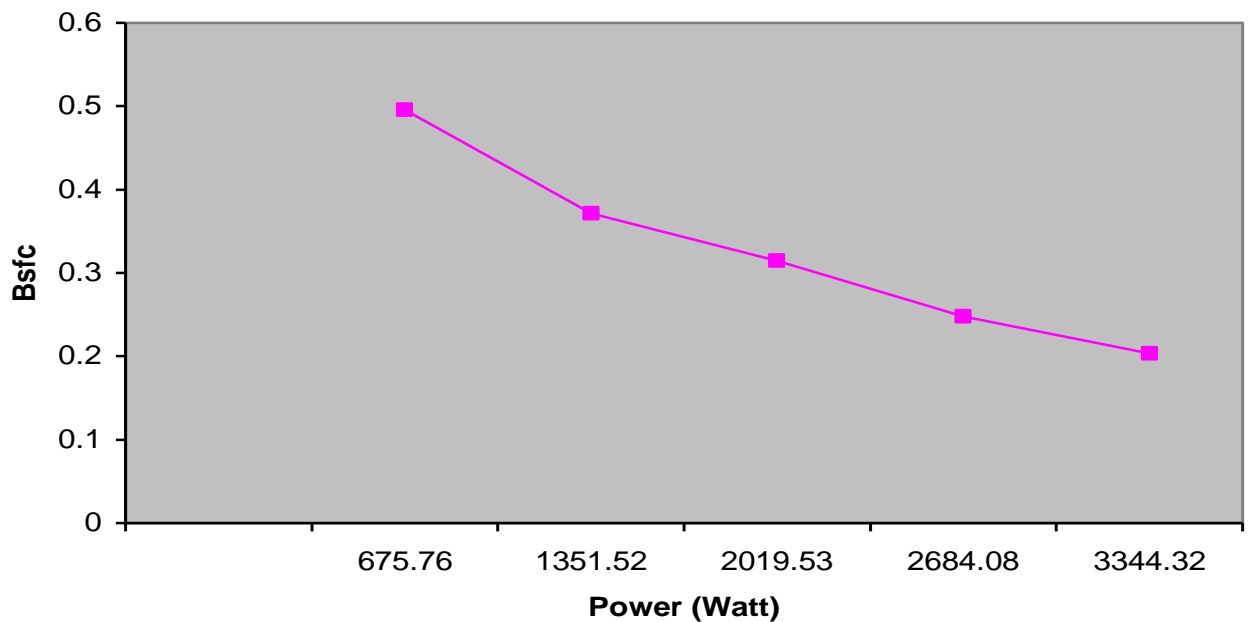## Comparison of Brake Specific Fuel Consumption between Gasoline v/s Ethanol blends

Figure 9.2 Variation of Bsfc with Power at various Ethanol blends flow rate.

iii. Exhaust Temperature

In S.I engine since the combustion occur after TDC because of decrease in flame velocity due to less reactive constituent; there for the exhaust temperature increases. From the graph it is clear that as the power on the engine increases Exhaust Temperature increases.

Comparison of Exhaust Temperature between

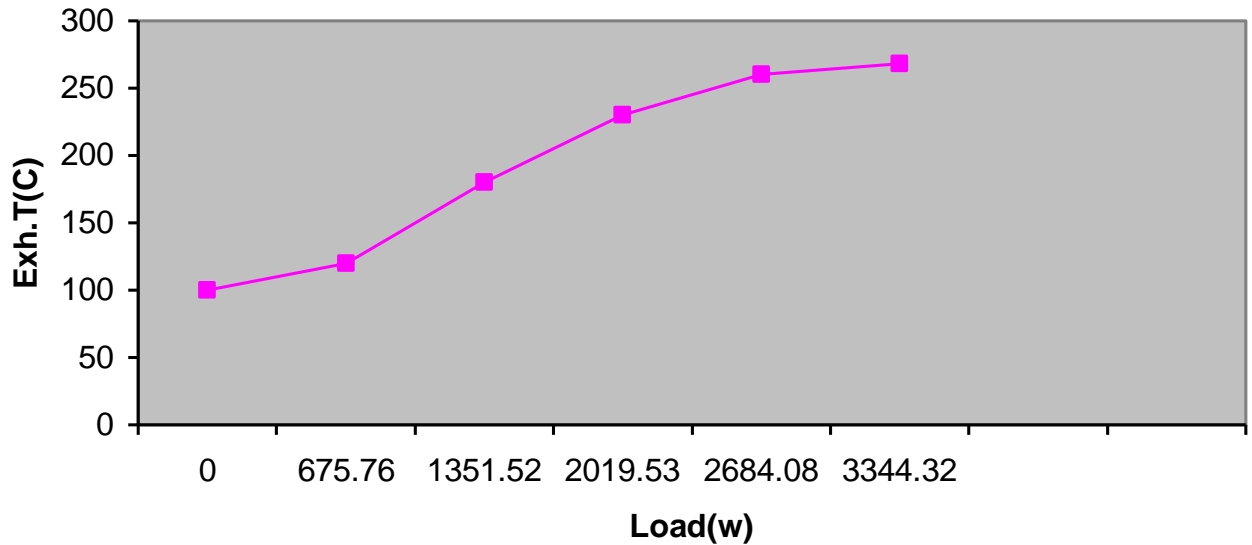## Gasoline v/s Ethanol blends

Figure 9.3 Variation of Exhaust Temperature with Power at various Ethanol blends flow rate.

- At a particular ethanol flow rate with increase in power exhaust temperature increase.
- At a particular load with increase in ethanol exhaust temperature increases.

Emissions Characteristics

a. CO Emissions

Co is the major component produced in a rich combustion where the fuel is in excess compared to the air intake. Figure shows the emissions of CO for both gasoline and LPG fuel system and it is found that the CO emissions of ethonal fuel system are higher compared to LPG fuel system.

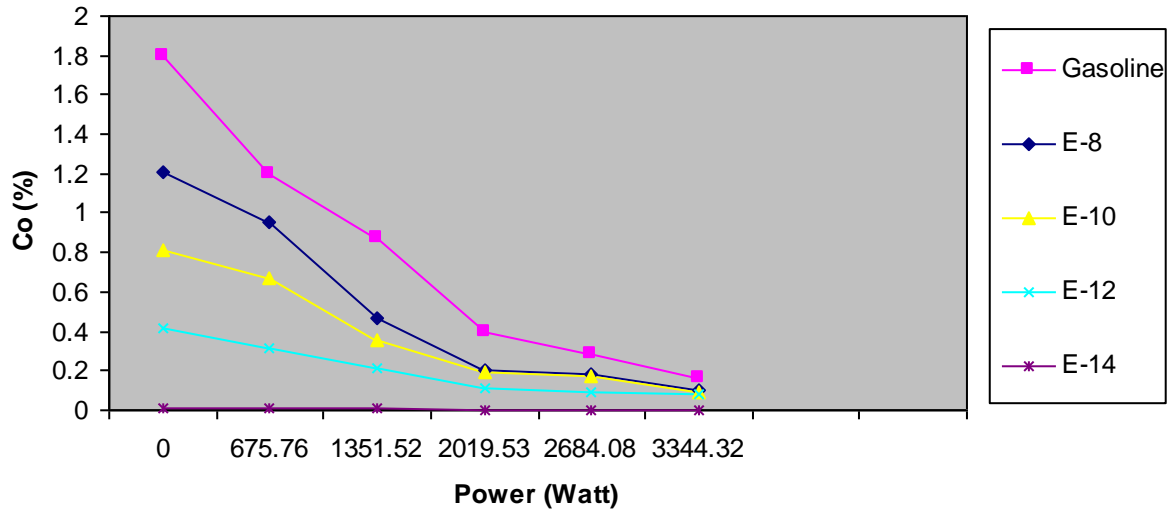## Comparison of CO between Gasoline v/s Ethanol blends

Figure 9.4 Variation of CO with Power at various Ethanol blends flow rate.

b. Nitrogen oxides (NO$_x$)

High peak temperature and availability of oxygen are two main reasons for the formation of Nitrogen oxides. In S.I engine the flame velocity of ethanol is less, which leads to decrease in peak temperature and hence decrease in Nitrogen oxides. With increase in Power the fuel intake increases which leads to increase in peak-localized temperature and increase in Nitrogen oxides.
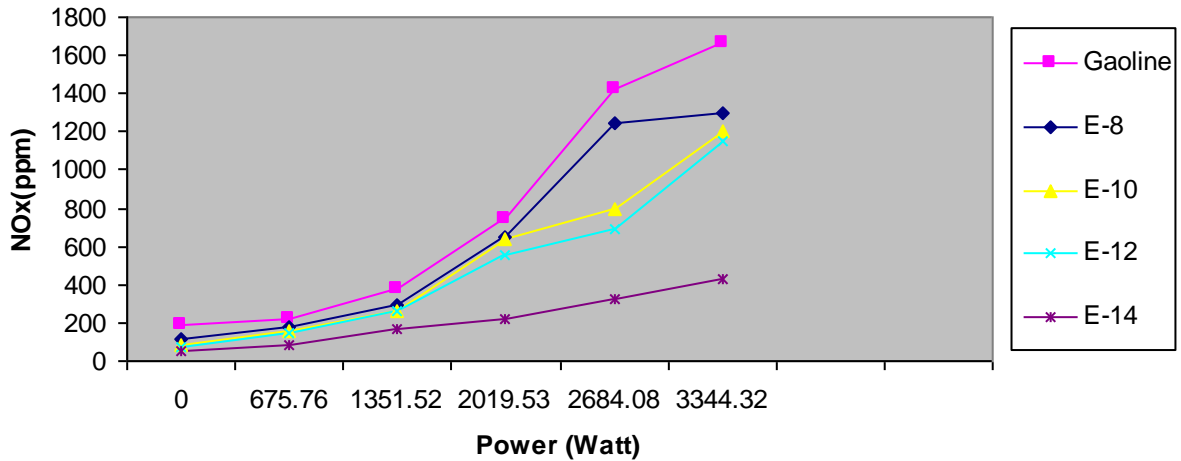
Figure 9.5 Variation of NO$_x$ with Power at various Ethanol blends flow rate.

c. Hydrocarbons

Unburnt hydrocarbon emissions are the results of incomplete combustions. The pattern of the hydrocarbon emissions is closely related to many design and operating variables. Total hydrocarbon emissions in vehicles tend to be higher, since methane is slower to react than other Hydrocarbons and in very lean mixtures. With increase in power unburnt hydrocarbons decreases.

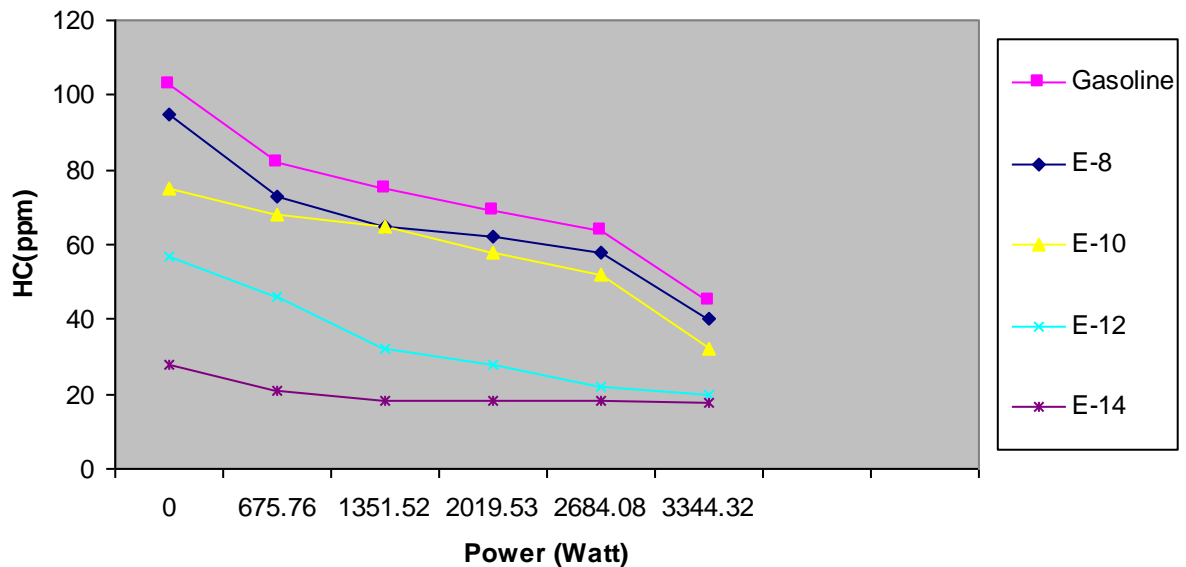**Comparison of Hydrocarbons between Gasoline v/s Ethanol blends**

Figure 9.5 Variation of Hydrocarbons with Power at various Ethanol blends flow rate.

CONCLUSION

1. The energy content of ethanol is its most limiting factor in acceptance for fuel economy and performance reasons.

2. Cold start and emission technologies are the most important technologies to develop as related with ethanol usage. Systems such as heating grids and hydrocarbon traps have proven to be effective solutions to both areas of interest.

3. Performance is greatly limited by the NO_X emissions created by high compression ratios. Adequate performance can be achieved but cannot be adequately utilized if emissions equipment is not utilized. If emissions can be controlled compression ratios of 11.0 to 12.0 should be used in dedicated ethanol vehicles.

4. Gasohol vehicles modified for dedicated E85 usage must have full emissions modifications to reap the benefits of using a clean air fuel.

5. Do not overlook safety issues involved with ethanol, as they are different than those for E10.

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