Dec. 2, 1947. K. D. MACKENZIE 2,431,875

METHOD OF OPERATING INTERNAL-COMBUSTION ENGINES

Filed June 24, 1943

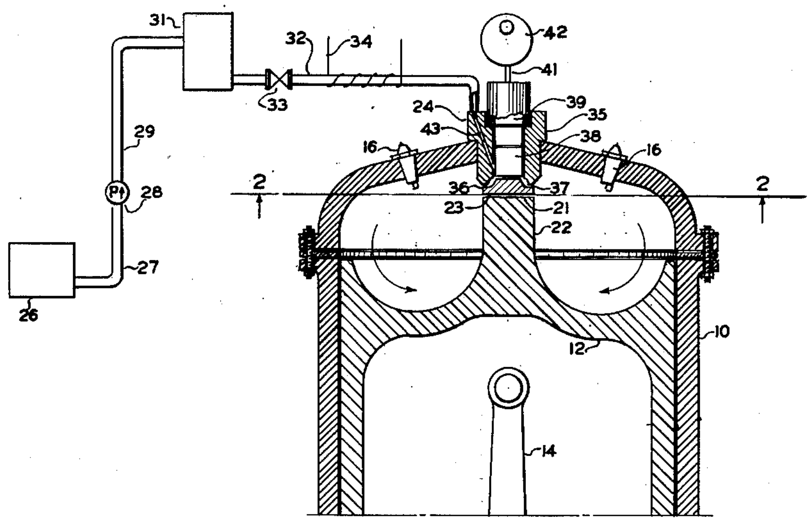

FIG. 1

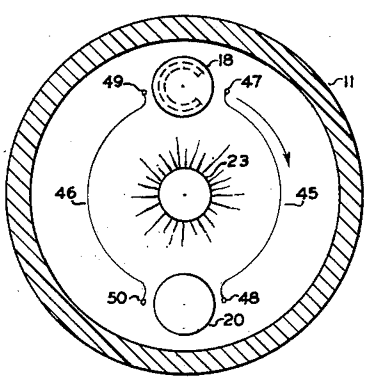

FIG. 3

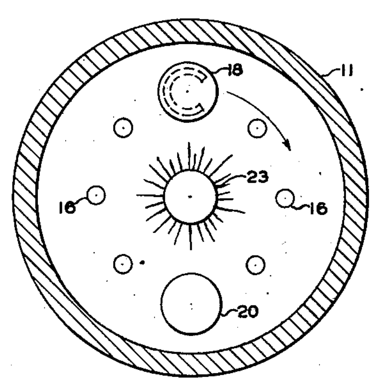

FIG. 2

KENNETH DONALD MACKENZIE
INVENTOR

BY HIS ATTORNEYS

[signatures]

Patented Dec. 2, 1947 2,431,875

UNITED STATES PATENT OFFICE

2,431,875

METHOD OF OPERATING INTERNAL-COMBUSTION ENGINES

Kenneth Donald Mackenzie, Oceanside, N. Y., assignor, by mesne assignments, to The Texas Company, New York, N. Y., a corporation of Delaware

Application June 24, 1943, Serial No. 492,027

3 Claims. (Cl. 123—32)

1

This invention relates to an internal combustion engine of the fuel-injection electrical-ignition type wherein spontaneous ignition with resultant knocking of the engine is prevented.

This invention constitutes a modification of and utilizes the broad basic principles of the non-knocking combustion method and engine disclosed and claimed in the copending application of Everett M. Barber, Serial No. 513,232, filed December 7, 1943, as a continuation-in-part of Serial No. 463,031, filed October 23, 1942. This involves the use of swirling compressed air in the combustion space, injection of fuel into the swirling air with spark ignition of combustible fuel vapor-air mixture substantially as soon as formed from the first increment of injected fuel to establish a flame front, and continuation of the injection immediately in advance of the flame front in its direction of movement to progressively form additional combustible fuel vapor-air mixtures which are ignited by the flame front and burned substantially as rapidly as formed. In the embodiments of said prior application, flame fronts extending generally across a radius or a localized segment of a disc-shaped combustion spece are produced, said flame fronts rotating or swinging about or through the compressed air within the combustion space.

An object of the present invention is to provide a flame front of greater extent, particularly an annular flame front extending more or less completely around the combustion space, whereby the rate of burning can be much greater, and constant volume combustion can be more nearly approached.

Other objects and advantages of the invention will be apparent from the following description when taken in conjunction with the attached drawing and the appended claims.

As distinguished from said co-pending application, Serial No. 513,232, the present invention involves the use of a combustion space of substantially toroidal shape having either simple air swirl in planes containing the longitudinal axis of the cylinder, or a compound helical air swirl about the toroidal combustion space in known manner, wherein the fuel is injected in the form of a flattened circular spray from a central location at a particular elevation of the combustion space, so that the swirling air is impregnated substantially through an annulus of the combustion space. Ignition of the resulting annular layer or ring of combustible fuel vapor-air mixture formed from the first increment of injected fuel from said circular spray is by a large num-

2

ber of spark plugs or annular electrical wires extending about the annular layer to thereby establish a more or less continuous flame front of substantial length extending annularly about the combustion space. Continued injection of fuel by the flattened circular spray then progressively forms with the compressed air having simple or helical air swirl additional combustible mixture in an annular layer immediately in advance of the said annular flame front, whereby the non-knocking combustion is accomplished with a relatively short period of fuel injection and a relatively rapid completion of the combustion.

In order that the invention may be understood more fully, reference should be had to the attached drawing in which:

Figure 1 is a diagrammatic illustration with parts in section of an engine cylinder and a fuel injection system;

Figure 2 is a sectional view of the cylinder taken along the line 2—2 of Figure 1 and looking in the direction of the arrows; and,

Figure 3 is a similar sectional view of another cylinder equipped to carrv out the process of the invention.

Refering to Figure 1, the engine cylinder is indicated at 10. The cylinder has a head 11, and disposed therein is a piston 12 linked to connecting rod 14, which runs to the usual crank shaft, not shown. It will be understood that cooling jackets and other structural details of the cylinder have been omitted in this and the other figures in the interests of simplicity of description. The cylinder head is equipped with a plurality of spark plugs 16 arranged circumferentially in the head of the cylinder, as shown in Figure 2. The head is also equipped with an intake valve 18 and an exhaust valve 20, which communicate with suitable pipes or manifolds, not shown.

The piston head is constructed so as to accomplish in cooperation with the cylinder head desired rotation of the air within the combustion chamber. Thus, the piston has a flat circular central section 21 and a circumferential channel 22. The head of the piston, when in the top dead center position, forms with the round cylinder head, a toroidal combustion chamber. The surface 23 of an injector device, indicated generally at 24, approaches very closely to the surface 21 when the piston is in the top dead center position.

The fuel system includes a suitable source of supply, such as storage vessel 26, from which a preferably liquid fuel is drawn through line 27 by means of fuel pump 28, which may be driven by the engine in any conventional manner. The pump forces the fuel under a pressure of about 1,000 to 2,000 pounds per square inch through line 29 to an accumulator tank 31, from which it passes through line 32 leading to the injector 24. Line 32 is equipped with a check valve 33 and with a suitable heating means, shown as an electrical heating coil 34.

The fuel injector comprises a body portion 35 having a circumferential slit opening or ring orifice 36, connected to a small, annular chamber 37, which communicates with the bottom of piston chamber 38. A spring-controlled injector piston 39, which operates in synchronization with the engine by means of stem 41 and cam 42 is disposed in the piston chamber. A fuel line 43 leads into the side of the injector piston chamber a short distance above the bottom of the chamber.

The engine cylinder is operated in the following manner: A charge of air or air containing insufficient fuel to form a combustible mixture is drawn into the cylinder on the suction stroke through intake valve 18. When this valve is shrouded, as shown in Figure 2, which is preferred practice, a swirling motion in planes substantially at right angles to the axis of the cylinder is imparted to the entering air. The air is preferably under a boost pressure, because the engine disclosed is particularly adapted for supercharged operation. The air is then compressed on the compression stroke. During this stroke, the swirling motion continues and at the same time, the air is caused to rotate in planes which substantially contain the axis of the piston, as shown by the arrows in Figure 1. Air is forced outwardly by the approaching surfaces 21 and 23, and the rounded cylinder head and groove in the head of the piston direct this air into the swirling movement indicated.

Prior to top dead center of the piston travel on the compression stroke, fuel is injected through circumferential orifice 36. The opening in this nozzle is small, so that the fuel is injected in a fine, flat circular spray in the direction of air movement. When a liquid fuel is used, the temperature and pressure on the fuel are adjusted such that at least a portion of the fuel immediately vaporizes upon entering the cylinder. This fuel vapor then immediately mixes with a localized portion of the rotating air to form a combustible mixture in a relatively flat, annular zone in the upper portion of the combustion chamber, surrounded by incombustible air and gas throughout the remainder of the combustion space. This mixture substantially as soon as it is formed is blown past spark plugs 16 and is ignited. The ignition of this air-fuel mixture initiates combustion and establishes a substantially annular flame front surrounding the central portion of the combustion chamber.

Looking at the system in another way, and regarding the combustion chamber as containing a number of layers of air in planes substantially containing the axis of the cylinder, it will be seen that there is created a number of distinct combustion zones, each containing a flame front cushioned by air or an incombustible air-fuel mixture. The flame front or the plurality of flame fronts tends to move toward the injection nozzle 36, but because of the rotation of the air, remains substantially stationary, relative to the walls and head of the cylinder. The injection of fuel in front of the flame front is continued until the desired amount has been introduced.

By causing swirling motion of the air in addition to the rotating motion, the possibility of the formation of pockets of combustible end gas between flame fronts is avoided. Thus, the swirling motion in planes substantially at right angles to the axis of the cylinder creates additional turbulence, which removes any combustible gases which might tend to be compressed by flame fronts spreading out from adjacent spark plugs.

It will be noted that in the arrangement shown, the fuel is injected in the direction of air rotation. This is generally preferred, because proper placing of the ignition means and correct proportioning of fuel and air is more easily accomplished. However, the invention also includes a process wherein the fuel is injected against the direction of the rotation of the air, and the resulting fuel-air mixture is blown past the ignition means.

The injection of the fuel may be started considerably before top dead center; for example, 60 degrees before this point, depending, of course, upon the amount of air introduced into the combustion chamber, and whether or not it is desired to consume substantially all of the air. It is generally preferred to start injection at about 40 degrees to 50 degrees before top dead center. The spark advance is synchronized with the injection and should occur not later than a few degrees after the beginning of the injection, so that ignition begins before any dissemination of the fuel throughout the combustion chamber has taken place.

It will be understood, however, that the optimum point for the beginning of fuel injection depends in great measure upon the specific structure of the engine and its size. Where the power requirement is low, the beginning of fuel injection may be at, or even slightly after top dead center; or, for the smaller power requirements, the injection may still be initiated considerably prior to top dead center and cut off, so that only that portion of the air is consumed which is necessary to supply the power required.

The duration of fuel injection may be varied over wide limits. However, by the arrangement shown, it is possible to accomplish regulated combustion of the injected fuel in a relatively short period of time, while avoiding the formation of combustible mixtures at points in the combustion chamber other than the area in advance of the flame front. On the other hand, by using high boost pressures on the entering air, a relatively large amount of fuel may be injected and burned efficiently, resulting in increased power.

Referring now to Figure 3, in this figure, similar parts bear the same reference numerals as the parts of Figures 1 and 2. The engine of Figure 3 is similar to that previously described, with the exception that the ignition means employed comprise two wires 45 and 46 disposed in the head of the cylinder. Wire 45 is connected to electrodes 47 and 48, and wire 46 is connected to electrodes 49 and 50. In operation, current is passed through these wires until they begin to glow, the current preferably being turned on prior to the injection of fuel. With the use of wires of this type, ignition of substantially the entire amount of initial mixture formed is accomplished at about the same time. Thus, the possibility of the accumulation of small quantities of combustible end gas is reduced. Also, by employing a continuous igniting means of this type, careful synchronization of the injection advance with the spark advance is not necessary.

It will be understood that the invention is not limited to the details of the foregoing description. For example, while a four-cycle operation has been disclosed, the method can be carried out in a two-cycle operation. It is only necessary that the air rotation and fuel injection as described be accomplished.

In the example given, the air is introduced into the cylinder by means of a poppet valve. It will be understood, however, that the air may be introduced in other ways, such as through a sleeve valve or through ports in the cylinder wall, opened and closed by the motion of the piston. When using either of these types of construction, the ports may be arranged so as to introduce the air at an angle and initiate the desired rotation in planes substantially containing the axis of the cylinder. For example, referring to Figure 1, by arranging a series of ports in the cylinder wall angled downwardly from the horizontal for air injection, the injected air on coming into contact with the groove in the piston head will begin to rotate in the desired manner. By arranging these ports also somewhat tangentially to the cylinder walls, both rotation and swirling of the air can be accomplished.

Obviously many modifications and variations of the invention, as hereinbefore set forth, may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

I claim:

1. A method of operating an internal combustion engine which comprises providing within the combustion chamber a compressed body of air substantially in the form of an annular ring disposed about the axis of the cylinder, causing said body of compressed air to rotate in planes substantially containing the axis of the cylinder, injecting fuel radially from a central location in a flattened circular spray into said combustion chamber at a localized elevation of said rotating air ring, the quantity of fuel and injection thereof being controlled to form a combustible mixture with a localized annular layer of the ring of rotating air, promptly electrically igniting said combustible mixture substantially throughout an annulus of said combustion chamber to form a substantially annular flame front tending to advance toward the locus of fuel injection, and continuing the injection of fuel by said flattened circular spray into other, following, localized portions of the rotating ring of air shortly in advance of the annular flame front to progressively form additional annular layers of combustible mixture immediately in advance of the annular flame front which are ignited thereby and burned substantially as soon as formed.

2. A method of operating an internal combustion engine having a substantially toroidal combustion chamber, which comprises causing a body of air to rotate within said combustion chamber in planes substantially containing the axis of the cylinder, also causing said body of air to swirl in planes substantially at right angles to the axis of the cylinder, thereby providing a helical swirl of the air about said toroidal combustion chamber, injecting fuel from a central location radially into said combustion chamber in a flattened circular spray at a localized elevation into said helically swirling air, the quantity of fuel and injection thereof being controlled to form a localized annular layer of combustible mixture with a localized annular portion of said body of swirling air, promptly electrically igniting said combustible mixture substantially throughout an annulus of said combustion chamber to form a substantially annular flame front tending to advance toward the locus of fuel injection, and continuing the injection of fuel by said flattened circular spray into other, following, localized portions of the helically swirling body of air shortly in advance of the flame front to thereby progressively form additional annular layers of combustible mixture immediately in advance of the annular flame front and which are ignited thereby and burned substantially as rapidly as formed.

3. A method of operating an internal combustion engine having a substantially toroidal combustion chamber, which comprises causing a body of air to rotate within said combustion chamber in planes substantially containing the axis of the cylinder, the direction of rotation being outwardly towards the wall of the cylinder in the upper part of the body of rotating air, injecting fuel from a central location radially into said combustion chamber in a flattened circular spray at an upper elevation of said combustion chamber so that fuel injection is in the direction of air movement, the quantity of fuel and injection thereof being controlled to form a localized annular layer of combustible mixture with a localized portion of the body of air, promptly and simultaneously spark igniting said combustible mixture at a large number of points disposed within and around the said annular combustible layer to form a substantially annular flame front tending to advance toward the locus of fuel injection, and continuing the injection of fuel by said flattened circular spray into other, following, localized portions of the rotating body of air shortly in advance of the annular flame front to thereby progressively form additional annular layers of combustible mixture immediately in advance of the annular flame front and which are ignited thereby and burned substantially as rapidly as formed.

KENNETH DONALD MACKENZIE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,116,596	Coffey	May 10, 1938
2,130,666	Coffey	Sept. 20, 1938
2,002,482	Kimball	May 21, 1935
2,002,483	Kimball	May 21, 1935
286,744	Leizaola	June 15, 1943
2,132,083	Pescara	Oct. 4, 1938
1,845,601	Herr	Feb. 16, 1932
1,613,226	Held	Jan. 4, 1927
2,033,810	Bernard	Mar. 10, 1936
1,419,702	Tartrais	June 13, 1922
1,867,682	Sperry	July 19, 1932
438,167	Fusion	Nov. 12, 1935

FOREIGN PATENTS

Number	Country	Date
421,101	England	Dec. 13, 1934
568,918	Germany	Jan. 26, 1933
821,488	France	Dec. 6, 1937