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Ahern et al.

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[54] **TWO-FLUID FUEL INJECTED ENGINES**

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[5] **F02M 67/02;** F02D 41/06

[52] **U.S. Cl.** .... **123/179 L;** 123/305; 123/491; 123/531

[58] **Field of Search** .... 123/179 L, 491, 531, 123/532, 533, 534, 305

[56] **References Cited**

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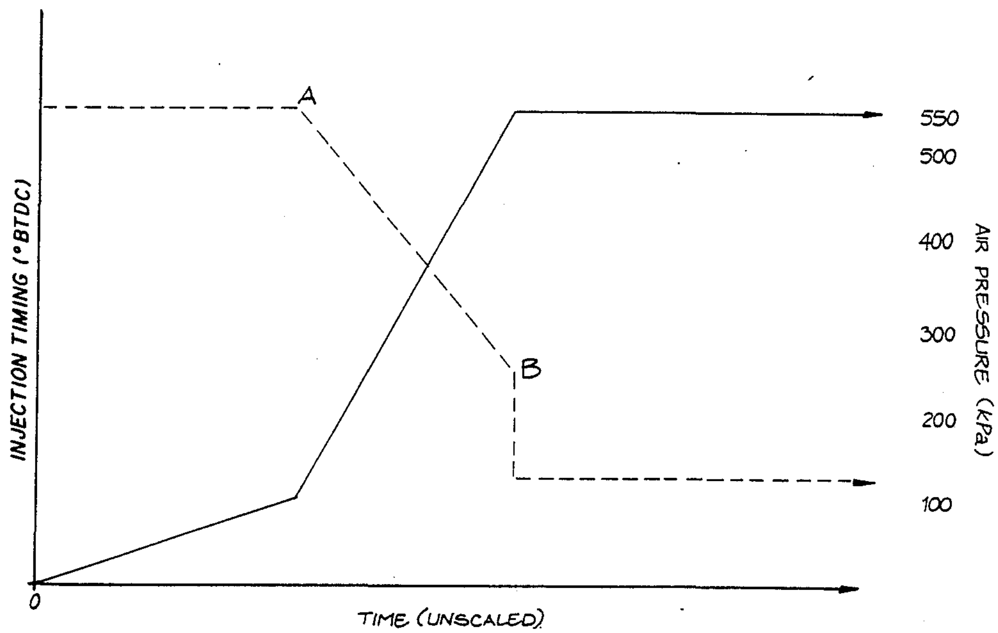
Attorney, Agent, or Firm—Armstrong, Nikaido, Marmelstein, Kubovcik & Murray

[57] **ABSTRACT**

A method and apparatus of controlling the direct injection of fuel directly into the combustion chamber of an engine by a charge of gas, wherein the control of the timing of injection of the fuel includes at the commencement of start up of the engine, adjusting the timing of injection so injection occurs at a timing earlier in the combustion chamber cycle than the normal timing of injection for idle running; and in response to the engine reaching a predetermined speed or rotation during start up, the timing of injection is progressively adjusted each engine cycle towards the normal timing of injection at idle running.

21 Claims, 3 Drawing Sheets



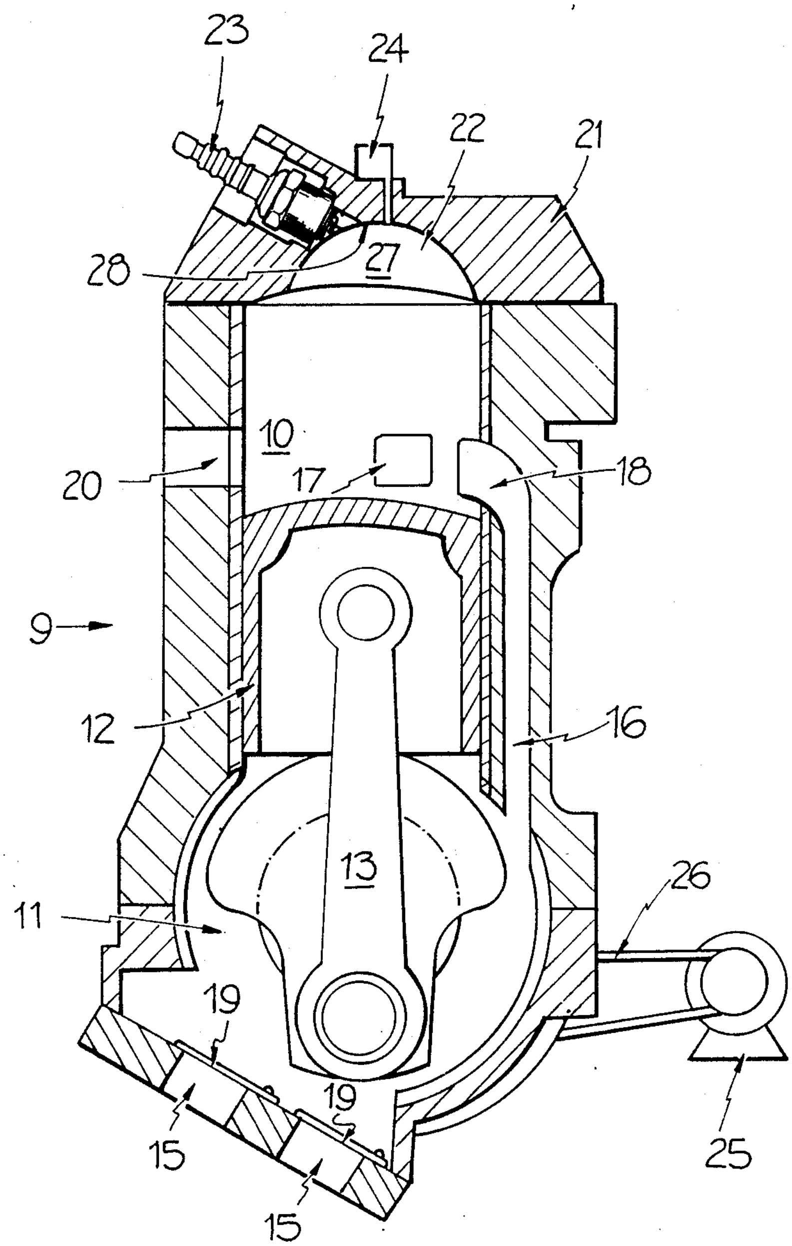


FIGURE.1

FIGURE.2

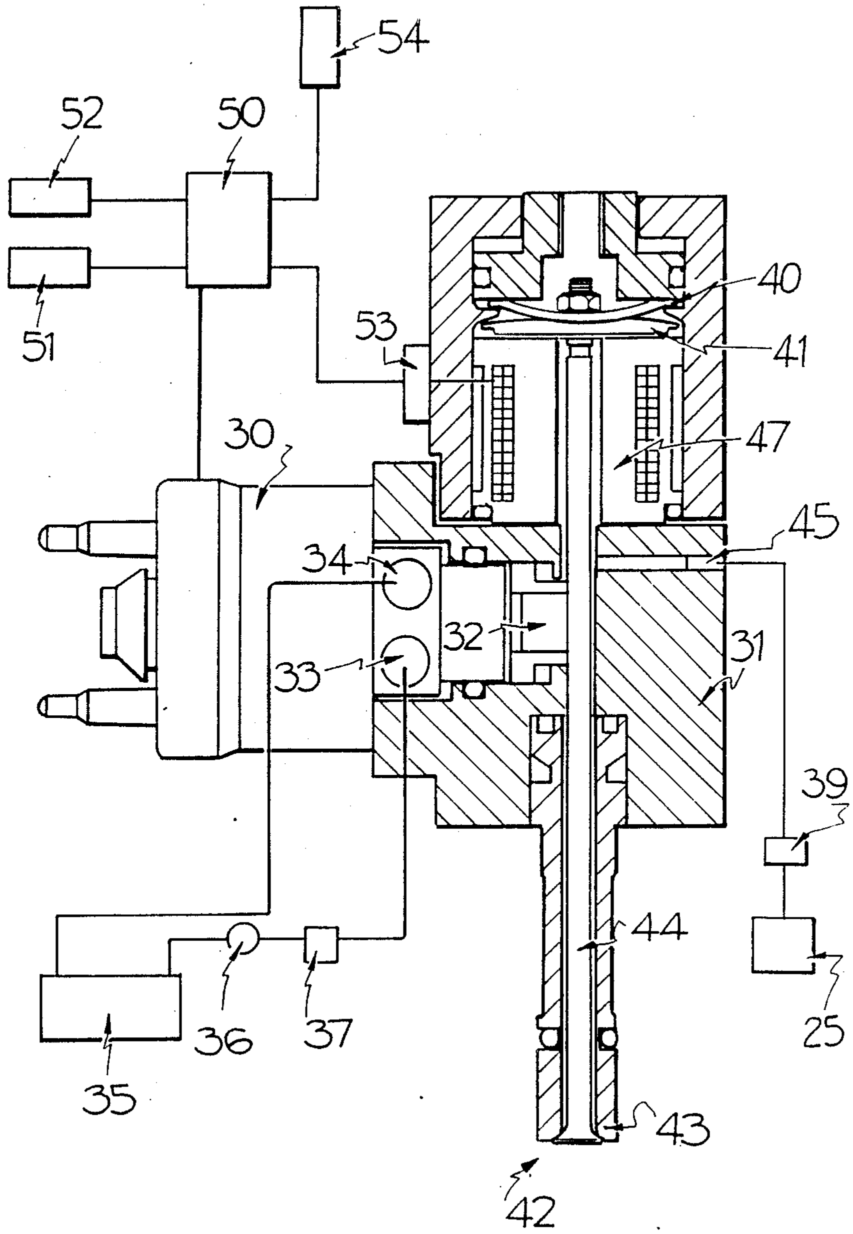
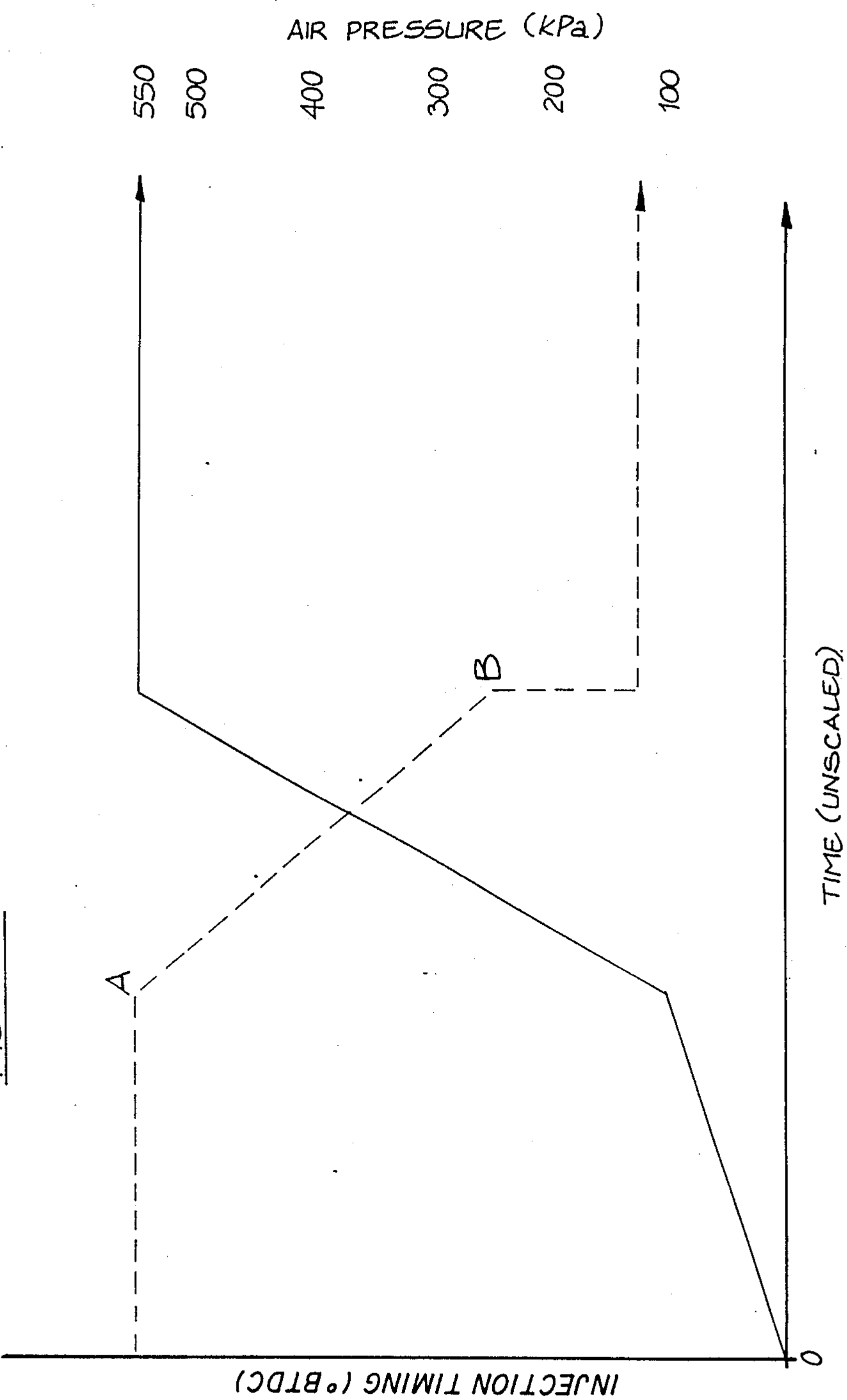


FIGURE 3


AIR PRESSURE (kPa)
550
500
400
300
200
100
A
B
TIME (UNSCALED)
INJECTION TIMING (°BTDC)
0

TWO-FLUID FUEL INJECTED ENGINES

This invention relates to fuel injected internal combustion engines wherein the fuel is injected directly into the combustion chamber in timed relation to the engine cycle, the fuel being delivered entrained in a gas with the pressure of the gas sufficient to effect the delivery of the fuel.

Fuel injection systems of the two-fluid type, that is, where a metered quantity of liquid fuel is delivered to the engine by a pulse of gas, such as air, the pressure of the gas available must be such that there is an adequate pressure difference between the gas delivering the fuel and the gas in the environment where the fuel is to be delivered. In manifold injected engines the fuel is delivered by the gas into the manifold where normally a sub-atmospheric pressure exists, whilst in direct injected engines, the fuel must be delivered into the combustion chambers of the engine, normally during the compression stroke when an above atmospheric pressure will exist of the order of 200 to 500 kPa. The compressed gas supply, such as air, is usually provided by a compressor driven by the engine, and for economic reasons, there is a minimum storage capacity for the compressed gas, and the compressor output is closely matched to the requirements of the fuel injection system, with only a limited excess.

It will therefore be appreciated that during start up of the engine, the gas pressure available may frequently be below the normal operating pressure and this may result in a lag in start up of the engine. In this regard, it should be noted that in order to have customer acceptability an auto or marine engine is required to start up with a minimum of cranking time. This requirement may be difficult to achieve with a two fluid fuel injection system when the engine has been not operating for a significant period, that is a period sufficient to allow the pressure of the gas available to effect injection of the fuel to have fallen substantially, due to inherent leakages in the gas supply system which cannot be effectively avoided.

It is also to be understood that the degree of the pressure drop experienced by the fuel/gas mixture during delivery to the engine contributes significantly to the atomisation of the fuel, particularly liquid fuel, and hence to the ignitability of the charge in the engine combustion chamber. Thus, under conditions where the pressure of the gas is below the desired working pressure at the commencement of start-up, the atomisation of the fuel will be adversely affected, and consequently the ignitability of the fuel/air charge will be reduced. It will be appreciated that such reduction in ignitability of the fuel/air mixture may further contribute to lengthening of the start up time of the engine.

It is therefore the object of the present invention to provide a method of injecting fuel and a fuel injection system for an internal combustion engine wherein provision is made to contribute to rapid start up of the engine under adverse fuel supply conditions.

With this object in view, there is provided according to the present invention a method of controlling the injection of fuel directly into the combustion chamber of an engine comprising injecting a metered quantity of fuel into the combustion chamber by a charge of gas at an above atmospheric pressure, and controlling the timing of said injection of the fuel in relation to the combustion chamber cycle whereby:

(1) the timing of injection when the engine is idling is preset,

(2) at the commencement of start up of the engine, the timing of injection is adjusted to occur at a preselected timing earlier in the combustion chamber cycle than said preset timing of injection at idle,

(3) in response to the engine reaching a predetermined speed of rotation during start up, the timing of injection is progressively adjusted each engine cycle towards said preset injection timing at idle during a time interval of between 0.2 to 0.5 seconds commencing from the engine attaining said predetermined speed; and

(4) thereafter adjusts the timing of injection in accordance with the engine speed and/or load.

There is also provided a fuel injection system for an internal combustion engine, wherein a metered quantity of fuel is injected directly into the combustion chamber by a charge of gas at an above atmospheric pressure, said system including means to control the timing of injection of the fuel in relation to the combustion chamber cycle, said timing of injection control means being arranged to:

(1) effect injection of the fuel at a preset time in the combustion chamber cycle when the engine is idling;

(2) to adjust the timing of injection for commencement of start up of the engine to occur at a preselected timing earlier in the combustion chamber cycle than said preset idle timing of injection,

(3) in response to the engine reaching a predetermined speed of revolution during start up, for each engine cycle progressively adjust the timing of injection towards said preset injection timing for idle during a time interval of between bout 0.2 and 1.0 seconds, preferably between about 0.2 and 0.5 seconds commencing from the engine attaining said predetermined speed; and

(4) thereafter adjust the timing of injection in accordance with the engine load and/or speed.

Normally the preselected injection timing is up to 60° earlier in the combustion chamber cycle than the normal injection timing at idle preferably in the range of 40° to 60° prior to injection timing at idle.

Conveniently, the rate of progressive adjustment of the timing of injection after the engine has reached the predetermined speed of rotation towards the preset injection timing at idle is at a rate of between 1° and 3° of crank angle per cycle of the engine, preferably 2°.

The engine normally would be cranked by the starter motor during start up at a speed of the order of 200 to 400 rpm, depending on starter battery condition, while normal idle speed of the engine will be of the order to 700 to 1200 rpm, depending on engine characteristics.

The means to control the timing of the injection of the fuel during start up may be arranged so that once the engine has been brought up to predetermined speed related to normal idling speed, such as of the order to 700 to 1200 rpm, the injection timing will commence to return to the preset timing for normal idle, as the engine will have now driven the compressor through sufficient cycles to have the gas up to normal operating pressure.

The timing of injection may be controlled by an appropriate electronic control unit (ECU), as is customarily used in fuel injection systems to control injection timing throughout the full operating load and speed range of the engine. The present invention may be incorporated into the program of that ECU so that the adjustment of the injection timing will occur in response to the initiation of revolution of the engine, which indicates that cranking for engine start up has

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