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INTERNAL-COMBUSTION ENGINE

Original Filed June 24, 1943

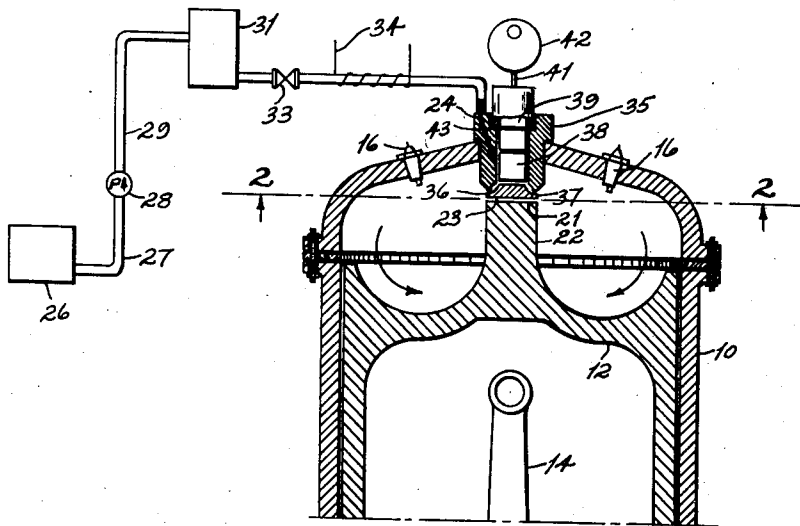


Fig. 1.

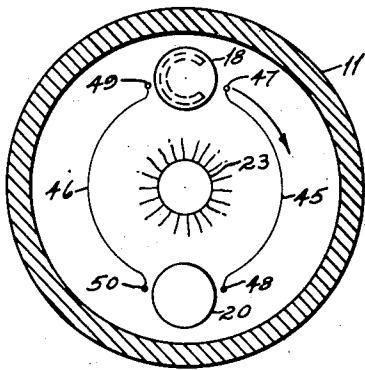


Fig. 3.

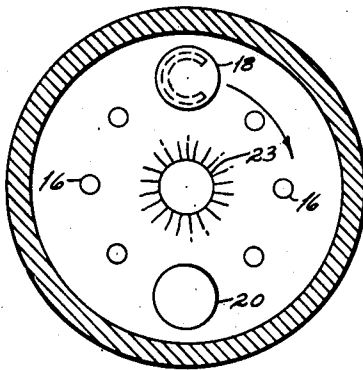


Fig. 2.

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2,466,321

INTERNAL-COMBUSTION ENGINE

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3 Claims. (Cl. 123—32)

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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 is a division of my copending application Serial No. 492,027 filed June 24, 1943, now Patent No. 2,431,875 dated December 2, 1947.

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. 10,598, filed February 25, 1948, as a continuation-in-part of Serial No. 513,232, filed December 7, 1943 now abandoned, the latter being in turn a continuation-in-part of Serial No. 463,031, filed October 23, 1942, now abandoned. 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 space 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. 10,598, 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

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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 number 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 carry out the process of the invention.

Referring 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 combustible 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. In an internal combustion engine of the character described, having a cylinder with cylinder head, a piston reciprocatingly mounted therein, said parts forming a substantially toroidal combustion space with the piston adjacent upper dead center position, and a fuel injection nozzle mounted centrally of said cylinder head, the improvement comprising a tip for said nozzle positioned adjacent the upper portion of said combustion space having an annular ring orifice adapted to inject a flattened circular fuel spray radially of said upper portion of the combustion space, a plurality of spark plugs mounted in spaced relation in a ring about said head with their electrodes positioned within the upper portion of said combustion space in position to contact the annular layer of combustible mixture formed from the first increment of injected fuel, and means synchronized with engine operation for producing sparks of ignitable intensity at said electrodes at the time said combustible mixture contacts said electrodes to establish an annular flame front.

2. In an internal combustion engine of the character described, having a cylinder with cylinder head, a piston reciprocatingly mounted therein, said parts forming a substantially toroidal combustion space with the piston adjacent upper dead center position, and a fuel injection

nozzle mounted centrally of said cylinder head, the improvement comprising air intake and exhaust passages with valves mounted in said cylinder head at diametrically opposed sides of said fuel injection nozzle, said air intake passage and valve being constructed to impart a swirling movement to the induction air about said cylinder axis, said piston during the latter part of the compression stroke being adapted to also impart an additional swirl to the compressed air in planes containing the cylinder axis, whereby the air has a helical swirling movement about said toroidal combustion space, with outward movement from the center toward the cylinder periphery at the upper portion of the said combustion space, a tip for said nozzle positioned in the upper portion of said combustion space at the level of said outward air swirl, said tip having an annular ring orifice adapted to inject a flattened circular spray radially in the direction of air movement, electrical ignition means arranged in an annular ring about the upper portion of said combustion space intermediate said valves, and means synchronized with engine operation for actuating said electrical ignition means to simultaneously ignite increments of combustible mixture contacting the ignition means throughout the extent of said annular ring to establish an annular flame front.

3. In an internal combustion engine of the character described, having a cylinder with cylinder head, a piston reciprocatingly mounted therein, said parts forming a substantially toroidal combustion space with the piston adjacent upper dead center position, air intake means for said cylinder whereby a high velocity compression swirl of said air is produced in the said toroidal combustion space in planes containing the cylinder axis as said piston approaches its upper dead center position, and a fuel injection nozzle mounted centrally of said combustion space, the improvement comprising means for simultaneously injecting fuel into said swirling compressed air substantially around said toroidal combustion space, the direction of injection being generally in the direction of movement of said air swirl therein, electrical ignition means arranged in an annular ring around said toroidal combustion space in position to be contacted by the first increments of injected fuel as soon as combustible fuel-air mixture is formed therefrom, and means synchronized with engine operation for actuating said electrical ignition means to simultaneously ignite said first increments around said annular ring to establish an annular flame front.

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