Sept. 17, 1935. P. SCHMALJOHANN 2,014,672

INTERNAL COMBUSTION ENGINE

Filed July 21, 1933 2 Sheets-Sheet 1

Fig. 1

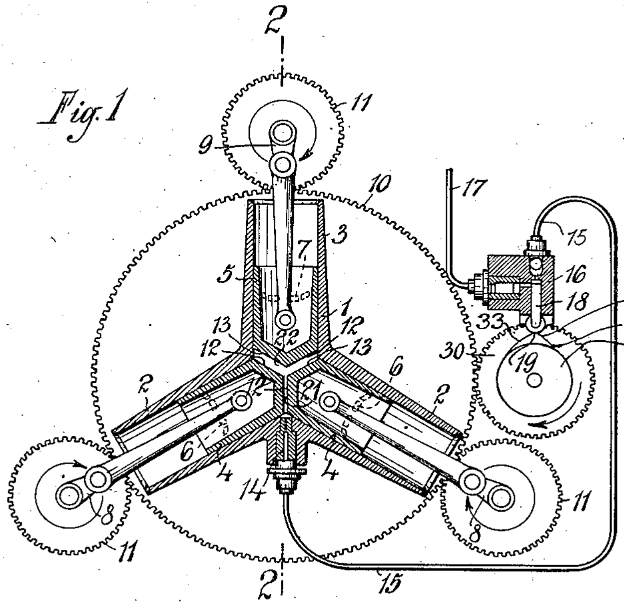

Fig. 2

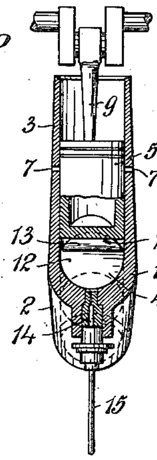

Fig. 3

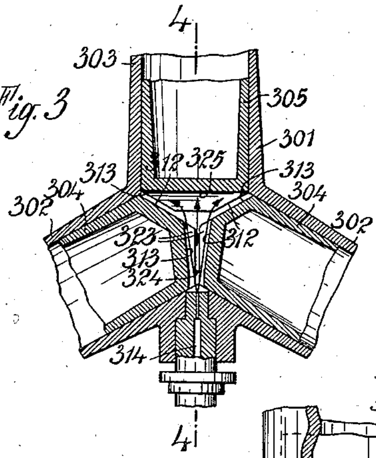

Fig. 4

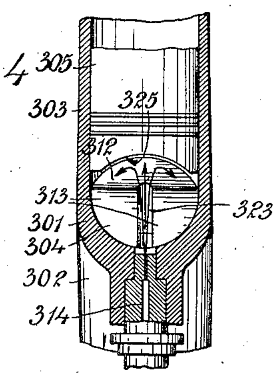

Fig. 5

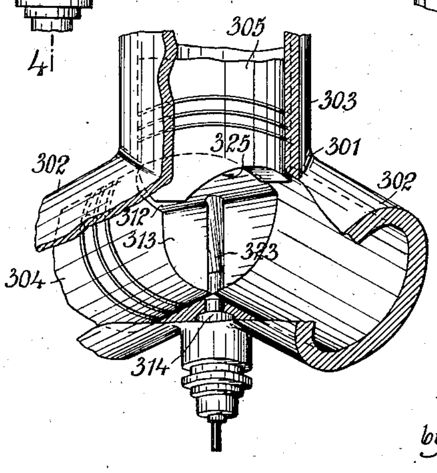

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Fig. 6

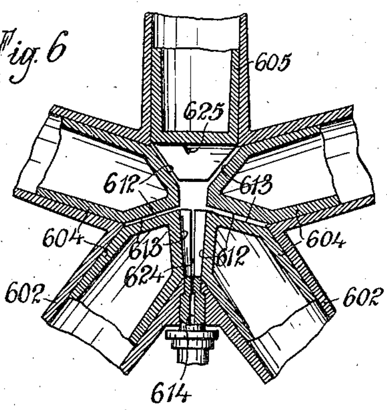


Fig. 7

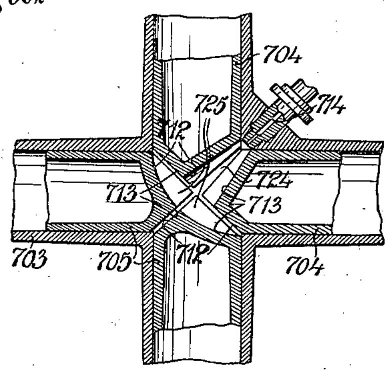


Fig. 8

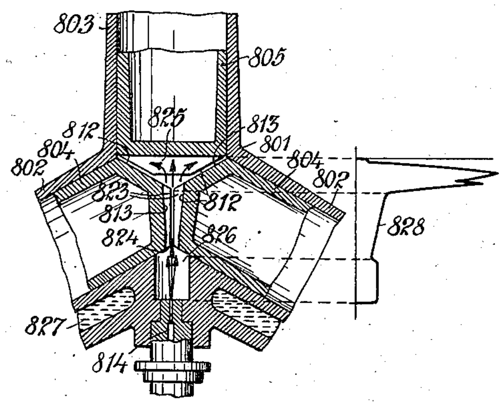
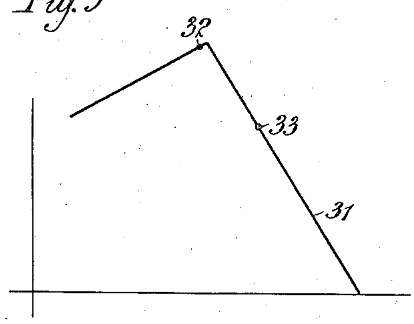


Fig. 9



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UNITED STATES PATENT OFFICE

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INTERNAL COMBUSTION ENGINE

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Application July 21, 1933, Serial No. 681,623
In Germany July 27, 1932

10 Claims. (Cl. 123—51)

My invention relates to improvements in internal combustion engines, and more particularly in engines of the type in which three or more cylinders are disposed radially of each other, so as to provide a common combustion chamber, and in which the pistons have piston heads which are formed by two slanting planes which intersect on one longitudinal face of the piston body on a line which is perpendicularly situated in relation to the longitudinal axis of the piston, and which heads are hereinafter termed "roof-shaped", that the combustion chamber is reduced so far that the fuel is ignited by the heat of the compression of the air. One of the objects of the improvements is to provide an engine of this type in which the fuel is thoroughly and uniformly distributed in the air within the combustion chamber so that complete combustion is insured. With this object in view my invention consists in constructing the roof-shaped (the significance of which term has been explained hereinbefore) ends of the pistons so that a compact combustion chamber is provided in which the fuel is thoroughly mixed with the compressed air, and into which the fuel is injected through a passage provided between two faces of adjacent pistons. By thus constructing the combustion chamber and the means for injecting the fuel, the said fuel impinges upon the end faces of the pistons located opposite to the nozzle, and it is raised to ignition temperature within the combustion chamber. Thus the fuel is uniformly distributed all through the combustion chamber, so that complete combustion within the said combustion chamber is insured. In addition the fuel which is still within the passage in front of the nozzle is likewise ignited, because by the ignition within the combustion chamber a body of gas is forced from the ignition chamber into the said passage and in opposition to the jet of fuel being injected. Thus the said portion of the fuel which is within the passage in front of the nozzle and a certain amount of compressed air are forced into the passage and ignited therein.

For the purpose of explaining the invention several examples embodying the same have been shown in the accompanying drawings in which the same reference characters have been used in all the views to indicate corresponding parts. In said drawings,

Fig. 1 is a diagrammatical sectional elevation showing the cylinders and pistons, the gearing connected with the pistons, and the fuel pump,

Fig. 2 is a sectional elevation taken on the line 2—2 of Fig. 1.

Fig. 3 is a fragmentary sectional elevation showing a modification,

Fig. 4 is a sectional elevation taken on the line 4—4 of Fig. 3,

Fig. 5 is a fragmentary perspective view of the example shown in Figs. 3 and 4, one of the pistons being removed,

Figs. 6 and 7 are fragmentary sectional elevations showing other modifications,

Fig. 8 is a similar fragmentary elevation showing a modification which is similar to the example illustrated in Figs. 3 to 5, and

Fig. 9 is a diagram showing the velocity of the fuel being injected.

In Figs. 1 and 2, I have shown a two-stroke cycle internal combustion engine, comprising a body 1 composed of three cylinders 2, 2 and 3 disposed star-like and radially of one another, and pistons 4, 4, 5, the cylinders 2, 2 being provided with slots 6, 6 for the admission of scavenging air, and the cylinder 3 being provided with slots 7 for the exhaust of the gases of combustion. The pistons are connected with cranks 8, 8, 9 cooperating with gear wheels 10, 11 as is known in the art.

In Fig. 1 the pistons are shown in their inner dead centers, and they provide a common combustion chamber between their end faces. The end face of each piston comprises two bevelled planes 12 and 13 disposed in the roof-like manner explained hereinbefore, so that the space between the ends of the pistons is reduced in size. Between the cylinders 2 of the pistons 4 controlling the admission of scavenging air a fuel injection passage 14 is provided coaxially of the piston 5 controlling the exhaust.

Fuel is supplied to the nozzle 14 through a pipe 15 connected with the pressure chamber of a fuel pump 16 the suction chamber of which is connected by a pipe 17 with a fuel tank. The plunger 18 is operated by a cam 19 provided on a shaft 20 connected with the accelerator.

The cylinder 3 of the piston 5 controlling the exhaust is extended, or the piston 5 is reduced in length so that a somewhat enlarged chamber 22 is provided between the end faces of the scavenging pistons 4, 4 and the exhaust controlling piston 5 when the said pistons are in their inner dead centers, the said chamber 22 being broader than the passage 21 provided between the faces 12 and 13 of the pistons 4, 4.

Injections begins near the end of the compression stroke, and the fuel is injected through the narrow passage 21 and into the chamber 22 containing compressed air. The chamber 22 comprises two flat portions disposed in roof-like manner, that is, in the form of an inverted V, and thus the jet of fuel is distributed to opposite sides and into the air contained in the flat portions of the chamber. When the pistons are in their inner dead centers as shown in Fig. 1, the pressure within the chamber 22 is at its maximum and the temperature of the mixture of air and fuel is higher than the ignition temperature of the fuel. Thus the mixture is ignited and completely burnt.

When the pistons are in their inner dead centers injection of fuel is interrupted. The amount of fuel which has last been injected through the nozzle 14 and which is about to flow through the narrow passage 21 and into the ignition chamber 22 is arrested by the gas within the chamber 22, which expands and flows into the passage 21 in opposition to the fuel injected into the same. Thus further movement of the particles of fuel which have last been injected is prevented, and the said particles are even forced backwardly into the part of the passage 21 which is adjacent to the nozzle. Within the said parts of the passage there is air under pressure which has not been consumed, because the previously injected fuel had been thrown into the inner part of the combustion chamber. Thus also the particles of fuel which have last been injected are completely burnt, and the engine operates with smokeless combustion even with very high speed.

The enlarged ignition chamber 22 may be provided also by reducing the scavenging pistons 4, 4 in length by retracting the end faces 12, 13 thereof away from the end face of the piston 5, in which case the slanting planes defining the end faces of the said pistons intersect on a line disposed laterally of the longitudinal center axis of the piston. Further, the pistons may be recessed at their ends.

In the modification shown in Figs. 3 to 5 the fuel passage 324 is provided between the scavenging pistons 304, 304 by providing the opposite faces 313 and 312 of the said pistons with corresponding grooves 323 located coaxially of the fuel nozzle 314 and flaring outwardly from the said nozzle towards the ignition chamber. When the pistons are in their inner dead centers the said grooves are combined into the fuel passage 324 which corresponds by its flaring shape to the form of the jet of fuel. The remaining portions of the end faces 312, 313 of the pistons are brought close to each other when the pistons are in their inner dead centers, so that the dead space the air content of which cannot be made use of in the combustion is reduced to a minimum.

The piston 305 controlling the exhaust is formed with a concave recess 325 disposed transversely of the ridge in which the roof-like faces 312 and 313 end, the said recess having the form of a groove. The said recess provides the ignition chamber which is bounded by the recessed end face of the piston 305 and the faces 312 and 313 of the opposite pistons 304.

In the construction shown in Figs. 1 and 2 in which the ignition chamber 22 comprises two portions, the fuel may not be uniformly distributed through the compressed air within the said portions, so that in some parts of the ignition chamber carbon monoxide might be produced by reason of a want of oxygen. In the construction shown in Figs. 3 to 5 in which the ignition chamber 325 is provided by the recess made in the end of the piston 305 the said ignition chamber takes the form of a single flat space. The fuel which is first injected passes through the passage 324 provided between the pistons 304, 304, and it expands by reason of the flaring shape of the said passage, whereupon it gets into the compressed air within the chamber 325. Thus a large surface of the said body of air is directly impinged upon by the jet. By reason of the flat shape of the chamber 325 the fuel is uniformly distributed all through the chamber into the outer corners thereof, so that by ignition at the time of highest compression complete combustion of the fuel is more effectively insured than in the construction described with reference to Figs. 1 and 2.

In Fig. 6 I have shown an engine comprising five cylinders. The fuel passage 614 is disposed between two cylinders 602 containing scavenging pistons 604 and opposite to the piston 605 controlling the exhaust. The pistons adjacent to the piston 605 may likewise be pistons 604 controlling the supply of scavenging air. The exhaust controlling piston 605 is formed at its end with a recess 625 which provides the ignition chamber together with the opposing faces 612 and 613 of the adjacent pistons 604 controlling the supply of scavenging air. The passage 624 for the supply of fuel is provided by grooves made in the opposing end faces 612, 613 of the pistons 604 located at either side of the injection passage 614.

In the modification shown in Fig. 7 the engine comprises four cylinders. The fuel passage 714 is provided between two pistons 704 controlling the supply of scavenging air and opposite to the line where the cylinders 703 containing the exhaust controlling pistons meet. In the construction shown in the figure the ignition chamber is provided by recesses 725 made in the roof-shaped ends of the exhaust controlling pistons 705 which are opposite to the pistons 704 controlling the supply of scavenging air, and by the faces 712, 713 of the said pistons. The passage 724 is provided by the opposing faces 712, 713 of the pistons 704 between which the fuel passage is located.

In the modification shown in Fig. 8 the fuel passage 814 does not directly open into the passage provided between the end faces of the pistons 804, but into a chamber 826 provided in the body 801 between the said passage and the fuel nozzle, the said chamber 826 being the continuation of the passage 824 and having the nozzle 814 thereof opening into the same. The chamber 826 is surrounded by a cooling jacket 827.

Within the passage 826 the jet of fuel is prepared for combustion. At the beginning of the injection and while the pistons 804, 804 and 805 perform their compression strokes a current of air is blown from the passage 824 into the chamber 826 in opposition to the jet of fuel. Thereby the jet of fuel is atomized within the chamber 826, particularly by friction on the current of air, so that it is effectively prepared for the following combustion.

The volume of fuel contained within the chamber 826 near the end of the injection is stowed within the said chamber by gas being driven in opposition to the jet of fuel at the end of the ignition from the ignition chamber 825, because the pressure wave produced within the ignition chamber 825 by ignition is transmitted through the passage 824 to the chamber 826. Thereby the fuel is distributed within the chamber 825 and ignition is transmitted through the passage 824 to the chamber 826. Thereby the fuel is distributed within the chamber 826 and intimately mixed with the air and ignited.

The distribution of the air at the moment of highest compression is illustrated in the diagram

828 forming a part of Fig. 8. The abscissae indicate the length of the total combustion chamber taken from the exhaust controlling piston 5 to the nozzle of the passage 814, and the ordinates indicate the cross-sectional area of the said space. The diagram shows that by far the larger portion of air is confined within the chamber 825, so that the air within the said chamber is first heated to the temperature necessary for self-ignition. The spaces 824 and 826 substantially provide only spaces for supplying the fuel to the combustion chamber.

In order to prevent premature ignition of the fuel within the chamber 826, the said chamber is provided with a cooling jacket 827 by means of which the temperature of the walls of the chamber is held below self-ignition temperature.

The cam 19 for operating the plunger 18 of the fuel pump 16 is constructed so that the injection is adapted to the combustion after ignition of the fuel within the ignition chamber 22 or 325. The cam 19 which rotates in the direction of the arrow shown in Fig. 1 has an ascending surface comprised of two parts 29*a* and 29*b*, and a longer descending surface 30. The part 29*a* is considerably steeper than the part 29*b*. The shape of the cam corresponds to the diagram illustrated in Fig. 9, in which the line 31 indicates the velocity of the fuel injection. The velocities of the plunger 18 have been represented by the ordinates, while the time has been represented by the abscissae. The plunger 18 is forced upwardly at high velocity, so that at the beginning of the injection indicated by the point 32 of the line 31 the fuel is forced with high velocity through the passage 24 and into the ignition chamber 22 or 325. Thereafter the velocity of the plunger is rapidly reduced, until the injection is terminated at the point 33. Therefore the particles of fuel which have last been injected get only to the passage 24, and the retarding action of the gas forced from the ignition chamber 25 into the passage 24 and in opposition to the jet of fuel during the last part of the injection is supported. The fuel particles remain near the nozzle of the fuel passage 14 and they fill the passage 24 which contains non-consumed oxygen. The exhaust passage may have a lead relatively to the pistons controlling the supply of scavenging air. The fuel nozzle may also be provided between a piston for supplying cooling air and a piston controlling the exhaust, or between two pistons controlling the exhaust.

By thus controlling the supply of fuel to the combustion chamber, the pressure on the fuel being injected decreases from the beginning of the injection towards the end thereof, and the fuel is injected at first at high velocity, and at the end of the injection at low velocity. Therefore the particles of fuel which are last injected remain within the portion of the passage 826 which is adjacent to the fuel nozzle, where they find non-consumed air for supporting combustion.

I claim:

1. In an internal combustion engine, a plurality of cylinders the number of which is greater than two arranged star-like and having a common combustion chamber, pistons reciprocating within said cylinders and formed with roof-like end faces, a fuel injection nozzle between two adjacent cylinders, and gearing connected with said pistons and controlling the movement thereof, the end faces of said pistons being shaped so that when the said pistons are in their inner dead centers between the end face of the piston opposite to the injection nozzle and the end faces of the pistons opposite to the said piston an ignition chamber is provided, and that between the end faces of the pistons reciprocating within the cylinders having the injection passage located between the same a passage is provided which connects the said nozzle with said ignition chamber.

2. A device according to claim 1, in which the said ignition chamber is provided by having the end face of the piston located opposite to the injection nozzle spaced from the end faces of the other pistons when the pistons are in their inner dead centers.

3. A device according to claim 1, in which the piston opposite to the injection nozzle is formed at its inner end with a recess providing an ignition chamber.

4. A device according to claim 1, in which the pistons meet in a line at their ends and in which the piston located opposite to the injection nozzle is formed with a recess in the form of a flat groove disposed transversely of the said line in which the faces of the pistons meet.

5. A device according to claim 1, in which the end faces of the pistons reciprocating within the cylinders having the fuel injection nozzle located between the same are formed with grooves which are disposed in the direction of the jet of fuel, and cooperating when the pistons are in their inner dead centers to provide a passage extending from the fuel injection nozzle to the ignition chamber.

6. A device according to claim 1, in which the end faces of the pistons reciprocating within the cylinders having the fuel injection nozzle located between the same are formed with grooves which are disposed in the direction of the jet of fuel, and flaring outwardly from the circumference of the pistons to the axes thereof and cooperating when the pistons are in their inner dead centers to provide an outwardly flaring passage extending from the fuel injection nozzle to the ignition chamber.

7. A device according to claim 1, in which the end faces of the pistons reciprocating in the cylinders having said injection nozzle located between the same are formed with grooves which are disposed in the direction of the jet of fuel, and cooperating when the pistons are in their inner dead centers to provide a passage located coaxially of said nozzle and extending from the circumference of the pistons towards the axes thereof, and in which device between the delivery end of the nozzle and the intake end of the said passage an enlarged chamber is provided in the body of the cylinder.

8. A device according to claim 1, in which the end faces of the pistons reciprocating in the cylinders having said injection nozzle located between the same are formed with grooves which are disposed in the direction of the jet of fuel, and cooperating when the pistons are in their inner dead centers to provide a passage located coaxially of said nozzle and extending from the circumference of the pistons towards the axes thereof, and in which device between the delivery end of the nozzle and the intake end of the said passage an enlarged chamber is provided in the body of the cylinder, the part of the body of the cylinders around said chamber located between the nozzle and the said passage being formed with cooling means.

9. A device according to claim 1, comprising

fuel injecting means adapted to inject the fuel under pressure which decreases from the beginning of the injection towards the end thereof.

10. In an internal combustion engine, comprising more than two cylinders disposed in star-like fashion and defining between them a common combustion chamber, pistons reciprocating within said cylinders and formed with roof-like end faces so shaped that they partly fill the said combustion chamber when they are at their inner dead centers, a fuel injection nozzle between two adjacent cylinders, gearing connected with said pistons for transmitting the power impulses thereof, the shape of the roof-like end faces of said pistons being such that when the pistons are at their inner dead centers an ignition chamber is provided between the end face of that piston which is opposite to the injection nozzle and the end faces of those pistons which are opposite to the said last-mentioned pistons, and so that a passage is provided between the end faces of those pistons reciprocating within the cylinders which have the injection passage located therebetween, and means defining an atomizing chamber between said nozzle and said passage, movement of the pistons towards dead center driving gas into said atomizing chamber against the jet of fuel to atomize the same, and the said passage connecting said atomizing chamber with said ignition chamber.

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