

## PERFORMANCE EMISSION CHARACTERISTICS OF AIR PREHEATED DIESEL ENGINE

\*N.Maheswaran, \*P.V.Prakaash, \*\*Dr.M.Murugan, \*\*Dr.E.Palanisamy

\*Assistant professor/Mech, Excel College of Engineering & Technology, Nammakal

\*\* HOD/Mech, Excel College of Engineering & Technology, Nammakal

### ABSTRACT

*In a diesel engine, the fuel-air mixture is introduced at room temperature and burned inside the cylinder. After the fuel is burned, the combustion products are discharged at atmospheric pressure and high temperature. The heat generated during the combustion of fuel is partially converted into work to drive the car (or any load) and remaining is wasted to the atmosphere through exhaust gas and coolant. The heat generated by the combustion of fuel is converted into the work because of the pressure created by the combustion process. The efficiency of the engines is between 20% and 30%. This paper highlights provision for incorporating a heating vessel for preheating air before admitting in to the cylinder of a diesel engine. The heating vessel comprises heating elements for heating the air flowing past said heating element, and a body for mechanically holding and electrically contacting said heating element. The effect of preheated air on standard diesel fuel engine indicated a good result on emission control. NO<sub>x</sub> and CO emissions at intake air temperature of 55<sup>o</sup>C were less when compared at intake air temperature of 32<sup>o</sup> C. Higher inlet air temperature causes lower ignition delay, which is responsible for lower NO<sub>x</sub> formation. Uniform or better combustion is occurred due to pre-heating of inlet air, which also causes lower engine noise. Easy vaporization and better mixing of air and fuel occur due to warm up of inlet air, which causes lower CO emission.*

*Keywords: Air pre-heater, Diesel Engine performance, CO, HC*

### INTRODUCTION

Diesel engine efficiency depends on multiple complex parameters like heat losses during cooling of engine, heat losses in exhaust gases, friction loss, transmission efficiency losses etc. However intake air temperature plays a predominant role in achieving better efficiency. Air Intake pre Heaters (also known as grid and manifold heaters) are used in diesel applications needing quick, reliable, and environmentally friendly starts. Air Intake Heaters are installed in the intake manifold and pre-heat the combustion air to the required temperature for ignition of fuel. Powered by the vehicle battery, air intake heaters provide an on-board, unplugged, cold weather starting aid. This type of engine preheating is cost-effective and good for the

environment. In addition to producing fast starts, Air Intake Heaters reduce white smoke ("cold emissions"), engine wear, battery consumption, and fuel consumption during start up. Lower temperature intake air leads to inadequate final compression temperature, increase in emission delay, and longer time between the injection of the fuel to ignition, local over-enrichment, incomplete combustion and high pressure gradients due to abrupt mixture conversion in the cylinder. These factors lead to knocking of the diesel engine, increase in emission of hydrocarbons in the exhaust gas leading to severe loading of the environment. In order to avoid this pre filter is introduced to heat intake air during start and/or warm running of the engine with the help of a electrical heating element. Heating period is selected on the basis of the temperature of the unheated air taken in by the internal combustion engine. Temperature controller is provided to control the outlet temperature at the downstream of heater. Based on air outlet temperature, the relay supplies current to the heater to attain desired temperature. A typical Air intake heater system for a engine comprises the following:

1. **Air heater** adapted to be positioned in communication with an intake passage way of an engine.
2. A **temperature controller** to modulate power to the air heater by switching on and cutting of as when required
3. **Temperature sensor** to provide a signal indicative of the air temperature located upstream of air heater.
4. **Temperature sensor** to provide a signal indicative of the air temperature located downstream of air heater.

## PROJECT OVERVIEW

This project relates to incorporating of a heating vessel for preheating air in an intake line leading to an internal combustion engine. Air is drawn from the upstream side of an intake manifold using an air supply unit. The air is heated using an intake heater and is supplied (injected) from the fuel injection side of a fuel injection valve. In this way, vaporization of the fuel is enhanced. One feature of the present disclosure provides an intake air heating apparatus having improved cold start ability. By heating air in an intake passage and a circulation passage to a sufficiently high temperature, high-temperature air flows into a combustion chamber during cranking and, therefore, vaporization of fuel is promoted. A warm air intake (WAI) is better than a cold air intake (CAI) on a diesel engine. A WAI improves fuel economy on a gas engine for 3 reasons:

- 1) The warm air is less dense, so the throttle opens up more to get the same air, therefore throttling losses are reduced.
- 2) The warm air improves the flame speed

3) The warm air improves the vaporization of the fuel.

In cold ambient air temperature environments, especially below zero degrees Fahrenheit, or when a cold engine is started, the coolant rarely becomes hot enough to boil. Thus, the coolant does not need to flow through the radiator. Nor is it desirable to dissipate the heat energy in the coolant in such environments since internal combustion engines operate most efficiently and pollute the least when they are running relatively hot. A cold running engine will have significantly greater sliding friction between the pistons and respective cylinder walls than a hot running engine because oil viscosity decreases with temperature. A cold running engine will also have less complete combustion in the engine combustion chamber and will build up sludge more rapidly than a hot running engine. In an attempt to increase the combustion when the engine is cold, a richer fuel is provided. All of these factors lower fuel economy and increase levels of hydrocarbon exhaust emissions.

In a typical internal combustion engine, it is ideal to heat the air entering the intake manifold to about 120 °C Fahrenheit. Heating the intake air to temperatures higher than about 130 °C Fahrenheit reduces combustion efficiency. This is due to the fact that air expands as it is heated. Consequently, as the air volume expands, the number of oxygen molecules per unit volume decreases. Since combustion requires oxygen, reducing the amount of oxygen molecules in a given volume decreases combustion efficiency. Although preheating intake combustion air is not beneficial in all environments, preheating the air in relatively cold ambient temperature environments (e.g., below 20° F.) provides many benefits, including improved fuel economy, reduced emissions and the creation of a supercharging effect.

A cold internal combustion engine emits exhaust gases containing a large amount of noxious ingredients such as hydrocarbons (HC's) and carbon monoxide (CO) which contaminate the atmosphere until the engine has warmed up.

Accordingly, reduction in the period required of the engine to warm up results in reduction or elimination of the total amount of air pollutants in engine exhaust gases. It is, therefore, to provide a warming-up system for use in an internal combustion engine which is adapted to rapidly warm up a cold engine. It is necessary to provide a warming-up system for use in an internal combustion engine which is adapted to maximize combustion efficiency of a combustible mixture during the engine warming up period

## DESCRIPTION OF THE PROJECT

Intake air systems may be equipped with electric heaters in order to rapidly heat the intake combustion air for a cold engine start. The heating of the intake air helps to decrease engine warm-up times, improving fuel economy and emissions. The heating device is arranged as close

as possible to the inlet openings of the cylinders. This arrangement assists the heating device in performing its function. The preheated combustion air is therefore given as little distance and time as possible to cool down. The thermal inertia of the part of the intake lines between the inlet opening at the cylinder and the heating device is minimized, specifically as a result of the reduction of the mass and the length of said part. Said measure ensures that the combustion air is at as high a temperature as possible when it enters the cylinders, as a result of which the largest possible amount of heat is introduced into the cylinders. These measures further reduce the number of components and therefore the assembly and procurement costs.

The flow cross section of the overall intake line narrows not in an step-like manner but rather continuously, as a result of which the constriction of the component air flows does not take place abruptly. Here, the heating elements cut into the incident flow of air in the manner of a knife. The resistance posed to the air flow by the heating device is reduced by means of the described design of the at least one strip-like heating element, as a result of which the pressure loss generated across the heating device is also reduced. With the embodiment in question, an impairment of the volumetric efficiency as a result of the heating device is counteracted. The heat transfer area, and therefore the amount of heat that can be transferred to the intake combustion air, also increase with the number of heating elements. The number of heating elements is of not inconsiderable significance with regard to the transfer of heat, because the flow speeds in the overall intake line are high, and the temperature of the heating elements and therefore the temperature difference between the heating elements and the air cannot be increased arbitrarily in order to increase the heat transfer. Fuel injector is coupled directly to combustion chamber for injecting fuel directly. Fuel injector provides what is known as direct injection of fuel into combustion chamber. The fuel injector may be mounted in the side of the combustion chamber or in the top of the combustion chamber, for example. Fuel may be delivered to fuel injector by a fuel system consisting of a fuel tank, a fuel pump, and a fuel rail. In some embodiments, combustion chamber may alternatively or additionally include a fuel injector arranged in intake passage in a configuration that provides what is known as port injection of fuel into the intake port upstream of combustion chamber. Ignition system can provide an ignition spark to combustion chamber via spark plug.

## **EFFECT OF LOW TEMPERATURE INTAKE AIR**

1. An inadequate final compression temperature occurs.
2. Increase in emission delay.
3. Time from the entry of the fuel into the combustion chamber until the ignition of the same becomes too long.

4. Local over-enrichment.
5. Incomplete combustion and high pressure gradients occur as a result of abrupt mixture conversion in the cylinder.

### **CONSEQUENCES OF LOW TEMPERATURE INTAKE AIR**

1. Increase in emission of hydrocarbons in the exhaust gas.
2. Knocking of the diesel engine.
3. Severe loading of the environment

### **SALIENT POINTS ABOUT THE PROJECT**

1. Intake air for an internal combustion engine is heated both during the starting and/or warm-running phases by electrical heating element arranged upstream of the air inlet to the internal combustion engine.
2. Heating period for the pre-start is selected on the basis of the temperature of the unheated air taken in by the internal combustion engine.
3. Heating period for the post-start is selected independently of the pre-start heating time.
4. Desirable to heat the intake air prior to attempting to start the engine. Typically, the air is heated for a predefined time based on the ambient air temperature.
5. Air intake heaters get electrical power from a battery. Thermostat provided at the down stream of heater to control the heating rate.
6. Based on air outlet temperature , the relay supplies current to the heater or does not
7. Heater is typically sized to provide a desired wattage based on engine size and duty cycle.
8. Typically, air heaters are sized such that the full battery voltage and current may be supplied to the heater for a defined period of time

### **AIR INTAKE HEATER SYSTEM FOR DIESEL ENGINE**

1. Air heater adapted to be positioned in communication with an intake passage way of an engine.
2. A thermostat to modulate power to the air heater by switching on and cutting of as when required.

3. Temperature sensor to provide a signal indicative of the air temperature located upstream of air heater.
4. Temperature sensor to provide a signal indicative of the air temperature located downstream of air heater.

### COMPONENTS USED

1. Single cylinder diesel engine
2. Heating vessel
3. Necessary piping
4. Brake dynamo meter

### INSTRUMENTATION USED

1. K Type thermocouples
2. Temperature controller
3. Emission checking instrument

### SCHEMATIC AND DESCRIPTION OF THE DIESEL ENGINE WITH AIR PRE HEATER

The intake air combustion is taken from the atmosphere through a air filter. The filtered air is passed through a heating vessel for preheating air in an intake line leading to an internal combustion engine. The heater comprises at least one heating element for heating the air flowing past said heating element, and a body for mechanically holding and electrically contacting said heating element. This arrangement guarantees fast heating of the intake air as well as increased robustness and simplified mounting. Operation of electrical heater is controlled by a temperature controller which gets temperature signal from the downstream of the heater. The intake air to the engine will be maintained at around 120<sup>0</sup>F by temperature controller. The power supply for the heater is drawn from the engine dynamo/battery.

Emission and fuel measurement: The emissions from the engine are measured using AVL Gas analyzer. The gases HC (ppm), CO (%), CO<sub>2</sub> (%) and NO<sub>x</sub> (ppm) with this analyser. The fuel flow rate is measured by volume basis using a burette and stopwatch. The fuel from tank is supplied to the engine through a graduated burette using a two-way valve.

### DESIGN AND FABRICATION OF PRE HEATER

The heating vessel for the pre heater is fabricated using 2mm mild steel plate. Six plates of required size was cut and fabricated as a cuboids by welding its edges. Proper type welding rod was used for welding. Healthiness of welding was censured by dry penetrate test. Two nozzles were incorporated for facilitating air to flow inside and exit out. A filter has been provided at the inlet of heater for removing the dirt present in the air. Thermocouples have been incorporated at the inlet and outlet lines of the heater. In addition one more thermocouple is fixed to measure the exhaust gas temperature. The heater is installed in the heating vessel and electrically isolated from the heating vessel. The out let of heater is connected to the engine.

### Design of heater coil

Mass flow rate of air in single cylinder diesel engine - 0.0069Kg/s

Desired temperature expected to be achieved by pre heater -75°C

Inlet temperature assumed – 25°C

Power of the heating coil -  $m \cdot c_p \cdot (T_o - T_i)$   
 -  $0.0069 \cdot 1.005 \cdot (75-25)$

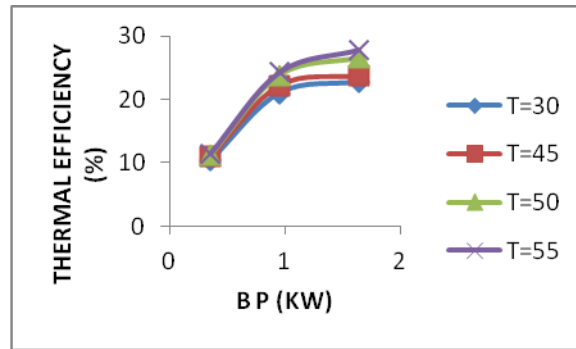
Heating power required - 0.4KW ~ 0.5KW.

### Experimental procedure

After connecting the test set up, diesel engine was run without switching on the electrical heater and parameters were logged. First, engine was run and data's were collected without switching on the heater when the ambient temperature is 35°C. Then heater was switched on and heater outlet temperature was maintained at 45°C, 50°C & 55°C at two different loads viz. 53.955N & 93.195. At each stabilization step, parameters CO, UBHC, CO<sub>2</sub>, O<sub>2</sub> & NO<sub>x</sub> were logged. In each load the heat input was calculated based on the fuel consumption. Using these data, brake thermal efficiency was calculated and plotted as shown.

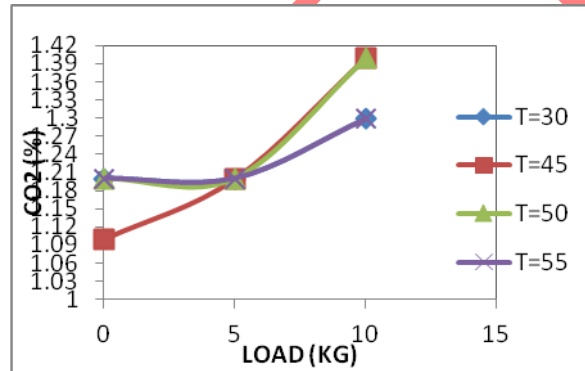
### TEST RESULTS

The heat input required for the engine reduces with increase in intake air temperature. This was observed in both loads. Since heat input reduces with increase in intake air temperature for the same load, brake thermal efficiency increases. The graph shows that increase in thermal efficiency with respect to brake power at different temperatures.



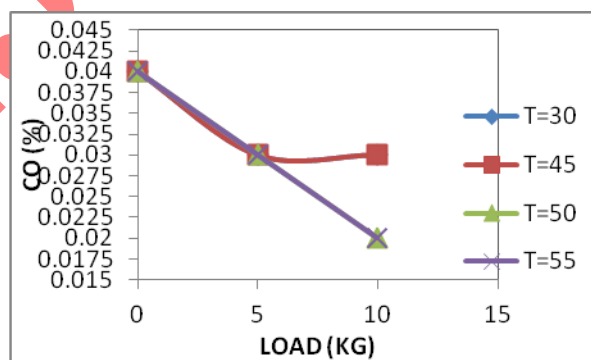
**Fig. Thermal efficiency VS Brake horse power**

CO content in the exhaust gas slightly reduces with increase in intake air temperature. The graph shows that increase in CO<sub>2</sub> with respect to brake power at different temperatures,



**Fig. Carbon di oxide VS Load**

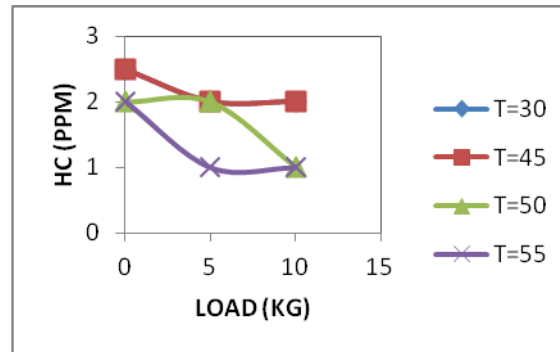
CO content in the exhaust gas slightly reduces with increase in intake air temperature. The graph shows that decrease in CO<sub>2</sub> with respect to brake power at different temperatures.



**Fig. Carbon monoxide VS Load**

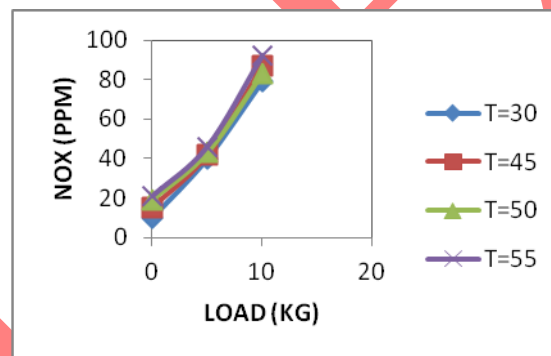


Un burnt hydro carbon (UBHC) reduces with temperature. The graph shows increase UBHC in with respect to brake power at different temperatures.



**Fig. Unburnt hydro carbon VS Load**

NOx content in the exhaust gas slightly increases with increase in intake air temperature. The graph shows that increase in NOx with respect to brake power at different temperatures.



**Fig. NOx VS Load**

## DISCUSSION

The following observations were made from the test.

- The heat input required for the engine reduces with increase in intake air temperature. This was observed in both loads.
- Since heat input reduces with in intake air temperature for the same load, brake thermal efficiency increases.
- CO content in the exhaust gas slightly reduces with increase in intake air temperature.
- CO<sub>2</sub> & O<sub>2</sub> content in the exhaust gas remains unaltered in the exhaust with increase in intake air temperature.

- Where as NO<sub>x</sub> content in the exhaust gas slightly increases with increase in intake air temperature.

From the test it is clear that the fuel consumption reduces and brake thermal efficiency increase with increase intake air temperature. The CO<sub>2</sub> & O<sub>2</sub> content remains unaltered.

## CONCLUSION

From the test it is clear that the fuel consumption reduces and brake thermal efficiency increase with increase intake air temperature. The carbon dioxide and oxygen content remains unaltered in the exhaust gas. Carbon monoxide content in the exhaust gas slightly reduces with increase in intake air temperature. Whereas NO<sub>x</sub> content in the exhaust gas slightly increases with increase in intake air temperature. Hence the test results indicated that the advantages gained are more with increase intake air temperature though there are few disadvantages

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