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(54) Title: SUPERCHARGED INTERNAL COMBUSTION COMPOUND ENGINE

(57) Abstract

The invention relates to an internal combustion fuel injection engine for two–stage expansion provided with one or more pairs of cylinders. Each unit includes a four–stroke first–stage cylinder (1) and a second–stage, double–acting, two–stroke cylinder (3) each driving a crankshaft (18 and 24). The crankshafts being interconnected by gear wheels of a 2 by 1 ratio. Cylinder (1) features fuel injection (5), inlet valve (5) and outlet valve (6), the latter being connected by duct (34) to the top of cylinder (3) for conveying the part–expanded gases for final expansion and expulsion through outlet valve (7). The bottom space of cylinder (3) serves as supercharger (14) which discharges compressed air to an intercooler (30) from where compressed and cooled air is conveyed to cylinder (1) via inlet valve (5).

SUPERCHARGED INTERNAL COMBUSTION COMPOUND ENGINE

The present invention relates to a positive-displacement internal combustion engine with two-stage expansion and high compression ratio due to supercharging. The engine features a high efficiency due to low internal flow resistance and low friction losses owing to a reduced-speed second expansion stage.

BACKGROUND OF THE INVENTION

It is known that increasing the the expansion ratio of a reciprocating internal combustion engine extracts more energy during the expansion of the combustion gases. Therefore, thermo-dynamic efficiency increases as the expansion ratio increases, and multiple staging has been known as a way of using more of the available energy left after expansion in a first stage. This solution was known in the construction of steam engines, of steam and gas turbines, and has been applied to reciprocating engines since their very early days.

As early as in the year '873 an American engineer by the name of Brayton designed a gas engine in which compression and combustion took place in two separate cylinders, while using compressed air both for starting and for continuous operation.

In the year 1896 the German Rudolf Diesel patented a self-igniting I.C, engine with a double-acting cylinder, having one side working as a combustion and expansion chamber and the other side for pre-compression of air for supercharge. During the first two decades of this century many types of positive displacement engines both for superexpanding and supercharging were designed and built, together with a compact light-weight turbo-charger which had been found most useful for two-staging internal combustion engines..

The fifties saw the development of the Diesel /gas-turbine compound engine which became used in aviation and in generation of electric energy The turbo-charger has two distinct drawbacks:- a limited gas-temperature intake and lack of power feed-back to the engine, thus using only a portion of the energy of the exhaust gas efficiently. The main disadvantage of the Diesel/gas-turbine compound engine in addition to the gas temperature limitation, lies in the heavy and costly transmission required to couple the high-rev turbine to the crankshaft of the Diesel engine.

In the sixties the Soviet press reported of a large multi-cylinder Diesel engine developed by a certain Engineer Kushul at the Leningrad Technical Institute. The engine was said to comprise a long row of different size cylinders and to reach a fuel efficiency of up to 60%. It appears that it was not used because of its weight and intricate design, and was much more expensive than a single-stage Diesel engine with the same power output, moreover since in those years fuel was cheap.

During the same period a British firm experimented with a two-stage Diesel-type Wankel engine, but this had been abandoned due to technical difficulties. And since then, more patents were filed and granted in respect of two-staged I.C. engines.

In general, up to now all positive displacement, multi-stage I.C. engines comprise a one- or two-staged pre-compression cylinders, one or two high-pressure combustion chambers used for first-stage expansion and a second stage expansion cylinder of a larger diameter. Gas passages join the different cylinders. Many of these include a pre-compressing cylinder unit as well as an accumulator and inter-cooler for the compressed air to be fed to the high-pressure cylinders, with the object of improving efficiency and acceleration.

The main drawback of these engines is their heavy and complicated construction, as for instance ,in an engine of this kind which includes five cylinders of different diameters with pistons driving - or being driven by - a single, long crankshaft. The other drawback is the relatively high speed of the exhaust gas which causes energy loss and creates undue noise.

It is the object of the present invention to provide an internal combustion engine with as many combustion chambers as are necessary for obtaining the required energy output.

It is another object of the invention to provide an engine with an almost continuous exhaust gas flow at relatively low speed and noise.

Still another object is to provide an engine suitable for power take-off at two different rotary speeds.

It is a further object to provide an engine with low Nitrogen-oxydes emission by controllable carbone-dioxyde retarding in the combustion chamber.

And it is a final object to provide an engine of high efficiency at low cost due to its simple design.

SUMMARY OF THE INVENTION

The internal combustion compound engine according to the present invention is characterized by two-stage expansion of the combustion gases by the provision of a first-stage four-stroke combustion unit and a second-stage two-stroke expansion unit running at half the rotary speed of the combustion unit. It is further characterized by the provision of a reciprocating or a rotary super-charger adapted to supply pre-compressed air to the combustion unit. In a first embodiment of the invention an I,C,-engine comprises one or more first-stage cylinders with pistons driving a crankshaft at N rpm and the same number of second-stage expansion cylinders with pistons driving a parallel crankshaft at N/2 rpm. The two crankshafts are coupled to each other by a toothed gear or chain gear having a ratio 1:2. A pre-compression cylinder/piston unit is driven by one of the ceankshafts and pumps pre-compressed air into an accumulator which contains air cooling equipment. The accumulator is connected to the inlet manifold of the combustion unit and delivers pre-compressed air to each combustion chamber during the suction stroke. After full compression fuel is injected and ignited whereupon expansion of the combustion gases drives the high-rev crankshaft in a conventional manner. With the exhaust valve or valves opening, the combustion gases are driven into the second-stage unit or units which act on the two-stroke principle and drive the exhaust gases into the open by their return stroke via an opening exhaust valve or valves.

In a preferred embodiment of the engine the second-stage unit is in the form of a double-acting cylinder whereof one side acts as the second expansion stage, while the other acts as pre-compressor or supercharger. The piston is connected to the slow rev crankshaft by piston rod and connecting rod with a shaft seal preventing escape of compressed air.

As an alternative the second-stage unit is connected to one crank of the crankshaft and the pre-compression unit is in the form of a separate cylinder/piston assembly driven by one of the two crankshafts.

In another preferred embodiment there is provided a bye-pass to the cooler in the accumulator and a valve serving to circumvent the cooler at low load or during starting, with the object of boosting ignition of the fuel in preheated air.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a vertical section of an internal combustion engine of the invention ,with fuel injection,

Figure 2 is a vertical section of an internal combustion engine similar to that illustrated in Figure 1, but with a second-stage pre-compressor and an additional accumulator,

Figure 3 illustrates an internal combustion engine for two-stage expansion in two single-acting cylinders,

Figures 4A and 4B show a top view and a schematic view of the crankshafts of an engine with three combustion and three expansion cylinders, i.e. three basic units.

Figures 5A and 5B show a top view and a schematic view of the crankshafts of an engine with two combustion and two expansion cylinders, i.e. two basic units,

Figures 6A and 6B show a top view and a schematic view of the crankshafts of an engine with a single combustion and a single expansion cylinder.

Figures 7A and 7B show a top view and a scematic view of the crankshafts of the engine shown in Figure 4 with the addition of a rotary supercharger, and

Figure 8 is a diagram of the intensity of the exhaust gases for different types of I,C.-engines.

DETAILED DESCRIPTION OF THE DRAWINGS

Figure 1 is a section through a high-pressure and a low-pressure cylinder of an engine which may consist of one or several two-stage expansion units driving two parallel crankshafts 18 and 22. The two cranshafts are inter-connected by two gearwheels 17 and 23 having a ratio of 1:2, whereby the crankshaft on the left of the drawing rotates at twice the rotary speed of that on the right. They are driven by a high-pressure cylinder/piston unit I on the left which works as a 4-stroke engine, and a low-pressure cylinder/piston unit II on the right which works on the two-stroke ptinciple, respectively. The two units form a two-stage expansion unit attaining a higher fuel efficiency than a single-stage unit, The high- pressure unit I comprises a piston 2 reciprocating in a cylinder 1 and a connecting rod 15 connecting the piston to the crankshaft. A combustion chamber 11 is formed between the cylinder top and the piston into which fuel is injected by injector 10 on or before the top position of the piston. An inlet valve 5 and an outlet valve 6 are operated by an overhead camshaft in a conventional manner (not shown in the drawing). The partly expanded combustion gases are transferred from cylinder 1 via a gas passage 34 to the second-stage cylinder 3 and operate a piston 4 of the low-pressure unit II. The reciprocating piston is double-acting and is connected to crankshaft 24 by means of a piston rod 19 and a connecting rod 21. For this purpose cylinder 3 is closed by a bottom cover 48 which features a shaft seal 41 around piston rod 19. The thus-formed chamber acts as pre-compression chamber 14 drawing air in through valve 8 and air inlet 36 during each upward stroke of piston 4. During expansion of the gases in expansion chamber 13 air is compressed in chamber 14 and is expelled by way of reed valve 9 and duct 37 into an accumulator 29 which also houses air cooling equipment 30. The drawing shows the accumulator to be provided with a safety valve 39 and a drain cock 40. The pre-compressed and cooled air is drawn into the high-pressure unit through a duct 32, a choke valve 69 and an inlet valve 5, during the suction stroke of piston 2, is compressed, fuel is injected and is partly expanded as described before.

At low load of the engine the pre-compressed air should remain at its higher temperature; this is obtained by means of a two-way valve 31 and a bye-pass 28 from the accumulator which circumvents the cooling means 30 in the accumulator.Bye-pass 28 is advan-tageously heat-insulated (38) or may even be provided with heating means.

It will be understood that the two crankshafts are driven by several units I and II forming the engine and that the accumulator and cooling means are designed to provide precompressed and cooled air to all cylinders 1 of the engine, a fact that shows a great improvement compared with the afore mentioned engine which must have not more and not less than two first-stage cylinders.

It is further proposed that exhaust valve 6 which communicates the two cylinders could be provided with an electric, mechanic, pneumatic or hydraulic locking device preventing its opening by high counter-pressure in cylinder 3. Instead of one valve (6) as shown, there may be provided two parallel valves of different diameters: hereby the small-diameter valve will be opened first in order to equalize the pressures, whereafter the large-diameter valve is readily opened by the camshaft. It is also proposed to provide two exhaust valves 7 for cylinder 3 in order to reduce the outlet flow resistance.

The engine illustrated in Figure 2 is in most details identical with that of Figure 1, with the addition of a second pre-compression unit in the 4-stroke unit and an accumulator and intercooler for the air compressed by this unit. The drawing shows, on the right side, an expansion unit identical with that in Figure 1 and, for this reason, no explanation is necessary. The combustion cylinder, on the left is double-acting and features a closed bottom wall 50 and a piston 2 driving the crankshaft 18 through a piston rod 51 and a connecting rod 52. Pre-compressed air is sucked in through inlet valve 53 and delivered to accumulator 29 and exhaust valve 54 and piping indicated by an arrow. The right-side pre-compressor 14 delivers the compressed air to accumulator and intercooler 55 from where it is conveyed into the second compression chamber 56 for further compression. From this compression chamber the compressed air flows into the second accumulator (29) and is delivered to the combustion chamber as described in respect of the foregoing embodiment. Accumulator 55 may be of the same size; or smaller than accumulator 29. A bye-pass duct and valve may be provided or not.

The compression and twin intercooling 1) saves energy during compresion, and increases fuel efficiency, 2) provides higher initial pressure in the combustion chamber 3) saves and provides reserve energy in the form of compressed air created during braking and downhill driving. 4) In case additional power is required the inlet valves 8 and 53 may be kept fully or partly open by solenoids, thus avoiding unnecessary power loss by pre-compression. 5) It gives the driver of a vehicle better control by the possibility of faster acceleration and deceleration.

The choke valve 69 is preferably installed in engines driving motor vehicles and motor vessels. The valve should be partly closed during deceleration or downhill driving causing the air in the accumulator to be compressed to a multiple of the normal pressure, thus providing a strong retarding momentum. In case of excessive pressure safety valve 39 will come into action. During following acceleration the accumulated high-pressurized air gives the engine additional high power, while the choke valve is still partly closed in order to prevent the engine from receiving an excessive amount of high-pressure air. The choke valve will be fully opened only after return of normal pressure operation. During this period inlet valves 8 and 53 are kept open, since no pre-compression of air becomes necessary.

The engine illustrated in Figure 3 has two reciprocating single acting cylinders which reduced the total height of the engine. Here, instead of one or two pre-compression chambers as in the afore descibed embodiments, precompression is carried out by a rotary supercharger 60 which is driven by the slower crankshaft 24. Such an arrangement is schematically shown in Figur 7B where a supercharger 60 is driven by the slow-speed crankshaft. Compressed air is conveyed to the accumulator 29 where it is cooled by intercooler 30. As described in the foregoing, for low load and starting the intercooler is circumvented by means of bye-pass 28 and two-way valve 31. In all other respects the construction and working of this embodiment is identical with those described in respect of the two previous engines.

Figures 4, 5, 6 and 7 show top views and crankshaft arrangements for engines with three, two and one basic two-stage expansion units. In the following the engine of Figures 4A and 4B will be described, which will save similar explanations regarding Figures 5 and 6.

Figure 4 shows three parallel cylinders 1 driving a crankshaft 18 and three parallel expansion cylinders 3 driving a crankshaft 24. The two crankshafts are coupled by gear wheels 17 and 23 at the ratio 1:2 permitting a four-stroke action of cylinders 1 and a two-stroke action of cylinders 3. Also shown in Figure 4B is a flywheel 61 mounted on the high-speed crankshaft. The air pre-compressed by the three cylinders 3 is conveyed to accumulator 29, is intercooled and delivered to the combustion chambers of the three cylinders 1 via a main airduct 61 and through separate ducts 62. At the present scale camshafts are not shown. The exhaust gases are delivered to an exhaust manifold 63 through two parallel exhaust valves 7 on each cylinder and from the manifold via the exhaust silencer (not shown) into the atmosphere.

As mentioned above, Figure 7 is identical with Figure 4 with the addition of a rotary supercharger 60 attached to one of the crankshafts. It is well understood that either crankshaft can be used as power take-off dependent on the required revolutions of the consumer.

One of the main advantages of the present invention is demonstrated in Figure 8, showing the exhaust period, duration "St" and gas flow intensity "I" for various types of internal combustion engines. Herein 8a shows the exhaust frequency and average intensity (amplitude and velocity) of a conventional four-stroke engine of one cylinder which shows the high intensity and resulting noise of the exhaust gases at every fourth stroke.

Figure 8b is the same diagram for a 2-cylinder four-stroke engine, showing two gas exhausts per every four-stroke cycle of one of the cylinders.

Figure 8c is a diagram of the exhaust duration and flow of one basic unit as depicted in Figure 6,i.e. one combustion and one expansion cylinder. The diagram shows that due to the 50% rotational speed of the second crankshaft the exhaust gases are expelled at half the intensity and during twice the duration compared with those of a conventional engine as demonstrated in Figure 8a.

Figure 8d is an exhaust diagram of an engine including two basic units shown in Figures 4 and 7, i.e. a more even and much quieter flow at relatively low speed.

C L A I M S :-

1. A supercharged internal combustion engine including at least one unit configured for two-stage expansion of the combustion gases, each unit comprising,

a first cylinder for fuel combustion and part expansion of combustion gases in a four-stroke process,said cylinder containing a piston driving a first crankshaft, inlet and outlet valves opened and closed by operational camshaft means and fuel supply in a conventional manner,

a second cylinder adapted to further expand the combustion gases in a two-stroke process, said cylinder containing a piston driving a second crankshaft, said cylinder being connected by a duct to said outlet valve of said first cylinder and being provided with a camshaft-operated outlet valve,

drive means connecting said first and said second crankshaft causing said first crankshaft to rotate at twice the rotational speed of said second crankshaft.

2. The engine of Claim 1, wherein said drive means of said crankshafts is a gear drive.

3. The engine of Claim 1, wherein said drive means of said crankshafts is a chain wheel drive.

4. The engine of Claim 1, wherein a supercharger is provided and driven by one of said crankshafts.

5. The engine of Claim 4, wherein pre-compressed air by said supercharger is conveyed into an accumulator connected to said at least one first cylinder.

6. The engine of Claim 5, wherein said accumulator is provided with intercooler means.

7. The engine of Claim 6, wherein said accumulator is provided with a bye-pass and valve means for conveying precompressed air to sad first cylinder without intercooling.

8. The engine of Claim 4, wherein said supercharger is a positive displacement, rotary supercharger.

9. The engine of Claim 4, wherein said second cylinder is double-acting, wherein one side of said piston is used for expanding the combustion gases and wherein the second side of said piston is used for pre-compressing air and for deliverng it to an accumulator.

10. The engine of Claim 4, wherein said first and said second cylinder are double-acting, wherein the sides of the pistons not contacting combustion gases are used for compression of outside air and for delivering it to two accumulators.

11. The engine of Claim 1, wherein said outlet valve on said first cylinder is provided with temporary locking devices to prevent its opening by higher pressure in said second cylinder.

12. The engine of Claim 1, wherein said second cylinder is provided with two outlet valves for slower gas motion and a lower noise level.

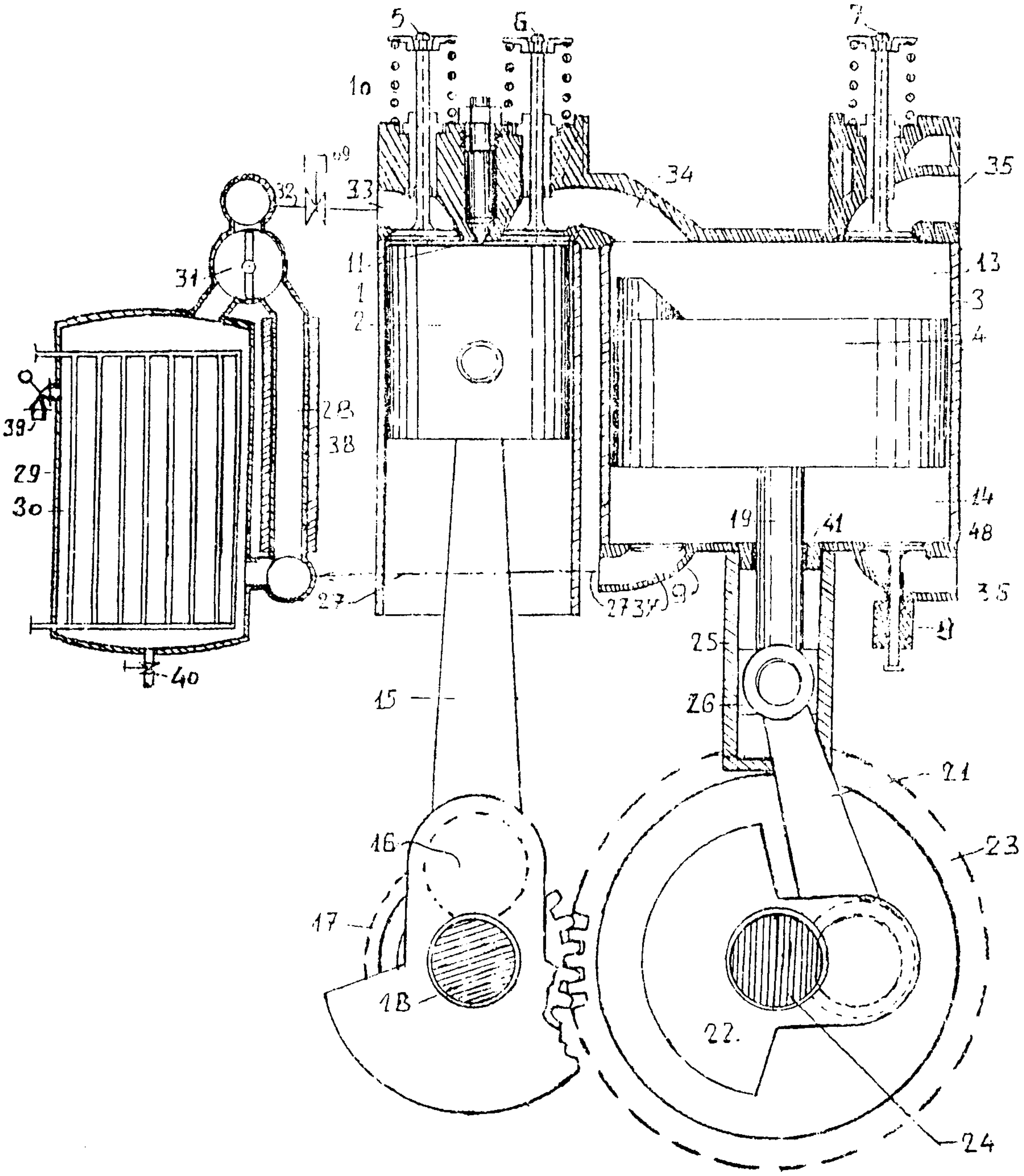
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FIG 1

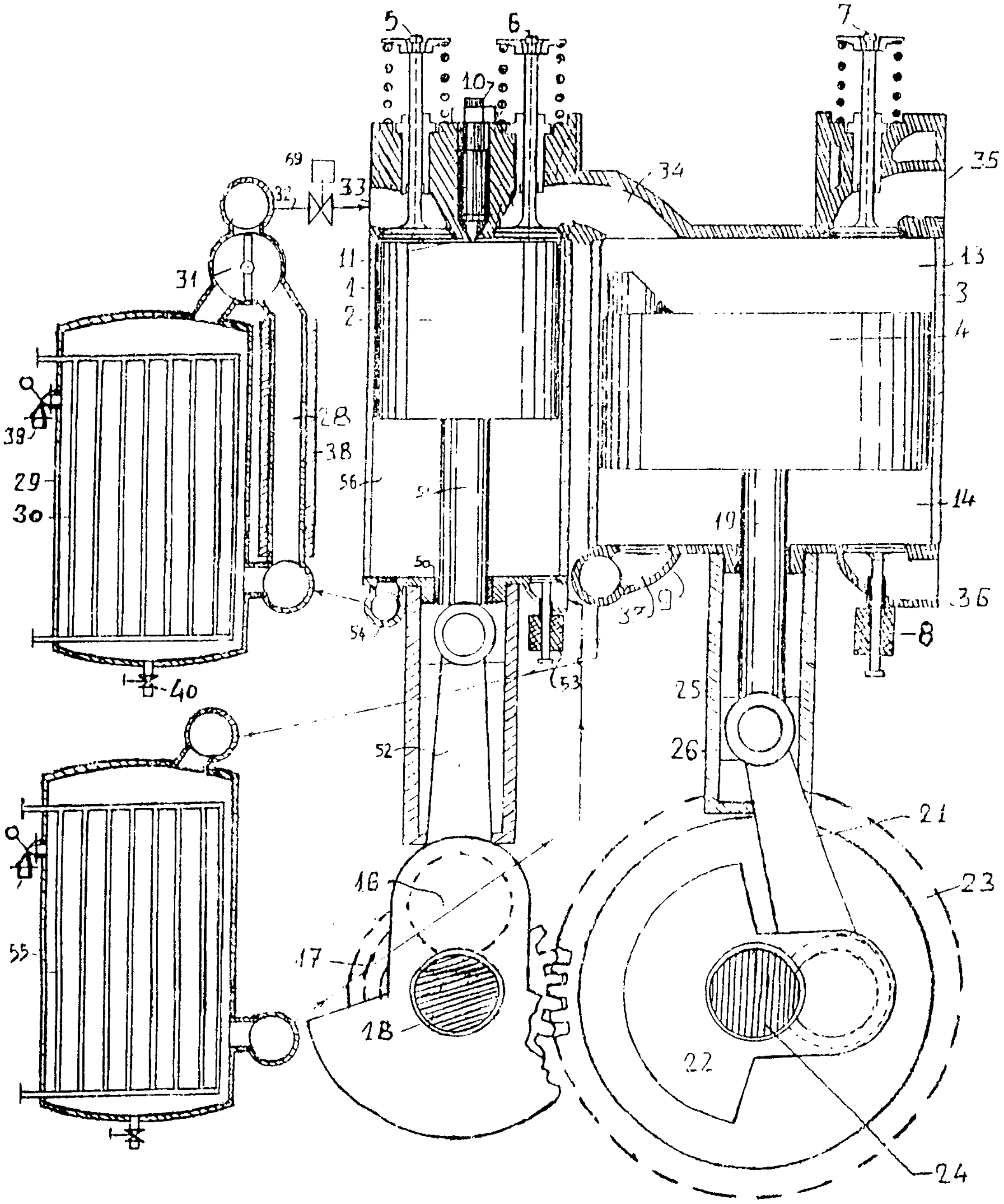
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FIG 2

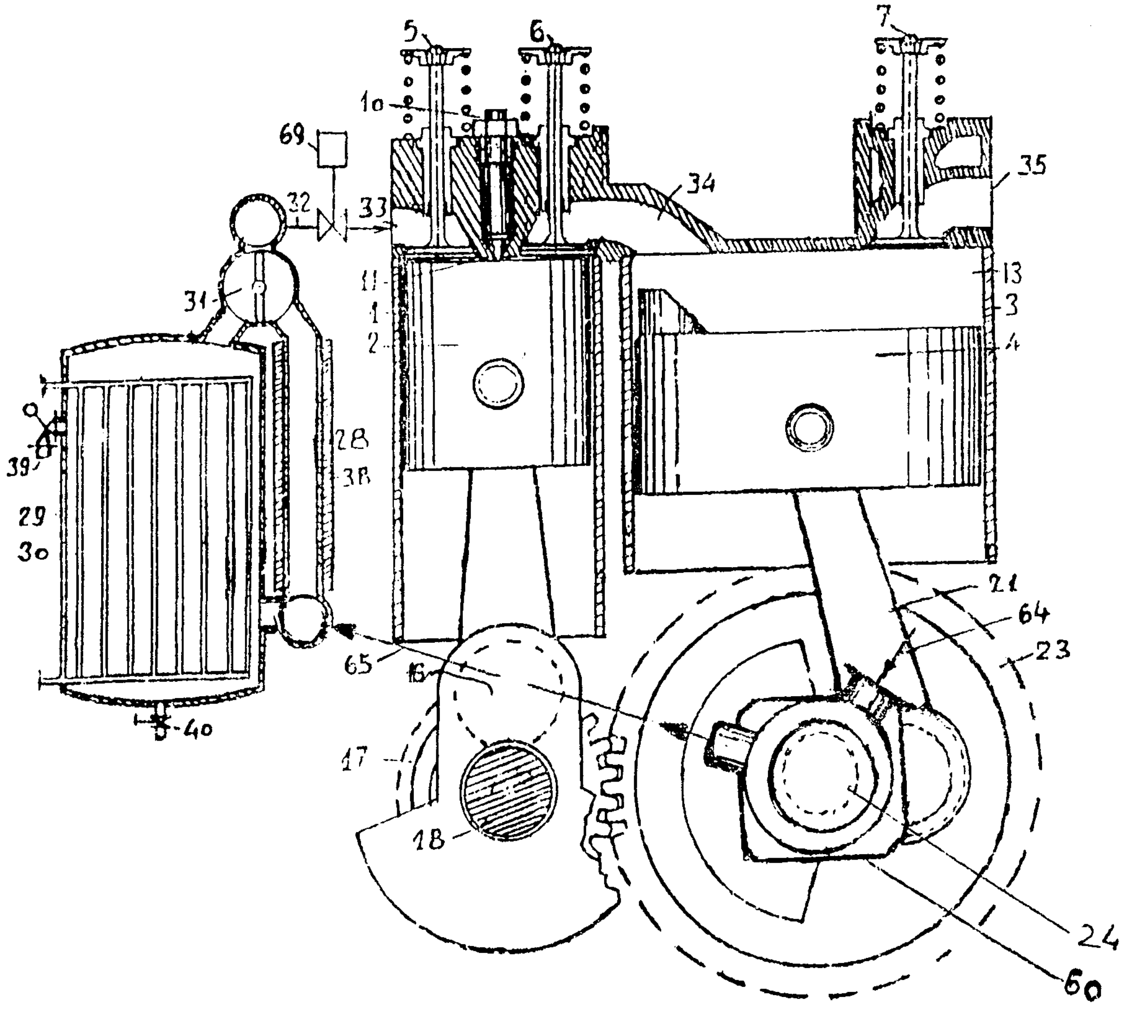
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FIG 3

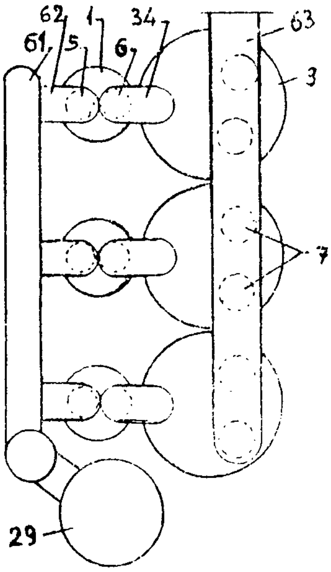

FIG 4A

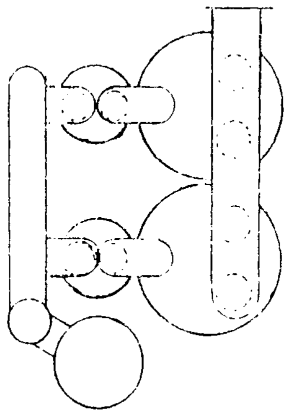

FIG 5A

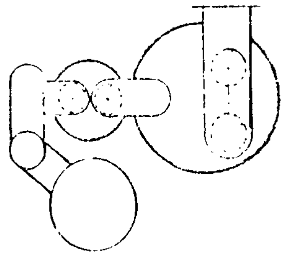

FIG 6A

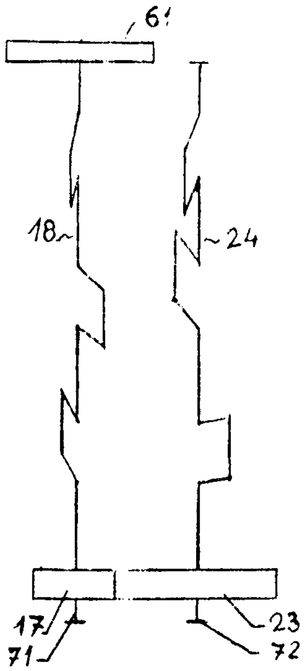

FIG 4B

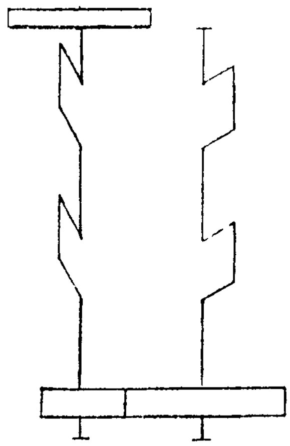

FIG 5B

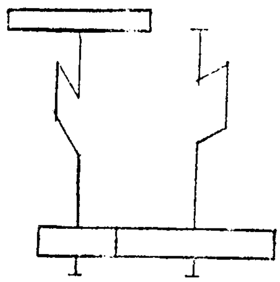

FIG 6B

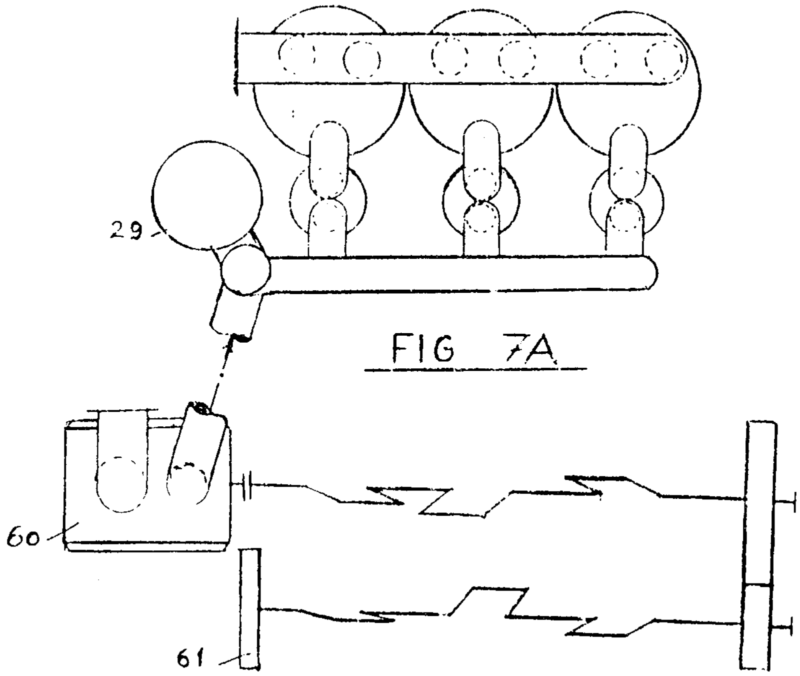

FIG 7A

FIG 7B

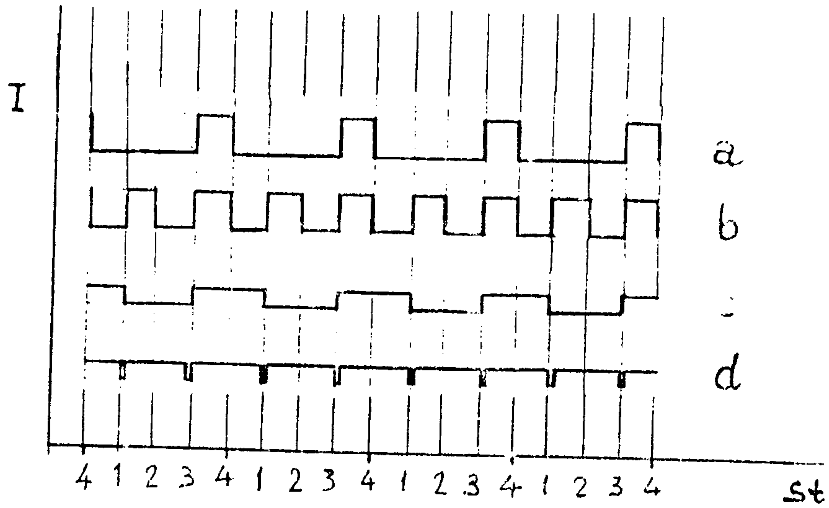

FIG 8