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IGNITION LAG CONTROL

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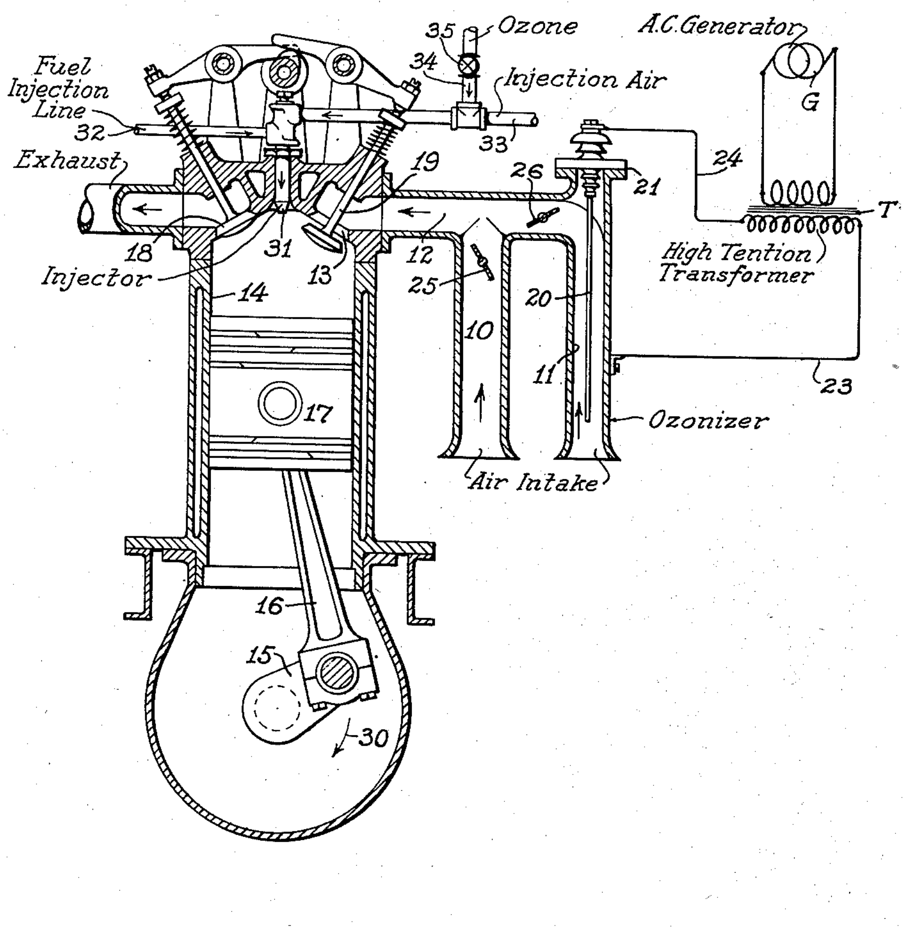

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IGNITION LAG CONTROL

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This invention relates to control of the combustion rates of liquid fuels in internal combustion engines and particularly to ignition lag control in solid injection, compression ignition, internal combustion engines such as Diesel engines burning hydrocarbon oil fuels.

Fuel ignition in a compression ignition engine never occurs simultaneously with the first appearance of the injected fuel in the combustion chamber, but at some time interval thereafter. This time interval between the initial appearance of the injected fuel in the combustion chamber and its initial spontaneous ignition is termed the ignition delay or ignition lag, and its duration is a measure of the ignition qualities of the fuel oil. Different fuels manifest different qualities in this respect.

The ignition delay has been conveniently expressed by the term "delay number" which is the number of degrees that the crankshaft rotates in the interval between the beginning of fuel injection and the instant of fuel ignition.

Until recently, the rotational speeds of compression ignition engines were relatively low as compared with the actual ignition delay of the injected fuels, hence the ignition lag did not materially affect engine performance even with fuels having poor ignition characteristics. However, in the recently developed high speed Diesel engines since the actual ignition lag time interval remains substantially constant on any given fuel for all engine speed, the same ignition lag time interval occupies a greater interval of time relative to the engine cycle, and hence the delay number becomes here proportionally greater. It is apparent, therefore, that the ignition lag characteristics of fuels become of more and more significance with the increase of Diesel engine speeds.

As a result of ignition delay or ignition lag, unburned fuel accumulates in the combustion chamber during the early portion of each injection cycle until spontaneous ignition finally occurs. A long ignition delay relative to the rotational displacement of the crank shaft, or, in other words, fuel ignition characteristics and relative engine speeds resulting in a high ignition delay number will allow, therefore, an excessive amount of unburned fuel to accumulate during injection, so that when ignition finally occurs the pressure rise in the combustion chamber due to the sudden combustion of the accumulated fuel will reach undesirable or even unsafe limits, and, additionally, the pressure rise will be of such suddenness as to produce what is known as Diesel knock. This Diesel knock may be even more detrimental to good operation in a Diesel engine than is detonation in a gasoline engine. Fuels which have poor ignition qualities are, therefore, the most common cause of knocking or rough-running high speed compression ignition engines. It may also be said that nearly all difficulties that apparently result from improper fuel combustion, such as knocking, rough running, loss of power, smoky exhaust and difficulty in cold starting, are primarily caused by poor ignition resulting from fuel having poor ignition qualities or high delay numbers.

Objects of this invention are, therefore, to reduce the objectionable ignition lag of compression ignition engine fuels, particularly those having poor ignition qualities.

A further object of this invention is to reduce the delay number of fuels, particularly fuels employed in high speed compression ignition internal combustion engines.

The objects of this invention are attained in general by employing ozone as an ignition accelerator.

It has been found that the addition of low concentrations of ozone to the combustion air in the cylinder of a compression ignition engine materially reduces the ignition delay of the injected fuel and thus reduces the delay number. This ozone may be supplied to the combustion zone of the engine cylinder by introducing it first into the air intake manifolding from which it is drawn along with the intake air into the cylinder on the air intake stroke of the cycle prior to compression. In the case of an air injection engine the ozone may be simultaneously injected with the fuel along with the compressed injection air to which it has been previously added. Ozone may also be supplied to the combustion zone through an auxiliary valve in the cylinder head either during the air intake portion of the cycle or just prior to or during injection of the fuel. The ozone may also be dissolved in the Diesel fuel oil prior to the injection and thus be carried into the combustion chamber upon injection in solution with the oil.

The ozone may be generated by any of the well known methods. For example, ozone can be generated by subjecting a stream of air or oxygen to a silent electric discharge or corona discharge between electrodes charged to a high potential differences or the air or oxygen may be subjected to the action of ultra violet light resulting in the formation of ozone. Ozone may also be generated chemically. The chemical reaction between nitric acid (HNO_3) and ammonium persulfate $(NH_4)_2S_2O_8$ in an atmosphere of carbon dioxide produces oxygen and ozone. The carbon dioxide can be absorbed in alkali and the oxygen and ozone thus chemically produced fed to the Diesel engine cylinder in the manner hereinabove described or the whole gaseous mixture including the carbon dioxide as a carrier, may be conveyed to the engine.

Fuels employed for compression ignition internal combustion engines such as Diesel engine fuels are generally hydrocarbons derived from petroleum and may cover a wide range of gravities and viscosities varying from light hydrocarbons in the gasoline range down to petroleum residues or waxes. Diesel engine fuels which are commonly used, however, range in viscosity from 35 to 125 Saybolt seconds at 100° F. and in gravity from 22 to 35° A. P. I. In general, the ignition qualities of these hydrocarbon fractions appear to vary as a function of their paraffinicity, those fractions which are most highly paraffinic having the lowest delay number, and those fractions which are most highly aromatic having the highest delay number.

The employment of ozone as an ignition accelerator is, thus, particularly advantageous with the hydrocarbon fuel oils which are least paraffinic in nature.

Ozone is therefore particularly effective in reducing the delay number of hydrocarbon fuels which contain appreciable quantities of cracked material.

Other types of fuels with which ozone may also be employed as an accelerator are alcohols, vegetable oils such as palm, cottonseed, corn, and soy bean oils, and animal oils such as sperm and lard oils.

The ozone may be used in quantities of the order of a thousandth of one percent up to much larger quantities of the order of several hundredths of one per cent by volume of the intake air, depending upon the degree of ignition lag control desired and the character of the fuel employed.

The invention broadly stated comprises a method for reducing ignition lag in compression ignition fuel oil engines such as the Diesel engine wherein ozone is employed in the combustible mixture in the cylinder. The invention more specifically includes the addition of ozone to the combustible mixture through the intake air, or through an auxiliary inlet valve in the combustion zone, or through the compressed fuel-injection air, or two or more of these combined.

The invention also includes a compression ignition engine fuel product such as Diesel engine fuel comprising a mixture or solution of ozone in oil.

The drawing, which illustrates a preferred embodiment of the apparatus of the invention, shows a cross-sectional elevation of a conventional compression ignition internal combustion engine of the Diesel type with its associated valve mechanism, fuel injection nozzle and air intake manifolding. The air intake manifolding departs from the conventional arrangement in comprising an air inlet **10** and an ozonizer both coupled to a common manifold pipe **12** which leads to the intake port **13** of the power cylinder **14**.

The ozonizer comprises a cylindrical tubing section **11** containing a coaxial rod electrode **20** which is supported and electrically insulated from the tubing **11** at the flanged head **21**. An alternating current generator G, a high tension transformer T and suitable interconnecting conductors **23** and **24** are provided for maintaining a high electric potential between the electrode **20** and the inside surface of the ozonizer cylinder **11**. The generator G and transformer T are preferably adapted to supply a high frequency alternating electric potential to the ozonizer. Butterfly valves **25** and **26** are provided as suitable pivots in the branches of the manifolding for controlling the proportion of air drawn through intake **10** and through the ozonizer **11** whereby the ratio of untreated ozonized air passing to the power cylinder can be regulated. The ozone is generated in the ozonizer in a well known manner by subjecting the air passing therethrough to a high electric potential.

The engine is shown with the crank **15** connecting rod **16** and piston **17** at one position of the air intake portion of the Diesel cycle, and the exhaust valve **18** is therefore closed and intake valve **19** open to allow passage of air from the manifold **12** into the cylinder **14**.

As the crank **15** continues in rotation as shown by arrow **30** the air-ozone mixture is drawn into the cylinder and upon completion of the intake portion of the cycle, valve **19** closes and the air-ozone mixture is compressed until, at the top of the stroke of the piston **17**, the temperature of the mixture in the combustion chamber is sufficiently high to spontaneously ignite the oil fuel which is then introduced through line **32** and into the cylinder through the injector **31**. The Diesel cycle is thus initiated and repeated in rapid succession with each revolution of the engine.

In an optionable method of operation of this invention the ozone instead of being mixed with the intake air may be introduced into the cylinder together with the fuel and when this operation is desired the ozone may be introduced into the combustion chamber through the fuel injector **31**, along with injection air. In this case the ozone from a suitable generator is mixed with the injection air in line **33** at suitable pressure by means of pipe **34** and the quantity regulated by valve **35**.

The injector nozzle is of the conventional mechanically operated type and the details of construction and mechanism for its operation are, therefore, not shown.

The foregoing is illustrative and not to be limiting in respect to the specific methods, apparatus or fuel products disclosed, but may include any method or product within the scope of the invention.

I claim:

1. In a compression ignition internal combustion engine cycle the steps comprising compressing ozone-containing gas and comingling fuel to be burned with said compressed gas.

2. In a compression ignition internal combustion engine cycle, the steps comprising compressing ozone-containing gas to the ignition temperature of the fuel to be burned and injecting the fuel into the thus compressed gas.

3. In a compression ignition internal combustion engine cycle the steps comprising injecting ozone-containing gas into a combustion chamber, compressing the mixture to the ignition temperature of the fuel to be burned and subsequently injecting the said fuel into the said compressed mixture.

4. In a compression ignition internal combustion engine cycle the steps comprising compressing gas containing oxygen in a combustion chamber to the ignition temperature of the fuel to be burned and subsequently injecting ozone-con-

taining gas and the said fuel into the combustion chamber.

5. In a compression ignition internal combustion engine cycle the steps comprising compressing gas containing oxygen in a combustion chamber to the ignition temperature of the fuel to be burned, intermingling ozone and a quantity of injection air, and injecting fuel together with the said injection air into the said compressed gas in the combustion chamber.

6. In a compression ignition internal combustion cycle where the fuel is a normally liquid hydrocarbon fraction, heavier than gasoline, the steps comprising compressing a mixture of ozone and air in the combustion chamber to the ignition temperature of said hydrocarbon fuel and subsequently injecting a quantity of said fuel into said compressed ozone-air mixture in said combustion chamber, whereby combustion takes place and power is developed.

7. A compression ignition internal combustion engine apparatus comprising in combination a combustion chamber, an ozone generator, means to introduce ozone from said ozone generator into said combustion chamber, means to compress gases in said combustion chamber to the ignition temperature of fuel to be burned and means to commingle combustible fuel with said ozone in said chamber.

8. A compression ignition internal combustion engine apparatus comprising in combination a combustion chamber, means to commingle air, ozone and a combustible fuel in said combustion chamber and means to compress gases in said combustion chamber to the ignition temperature of fuel to be burned.

9. Apparatus according to claim 8 in which the means to commingle air, ozone and combustible fuel comprises an air injection fuel nozzle and means to introduce ozone into the injection air.

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