PATENT SPECIFICATION

409,541

Convention Dates (Germany) | Corresponding Applications in United Kingdom

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COMPLETE SPECIFICATION.

Improvements in and relating to Two-stroke Cycle Internal Combustion Engines.

We, CENTRA HANDELS- & INDUSTRIE A.-G., of Quaderstrasse, Chur, Switzerland, a Swiss Company, Assignees of MICHELMOTOR-GESELLSCHAFT M.B.H., of Paulstrasse 2, Hamburg, Germany, a German Company, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to two-stroke cycle internal combustion engines of the type in which the compression is so high that self-ignition of the injected fuel occurs and in which the cylinders, of which there are three or more, are disposed in "star" form and their pistons are associated with a common combustion chamber. In engines of this type, in order to obtain a sufficiently small combustion chamber, it has previously been proposed to make the piston heads of roof-like shape, i.e. with two inclined surfaces meeting along a line forming a ridge. For the purpose of effecting a better distribution of the fuel in the combustion chamber the fuel injection valve has been arranged between two adjacent cylinders.

If the heads of the pistons are made in the shape of a symmetrical roof i.e. with equal sides, and if at the moment of the maximum compression pressure the combustion chamber is formed by the space which is left free uniformly between all of the heads of all the pistons, then this chamber consists of a number of relatively narrow spaces extending in starlike form from a central point. It then becomes difficult to distribute the fuel throughout a combustion chamber of this form in such a manner that the compressed air for combustion which is located in the narrow spaces is sufficiently mixed with the fuel to obtain complete combustion. The formation of air eddies must be avoided as far as possible since it has been found by experience that the fuel is only carried along by the individual rapidly flowing "threads" of the eddy, so that the fuel which is outside these threads does not come into intimate contact with the air.

According to the invention, in internal combustion engines of the type set forth, and in which the injection valve is arranged between two of the cylinders, a smokeless combustion is obtained by providing, as the ignition chamber, and for receiving the main portion of the combustion air, a space which is situated between the roof-like surfaces of the piston or pistons opposite to the injection valve and the opposite roof-like surfaces of the pistons adjacent the injection valve, and by arranging for the jet of fuel to enter this space through a passage the axis of which coincides with the axis of the jet and is formed between those roof-like surfaces of the pistons adjacent the injection valve which are situated laterally of the jet of fuel. Since, at the beginning of the injection, the fuel is injected through the passage between the pistons adjacent the injection valve and impinges on the head or heads of the opposite piston or pistons, it is first brought to the ignition temperature in the space between these piston heads and the piston heads opposite to one another of the pistons adjacent the injection valve. This space therefore forms the ignition chamber. In the middle of this chamber the conditions for initiating the ignition are particularly favourable, since it is limited only by the hot heads of the pistons and the surfaces which can conduct away the heat are extremely small relatively to the enclosed volume of air. Since the atomised fuel is uniformly distributed over the entire ignition chamber owing to its shallow form, a complete combustion takes place in the chamber itself. The complete combustion of the fuel which is the last to be injected is ensured owing to the fact that, on ignition of the mixture present in the ignition chamber, a piston-like column of gas from the ignition chamber enters the passage between the pistons adjacent the injection valve and is driven in the opposite direction to the jet of fuel. The fuel which is the last to enter that part of the passage which adjoins the injection nozzle and which contains some air which is still unconsumed is driven backwards and thus consumed or burnt.

Instead of forming the space which receives the main combustion air and which acts as an ignition chamber between the piston or pistons which are opposite to the injection valve and the pistons which are adjacent to it, this space can be formed, in accordance also with the invention, between the adjacent pistons, that is to say between those roof-like surfaces of these pistons which are situated laterally of the jet of fuel. In this case, in order to reduce unavoidable dead spaces as far as possible, the roof-like surfaces of the opposite piston or pistons must, at the maximum compression pressure, be brought as close as possible to the roof-like surfaces of the adjacent pistons. Thus the combustion chamber extends directly in front of the injection nozzle while only narrow gaps remain between the adjacent pistons and the opposite piston or pistons. In order to be able to use the air present in these gaps also for combustion purposes, the opposite piston or pistons which at the same time act as the exhaust pistons lead the pistons situated laterally of the jet. Owing to the suction effect of the exhaust piston or pistons which occurs in consequence of this lead fuel is sucked into the gaps and mixed with the air therein.

The fuel which impinges on the head or heads of the piston or pistons should already be mixed as far as possible with air and converted into vapour form. This preparation of the fuel for the combustion is obtained by providing a preliminary mixing chamber between the cylinders adjacent the injection valve. This preliminary mixing chamber directly adjoins the passage formed by the heads of the pistons in the cylinders adjacent the injection valve and the injection valve opens into it. During the injection process a stream of air, the direction of flow of which is opposite to that of the jet of fuel, is blown out of the compression chamber between the pistons into the preliminary mixing chamber. Considerable friction is thereby produced between the charge of air and the jet of fuel so that the latter is partly atomised and thereby mixed with air. Further, owing to the fact that on ignition a piston-like column of gas is driven out of the ignition chamber in the opposite direction to that of the jet of fuel, a blockage occurs in the preliminary mixing chamber, which has the effect that the fuel present in this chamber is distributed and mixed with the air present and is brought to ignition. Pre-ignition of the fuel in this chamber can be prevented by cooling the chamber.

As a further aid to these conditions, in accordance also with the invention, the pressure with which the fuel is injected into the combustion chamber is decreased as the end of the injection is approached. For example, the cam on the camshaft which drives the plunger of the fuel pump is so shaped that at the beginning of the injection the fuel enters the combustion chamber with a higher velocity than it does towards the end of the injection, when the velocity of the plunger decreases, and the fuel enters with a lower velocity. The particles of fuel which are last injected, owing to their low velocity, then remain in that part of the passage or preliminary mixing chamber which is adjacent the nozzle where they meet some air for combustion which is still unconsumed.

Various constructional embodiments of internal combustion engines in accordance with the invention are illustrated by way of example in the accompanying drawings, in which:—

Figure 1 illustrates one form of engine diagrammatically in longitudinal section through the cylinder star and the fuel pump and illustrates the drive of the pistons, and the fuel pump.

Figure 2 is a section on the line A—B of Figure 1.

Figure 3 is a section through a part of the cylinder star with a different form of construction of the combustion chamber.

Figure 4 is a cross-section on the line C—D of Figure 3.

Figure 5 is a perspective view of a portion of Figure 3.

Figures 6 and 7 illustrate further forms of construction in longitudinal section.

Figure 8 is a longitudinal section through the cylinder star of a modification of the form shown in Figure 3 and illustrates the distribution of the air in the combustion chamber at the maximum compression pressure.

Figure 9 is a diagram illustrating how the speed of the pump plunger varies during the time of injection.

Figure 10 illustrates diagrammatically in longitudinal section through the cylinder star a modified form of construction and shows also the drive of the pistons, and

Figure 11 shows a part of Figure 10 on a larger scale.

Referring to the drawings, in the two-stroke cycle three cylinder engine according to Figures 1 and 2, the pistons 4, 4, and 5 work in a cylinder star 1 having three cylinders 2, 2 and 3. The two pistons 4 control the scavenging air by means of the slots 6 provided in the cylinders 2 and the piston 5 controls the exhaust by means of the slots 7. The three pistons work on to the cranks 8, 8 and 9, the movement of which is transmitted by means of toothed wheels 10 and 11.

A common combustion chamber is formed, at the inner dead point of the pistons, between the piston heads. The piston heads are of roof-like shape. Thus, each piston has a roof-like surface 12 and a roof-like surface 13 which meet in a ridge. Between the two cylinders 2 of the scavenging air pistons 4, the fuel valve 14 is arranged in the cylinder star 1 in such a manner that its nozzle is situated on the axis of the exhaust piston 5.

The fuel is supplied to the fuel valve 14 through a pipe 15 from the pressure chamber of the fuel pump 16, the suction chamber of which is connected by a pipe 17 with the fuel reservoir. The plunger 18 of the pump is driven by a cam 19 which is fitted on a shaft 20 which is driven from the engine.

The cylinder 3 of the exhaust piston 5 is so much longer than the cylinders 2 or the piston 5 is so much shorter than the pistons 4 that, at the inner dead point position of the three pistons 4, 4, and 5 which is illustrated in Figure 1, the scavenging air pistons are adjacent to one another leaving only a small passage 21 between their heads, whereas the head of the exhaust piston 5 is considerably further removed from the surfaces 12 and 13 respectively of the two pistons 4 which are opposite to it. Therefore, at the inner dead point a space 22 is formed between the two scavenging air pistons and the exhaust piston.

The ignition space 22 may also be formed in such a manner that the roof-like surfaces 12, 13 of the scavenging air pistons 4, 4 which bound the bottom of the space 22 are set back in such a way that these surfaces become longer and the passage 21 is shortened. In this case the heads of these pistons then have the shape of a roof with unsymmetrical sides. Also these roof surfaces may be provided with recesses.

The injection of the fuel begins near the end of the compression stroke and the fuel then passes through the passage 21 which separates the two opposite surfaces 12 and 13 of the scavenging air pistons 4 and enters into the space 22 in which most of the compressed air is present. The jet of fuel impinges against the ridge of the piston 5 and is diverted to two opposite sides and distributed over the air which is present in the space 22. Where the pistons have reached the inner dead point as illustrated in Figure 1 the maximum compression pressure prevails in the space 22 at which pressure the mixture of fuel and air has reached a temperature which exceeds the self-ignition temperature of the fuel. The mixture is, therefore, ignited and is completely combusted since the quantity of air necessary for this is present. The beginning of the ignition occurs in the middle of the space 22 since this space is limited only by the hot heads of the pistons 4. 4 and 5 and the conduction of heat by these surfaces is very small in comparison with the volume of air which is enclosed.

At this inner dead point position of the pistons, the injection of the fuel is also completed. The fuel which is last injected through the nozzle 14 and attempts to penetrate through the narrow passage 21 into the ignition space 22 is then prevented from doing so, because the gas present in the space 22 expands and flows in the opposite direction to the jet of fuel in the passage 21. The further advance of the particles of fuel which are last injected is thereby retarded and these particles are driven back into the portions of the passage 21 which are adjacent the nozzle of the fuel valve 14. At these parts of the passage, however, compressed air which has not yet been consumed is present, since the fuel which was previously injected was at once driven further along the passage. Therefore, the particles of fuel which are injected last are also completely burnt. Consequently even at very high speeds of revolution smokeless combustion takes place in the engine.

In the form of construction according to Figures 3 to 5 the passage for the fuel is formed between the two scavenging air pistons 4, 4 by providing grooves 23 in the two roof surfaces 13 and 12 respectively which are opposite one another on these pistons. These grooves lie in the direction of injection of the jet of fuel and widen out as they approach the combustion chamber. At the inner dead point the two grooves together form a passage 24 for the fuel which, in consequence of the widening of the grooves towards the ignition chamber, conforms to the cross sectional shape of the jet of fuel. In this case the remainder of the surfaces 12, 13 may come close together at the inner dead point, so that dead spaces containing air which cannot be utilised for combustion purposes are avoided as far as possible.

The exhaust piston 5 is provided with a groove or recess 25 which lies at right angles to the ridge of the roof-like head of the piston. This recess together with the opposite roof surfaces 12 and 13 of the scavenging pistons 4 forms the ignition or combustion chamber.

In the case of an ignition chamber 22 of the form shown in Figures 1 and 2 there is always the danger due to the roof-like shape of this chamber, that owing to the division of the stream of fuel into two branches, its distribution throughout the compressed air does not take place uniformly, so that carbon monoxide may be formed in the corners of the ignition chamber owing to lack of air. The ignition or combustion chamber of the form shown in Figures 3 to 5 owing to the omission of the ridge which is present in the ignition chamber 22 of Figs. 1 and 2 has the form of a shallow trough. The fuel which is first injected is shot through the passage 24 between the scavenging air pistons 4 and can expand owing to the conical shape of this passage and meets the compressed air contained in the combustion chamber. Thus a very large surface of this air is directly impinged upon by the jet of fuel. Owing to the shape of the combustion chamber the fuel is distributed over the entire chamber as far as its outermost corners and so uniformly that, when ignition occurs at the moment of maximum compression pressure, complete combustion of the fuel in this chamber is ensured with greater certainty than in the form of construction according to Figures 1 and 2.

Figure 6 illustrates an engine having five cylinders in which case also the fuel valve 14 is arranged between the two cylinders 2 of the scavenging air pistons 4 and opposite an exhaust piston 5. The two pistons 4 adjacent the exhaust piston 5 may also be scavenging air pistons. In this form the exhaust piston 5 is again provided with a recess 25 which together with the roof-like surfaces 12, 13 of the adjacent scavenging air pistons 4 which are opposite the groove forms the ignition chamber. The passage 24 for the fuel is formed by the opposite roof surfaces 12, 13 of the scavenging air pistons 4 adjacent the fuel injection valve 14.

Figure 7 shows a form of construction of an engine having four cylinders. The fuel valve 14 is arranged between two scavenging air pistons 4 opposite the dividing line of the cylinders 3 of the two opposite exhaust pistons 5. In the form of construction illustrated, the ignition chamber is formed by recesses 25 in the roof-like surfaces of the exhaust pistons 5 which are opposite the scavenging air pistons 4 and by the roof-like surfaces 12, 13 of the latter pistons. The passage 24 is again formed by the opposite roof surfaces 12, 13 of the scavenging air pistons 4 adjacent the fuel valve 14.

In the form of construction according to Figure 8 the fuel valve 14 does not open directly into the passage between the two scavenging air pistons 4 but there is provided in the cylinder star 1 between this passage and the fuel valve a chamber 26 which is directly adjoined to the passage 24 and into which the nozzle of the injection valve opens. This chamber 26 is surrounded by a water cooling jacket 27.

The object of the chamber 26 is to prepare the jet of fuel for combustion. At the beginning of the injection while the pistons 4, 4 and 5 are still making their compression strokes a current of air is blown from the passage 24 into the preliminary mixing chamber 26, that is to say in the opposite direction to the direction of flow of the jet of fuel. The jet is, therefore, already atomised and mixed with air in the preliminary mixing chamber 26 owing in particular to friction with the opposing current of air, whereby it is well prepared for combustion later.

The fuel present in the preliminary mixing chamber 26 towards the end of the fuel injection period, owing to the fact that after ignition has occurred gas is driven from the ignition chamber 25 against the direction of flow of the jet of fuel, is dammed-up in the preliminary mixing chamber, since the wave of pressure which is caused by the ignition in the ignition chamber 25 advances through the passage 24 into the preliminary mixing chamber 26. Owing to this accumulation or damming, the fuel is distributed throughout the chamber 26 and is intimately mixed with the air present there and is thus consumed or burnt.

The curve 28 shown at the side of figure 8 shows the distribution of the air at the maximum compression pressure. In this curve as abscissæ are plotted the lengths of the entire combustion chamber from the exhaust piston 5 to the nozzle of the fuel valve 14 and as ordinates are plotted the cross-sectional areas of this chamber. The curve shows that by far the greatest quantity of air is contained in the space 25 so that this space first reaches the temperature which is necessary for the self-ignition of the fuel. The spaces 24 and 26 are substantially only conducting passages for the fuel.

In order to avoid with certainty premature ignition of the fuel in the preliminary mixing chamber 26, this chamber is maintained by means of the cooling water in the jacket 27 at a temperature which lies below the self-ignition temperature of the fuel.

The cam 19, which rotates in the direction of the arrow indicated in Figure 1, has an ascending surface composed 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*. This shape of the cam corresponds to the velocity characteristic 31, illustrated in Figure 9, with which the fuel is injected. In the diagram the speeds of the plunger 18 are plotted as ordinates and the times as abscissæ. The plunger 18 is first rapidly raised so that, at the beginning of injection, at the point 32 of the characteristic line 31 the fuel is driven with great force through the passage 24 into the ignition chamber 25. The velocity of the plunger is then reduced relatively rapidly until at the point 33 the injection of fuel ceases. The result is thereby obtained that the last particles of fuel which are injected can only penetrate as far as the passage 24. The retarding effect which the gases driven out of the ignition chamber 25 into the passage 24 in the opposite direction to the jet of fuel exert on the particles which are last injected is thereby augmented. These particles of fuel remain in the vicinity of the nozzle of the fuel valve 14 and at this place fill the passage 24 in which some unconsumed air is still present.

The fuel valve can also be arranged between a scavenging air piston and an exhaust piston or between two exhaust controlling pistons.

In the form of construction of the engine which is illustrated in Figures 10 and 11, the head of the exhaust controlling piston 5 has the normal roof-like shape with roof-surfaces 12, 13. The heads of the two scavenging air pistons 4 are in the form of unsymmetrical roofs, the shorter surfaces 34 of which are opposite the roof-like surfaces 12 and 13 of the exhaust piston 5 and the longer surfaces 35 of which are opposite to one another and are parallel to the axis of the exhaust piston 5. The exhaust piston leads the scavenging air pistons by a certain angle (see Fig. 10).

The heads of the scavenging air pistons 4 are of unsymmetrical roof-like shape, their longer surfaces 35 being set back in such a way that, at the moment of maximum compression pressure, the combustion chamber 36 is left between these two surfaces. The position of the pistons at this moment is illustrated in Figure 10. In this case the design of the engine is such that the roof-like surfaces 12, 13 of the exhaust piston 5 are in close proximity to the shorter roof-like surfaces 34 of the scavenging air pistons 4, that is to say only narrow gaps 37 remain between these piston surfaces.

During the compression strokes of the three pistons 4, 4 and 5 the air in the space between the heads of the pistons is compressed and fuel is injected through the fuel valve 14 in the form of a fan-shaped jet into the combustion chamber 36. This combustion chamber which is located between the two surfaces 35 of the scavenging air pistons 4 is in the form of a narrow space, the plane of which is located in the plane of the fan-like jet of fuel. The fuel therefore reaches directly all parts of this combustion chamber, so that it is well distributed over the highly compressed air present in the chamber. The exhaust controlling piston 5 has then already come very close to the scavenging air pistons 4, so that substantially only compressed air is present in the gaps 37. Then, shortly before the maximum compression pressure is reached, that is to say before ignition, the exhaust piston 5, owing to its lead, already begins its outward stroke while the two scavenging air pistons 4 are still approaching one another slightly. Owing to this movement of the exhaust controlling piston 5 a vacuum is produced in the narrow gaps 37, the consequence of which is that a fuel-air mixture is sucked out of the combustion chamber 36 into these gaps. After this ignition takes place. Since on the one hand owing to the conformity of the combustion chamber to the fan-like shape of the jet of fuel, the fuel in the combustion chamber is well mixed with the air and on the other hand a combustible mixture is also present in the gaps, a complete combustion is obtained. The preliminary mixing chamber 26 and the method of injection illustrated in Figure 9 may also be used with advantage in this form of construction. The exhaust piston, or pistons, in the forms of construction illustrated in the Figures 1 to 8 may also lead the scavenging air pistons.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A two-stroke cycle internal combus-

tion engine in which self-ignition of the injected fuel occurs and in which the cylinders, of which there are three or more, are disposed in star form and their pistons are associated with a common combustion chamber and the piston-heads are of roof-like shape and a fuel injection valve is arranged between two of the cylinders, characterised by the features that there is provided as a combustion chamber and for the reception of the main air for combustion a space which is located between the roof-like surfaces of the piston or pistons which are opposite the injection valve and the roof-like surfaces opposite thereto of the pistons adjacent the injection valve and that the jet of fuel enters this space through a passage of which the axis coincides with the axis of the jet and is formed between the roof-like surfaces situated laterally of the jet of fuel of the pistons adjacent the injection valve.

2. Internal combustion engine in accordance with claim 1, in which the head of the piston, or pistons, opposite the injection valve is provided with a recess which, together with the roof-like surfaces of the pistons adjacent the fuel injection valve, forms the combustion chamber.

3. Internal combustion engine in accordance with claims 1 and 2 in which the recess in the head of the piston is in the form of a groove disposed at right angles to the ridge in which the roof-like surfaces of the piston-head meet.

4. Internal combustion engine in accordance with claims 1 to 3, in which there are provided in the opposite roof-like surfaces of the pistons adjacent the fuel injection valve grooves which are disposed in the direction of the jet of fuel and form a passage for the fuel at the maximum compression pressure.

5. Internal combustion engine according to claims 1 to 4, in which the grooves widen out as they approach the combustion chamber.

6. Two-stroke cycle internal combustion engine in which self-ignition of the injected fuel takes place and in which the cylinders, of which there are three or more, are disposed in star form and their pistons are associated with a common combustion chamber and have heads of roof-like form, and in which a fuel injection valve is arranged between two adjacent cylinders, characterised by the feature that there is arranged in front of the fuel injection valve a combustion chamber which is formed between the roof-like surfaces situated laterally of the jet of fuel of the pistons adjacent the injection valve and that the head, or heads, of the remaining piston, or pistons, are brought as near as possible to the roof-like surfaces of the former pistons and the latter piston or pistons lead the pistons adjacent the injection valve.

7. Internal combustion engine according to any of claims 1 to 6 in which a preliminary mixing chamber is provided between the pistons adjacent the injection valve, which preliminary mixing chamber directly adjoins the space formed between the heads of the corresponding pistons and the injection valve opens into this chamber.

8. Internal combustion engine according to claim 7 in which the preliminary mixing chamber is cooled.

9. Internal combustion engine in accordance with any of claims 1 to 8 in which the pressure with which the fuel is injected into the combustion chamber decreases as the end of the fuel injection period is approached.

10. Two-stroke cycle internal combustion engines substantially as described with reference to the accompanying drawings.

Dated this 27th day of July, 1933.

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[This Drawing is a reproduction of the Original on a reduced scale.]

Fig. 1

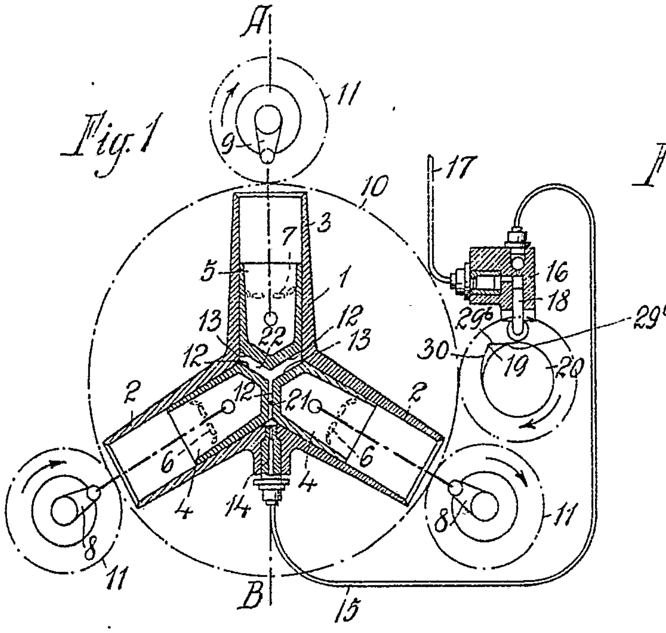


Fig. 2

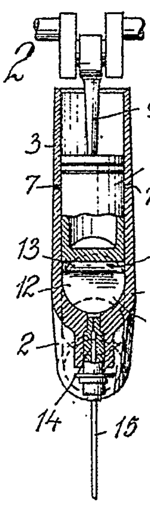


Fig. 3

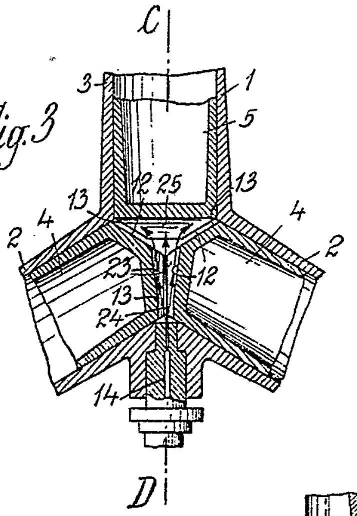


Fig. 4

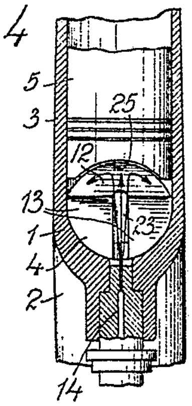


Fig. 5

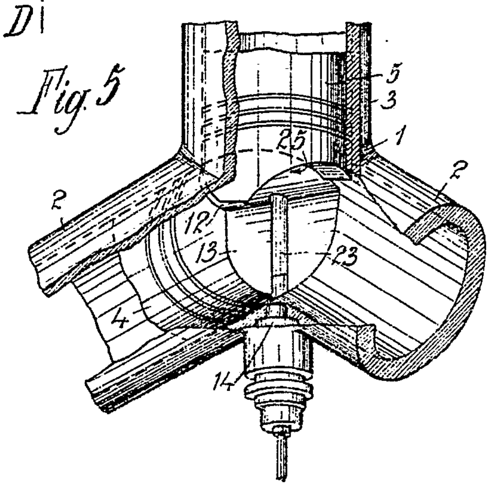


Fig. 6

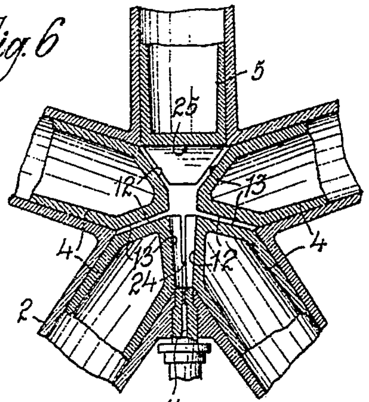


Fig. 7

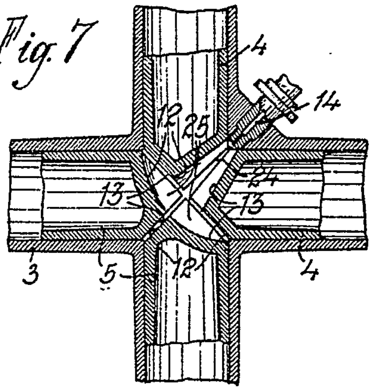


Fig. 8

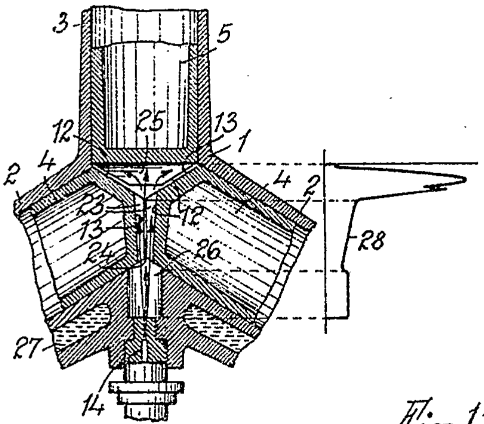


Fig. 9

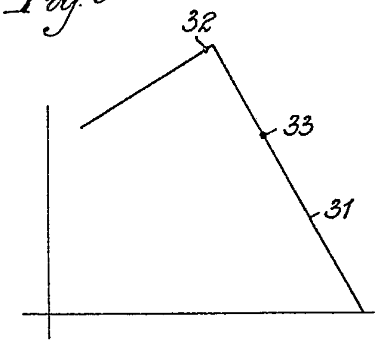


Fig. 11

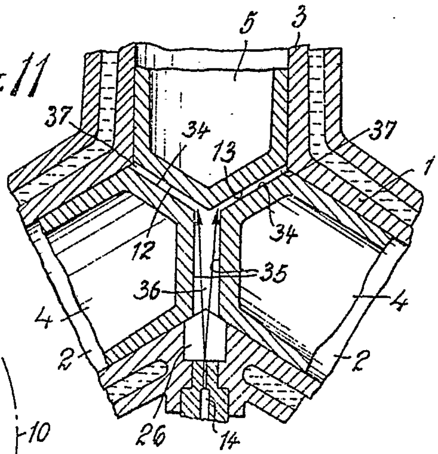
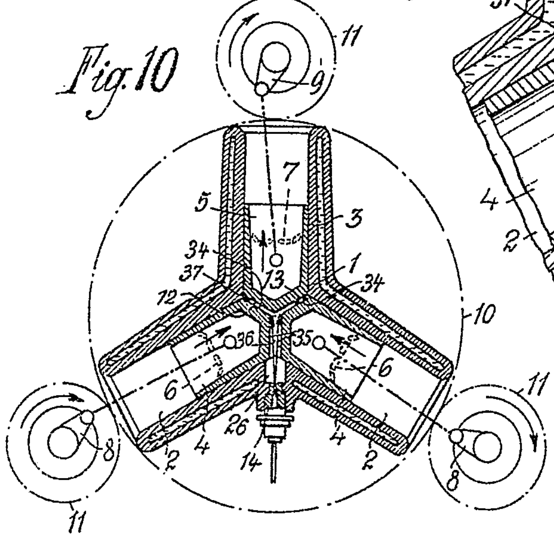
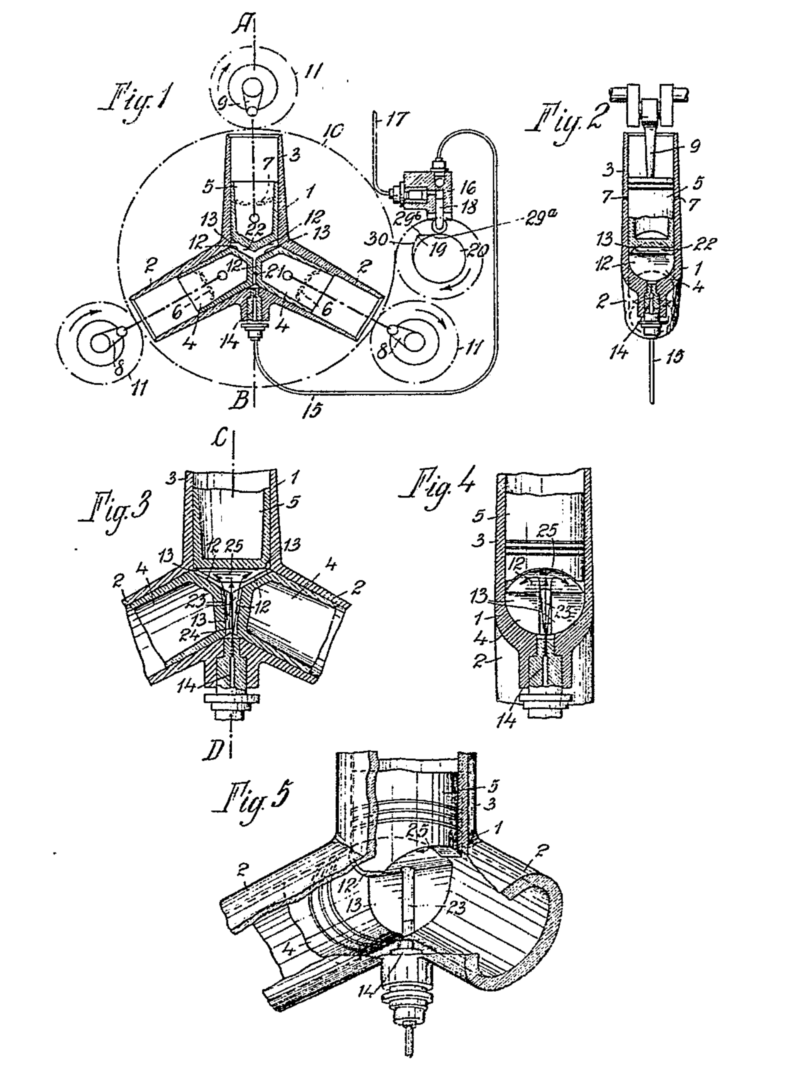


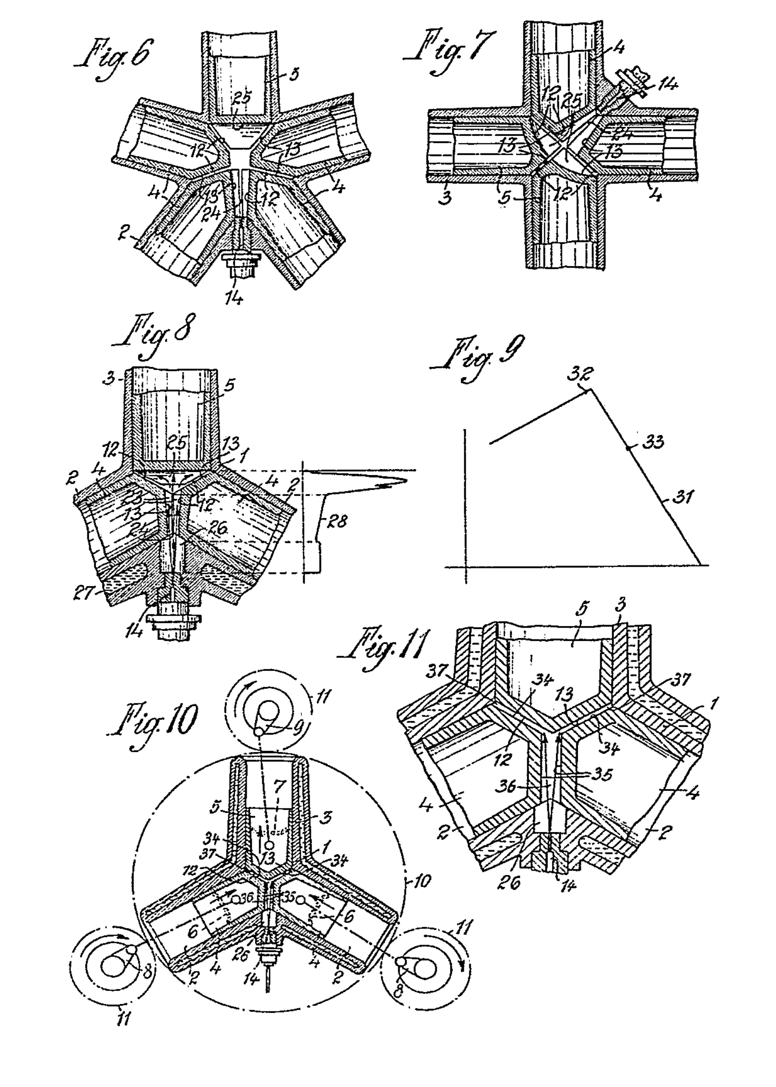
Fig. 10



SHEET 1



SHEET 2



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