March 29, 1932. B. C. STICKNEY 1,851,547

INTERNAL COMBUSTION ENGINE

Filed April 19, 1929 3 Sheets-Sheet 1

Fig. 1

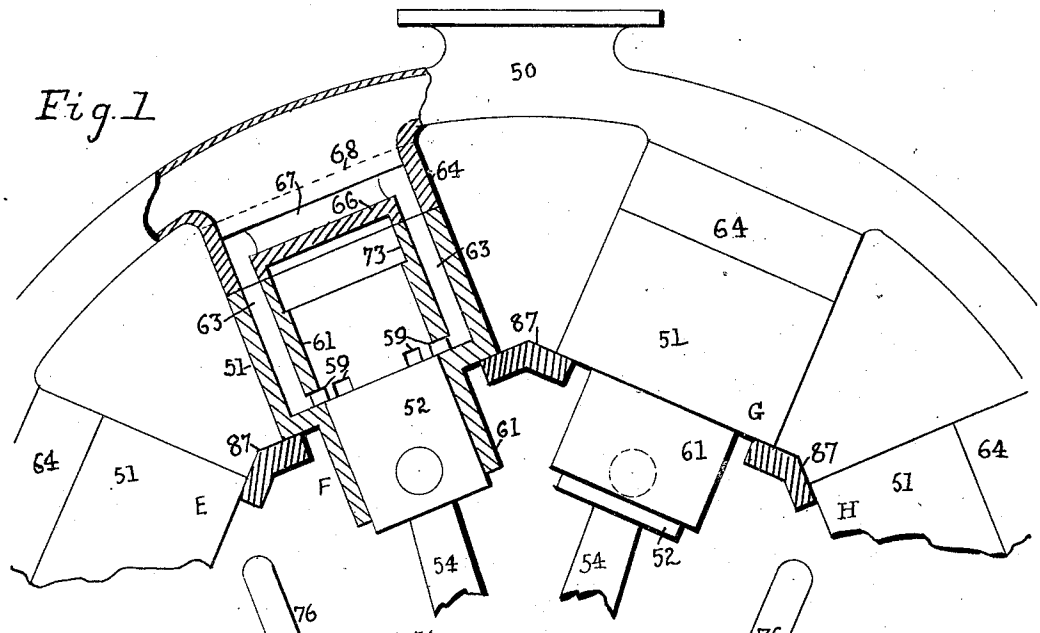
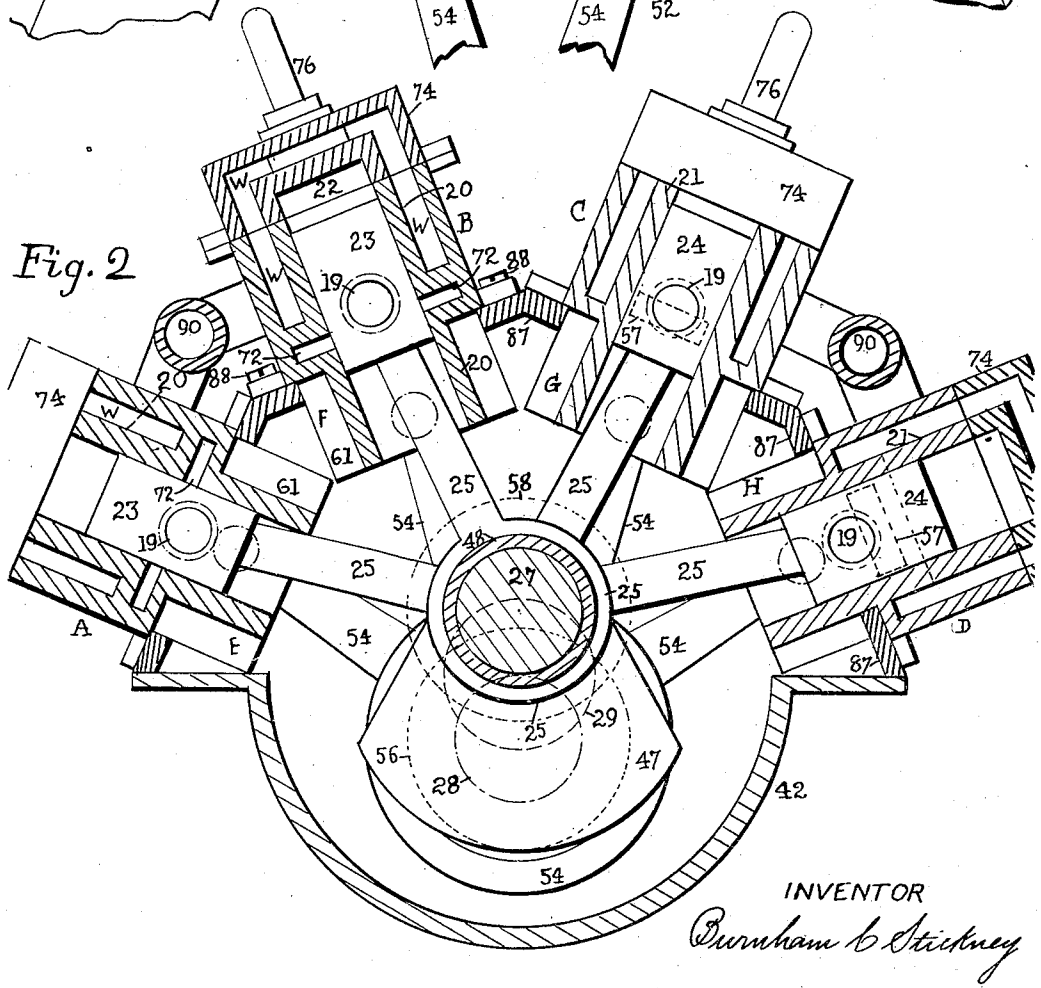


Fig. 2



INVENTOR

Burnham & Stickney

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INTERNAL COMBUSTION ENGINE

Filed April 19, 1929 3 Sheets-Sheet 2

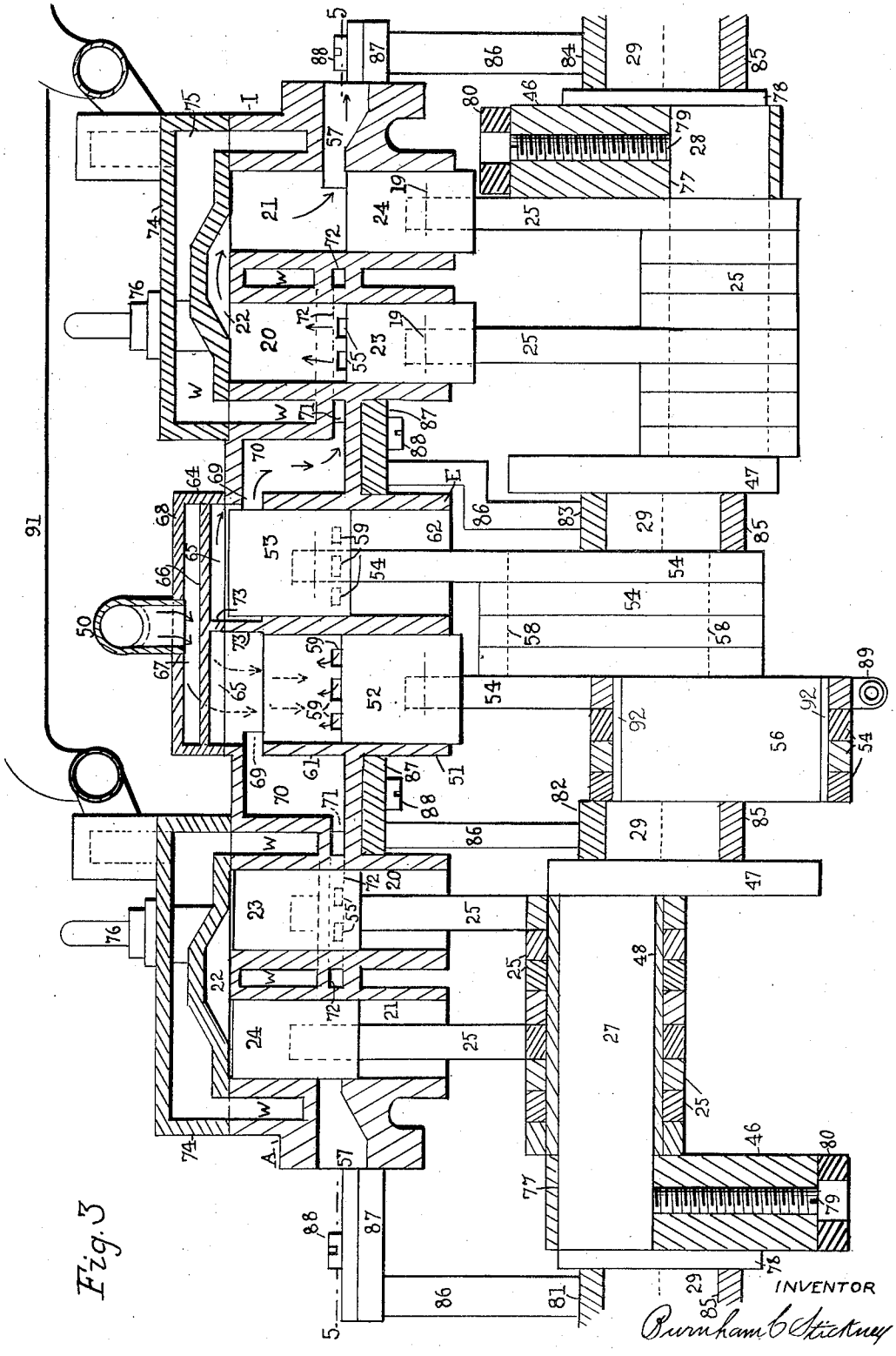

Fig. 3

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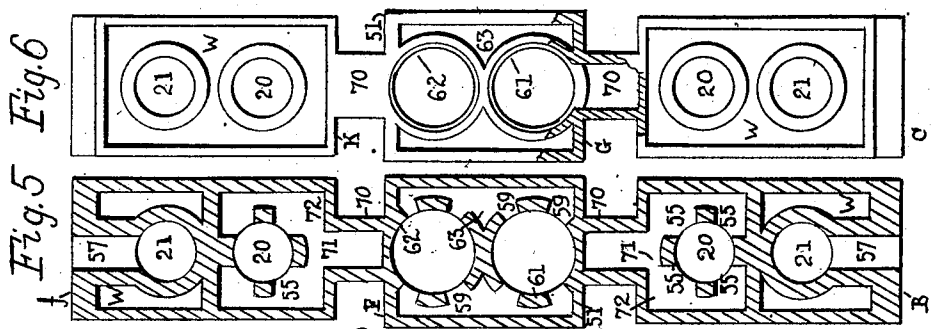
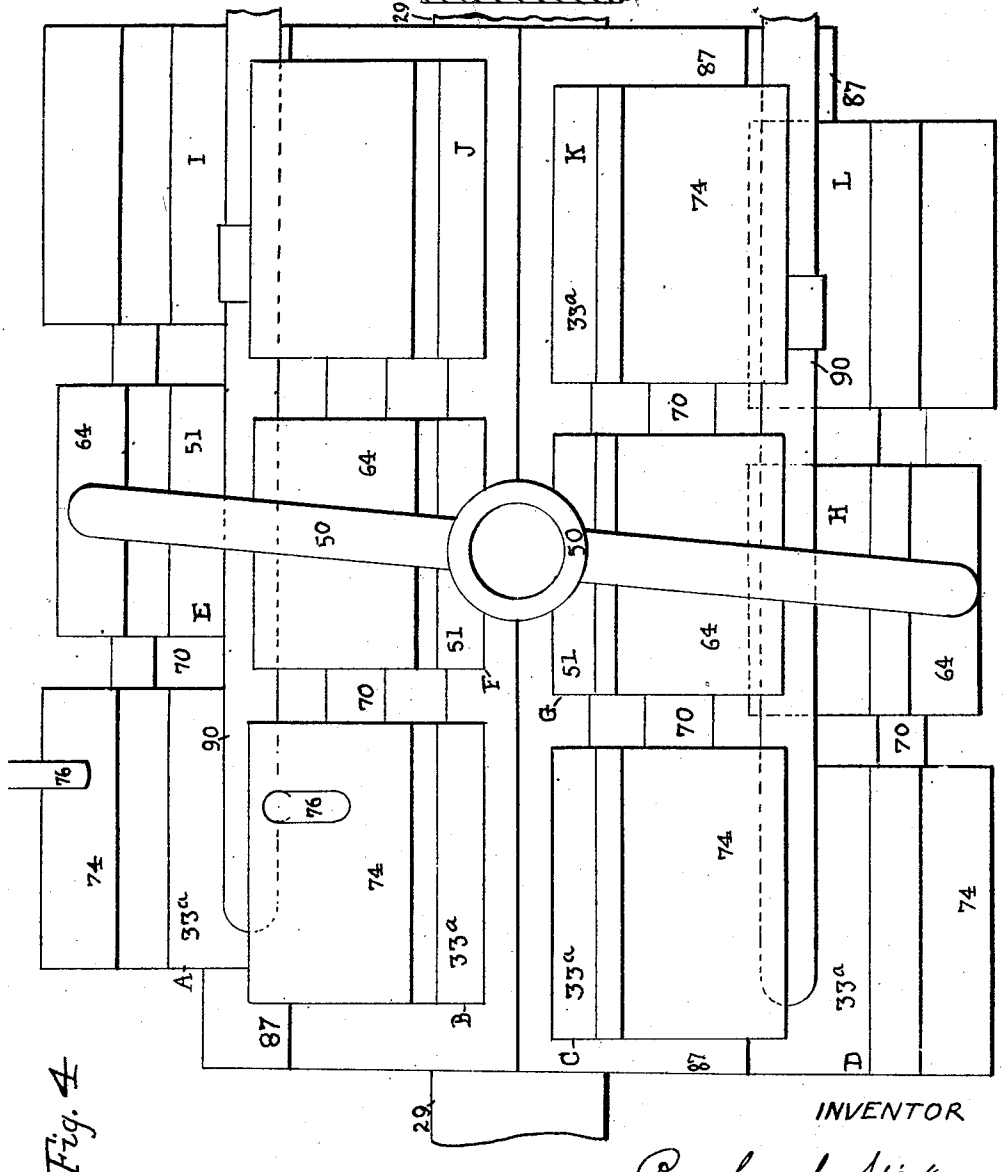
INTERNAL COMBUSTION ENGINE

Filed April 19, 1929 3 Sheets-Sheet 3





INVENTOR

Burnham & Stickney

Patented Mar. 29, 1932 1,851,547

UNITED STATES PATENT OFFICE

BURNHAM C. STICKNEY, OF HILLSIDE, NEW JERSEY

INTERNAL COMBUSTION ENGINE

Application filed April 19, 1929. Serial No. 356,381.

This invention relates to internal combustion engines of the two-cycle type, although some of the features are useful for four-cycle engines.

The principal object of the invention is to produce at low cost a relatively light, compact, powerful and durable and dependable high-speed engine of simple construction.

Another principal object is to provide improved means for pumping the charges into the cylinders, and an improvement in the construction and balancing of the crank-shaft.

The crank-shaft illustrated is of the two-throw type having only two wrists, which are diametrically opposite. Each wrist is operable by eight pistons, the piston-rods placed side by side and extending in various directions from the wrists to their respective cylinders. The cylinders are arranged in rows which extend longitudinally of the crank-shaft, four cylinders in each row. Each of the four rows is divided into two pairs, and the cylinders in each pair are inosculated and driven by the same explosion of gas, which is ignited by a single spark-plug. In other words, there are preferably eight pairs of cylinders, four pairs working on one crank-wrist and four pairs upon the other. All of the rows of cylinder-heads preferably radiate at angles of 45 degrees from one another, thus producing a balanced action; two pistons rising while the other two descend in the same row. The pistons may be very small in diameter and have a moderate stroke. One of the wrists may be integral with the middle journal section of the shaft, and piston-rods may be slipped upon one wrist, one after another, and suitably connected to the pistons and arranged in the cylinders. Then the other wrist may be slipped through the remaining pitmen, and the pin may be rigidly secured. Upon each wrist is a sleeve, and the hubs of the pitmen fit upon the sleeve.

There are eight equally spaced explosions in each revolution.

Each pair of inosculated cylinders includes an intake-cylinder having a port opened by the piston at the last portion of its power-stroke. In the other cylinder inosculated therewith, there is an exhaust-port of preferably double or more than double the height of said intake-port, the exhaust-port opening first and producing a reduction of pressure in both cylinders before the intake-port opens.

Fuel is drawn through a carburetor of the usual type. The charge of mixed gas and air is pumped from the carburetor to the intake-cylinder in each pair. The intake-cylinders are arranged in the middle zone of the engine between the exhaust-cylinders which occupy the outer zones. There is provided one pump for each inosculated pair of cylinders, making preferably a group of eight pumps. Each pump is connected by a pitman to the crank-shaft. The pumps are grouped in a middle zone, i. e., between the zones of the intake-cylinders.

Each pump compresses a charge upon its outward stroke so that it becomes practicable to connect the piston by a simple pitman to the crank-shaft. While one pump-piston is being thrust out by the crank-shaft, the engine-pistons which are to be fed thereby are being driven towards the crank-shaft. The outward thrust of the pump compresses the charge, and when the engine-pistons reach the ends of the down strokes, they open the ports in the intake-cylinders, and the aforesaid compressed charges enter said ports, and drive the exhaust gas out of both engine-cylinders in each pair; the engine being of the two-cycle variety. When said paired engine-pistons are rising, their pump-piston is descending and drawing in a new charge; the intake-ports of the pump being closed during the most of the down stroke of the pump-piston, but being opened at the bottom of the stroke and admitting a charge from the carburetor.

During this pumping operation, the ports in the intake-cylinder of the engine remain covered or closed by the intake-piston of the engine.

The pumps may be of over capacity, that is, each pump may have enlarged clearance therein, so as to make it unnecessary to develop excessive pressure at the outward stroke of the pump-piston; and the intake-ports of

the pump may be over-sized, so as to afford time for the charge to flow in from the carburetor, even though in some cases there may not be produced a high degree of exhaust in the pump-cylinder, owing to over-size or over-clearance and owing to large clearance chamber between pump and engine-cylinder.

The engine-body may comprise a main frame, and upon this frame may be separately attached four different rows of cylinders, each row containing two groups of four engine-cylinders and two pump-cylinders. These six cylinders may be cast in one piece, and this piece may be fastened radially on the main frame which has angularly placed seats for all four groups of cylinders. Each pair of engines may have a separate water-jacket, or all of the cylinders in each group or casting may have a separate water-jacket.

The crank-shaft in this engine may be made with four main bearings, namely, two middle ones and two end ones. Between the middle bearings may be two opposite eccentrics, one eccentric adjacent to the other. The entire crank-shaft may be in one piece except for the two end cranks, which may be separately attached to the ends of the crank-wrists. Each eccentric is placed diametrically opposite to its associated crank-wrist. On each eccentric are four straps, each strap forming part of a pitman which at its free end is pivoted to a pump-piston. The pumps are arranged in two sets, of four pumps each, each set in echelon. The pumps are in pairs, each pair in line with two pairs of engine-cylinders, the pumps being between the pairs of cylinders. Each inosculated pair of engine-cylinders is provided with one pump, having a piston which always moves in the opposite direction from the pistons in the engine-cylinders, each pump being driven by an eccentric. The eccentric arrangement is preferred, being more compact than crank-wrists would be, and also cheaper, and the great diameter of the eccentric is not objectionable, because the eccentric does not do very much work, merely pumping in the charge of fuel and compressing it to a pressure of from five to fifteen pounds above atmospheric preparatory to discharging into its engine-cylinders. This arrangement gives very good balancing, because each pump-piston is traveling oppositely from its associated engine-pistons. For the shaft to have four bearings instead of three is an advantage, the middle bearings being well separated, and the length of the engine-crank wrists being short. Each pump-cylinder discharges directly into the nearest engine-cylinder through a short passage or chamber of proper capacity. The engine and pump cylinders are aligned in three-cylinder groups, each group having a pair of engine-cylinders and a pump-cylinder therefor. There are several advantages gained by having the eccentric diametrically opposite the crank-wrist, since the pump-piston thrusts outwardly to compress the charge, while the engine-pistons are driven inwardly by an exploded charge. Each pump-piston completes its outward thrust to compress the charge, which discharges into the adjacent intake-cylinder as soon as the ports of the latter are opened by the descending engine-piston. Four eccentric-straps may be attached upon each eccentric.

When the compressed charge reaches the engine, it scavenges first the intake-cylinder and then the exhaust-cylinder, with very little mixing of fresh gas with spent gas, as the intake-port may be formed so that it will close at the desired point, in advance of the closing of the exhaust-port; so that the fuel gas has opportunity to expand and drive out more of the spent gas after the intake-port closes and before the exhaust-port closes.

Other features and advantages will hereinafter appear.

In the accompanying diagrammatic drawings,

Figure 1 is a cross-sectional elevation showing an array of pumps.

Figure 2 is a cross-sectional elevation of the engine-block, showing eight engine-pistons connected to one of the crank-wrists, and four pumps connected to an eccentric.

Figure 3 is a longitudinal sectional elevation of the engine and pumps.

Figure 4 is a plan of the engine partly in section.

Figure 5 is a section and Figure 6 a plan showing a row of engine and pump cylinders forming a single radial casting; Figure 5 being taken at about the line 5—5 of Figure 3.

In the preferred form of the invention there are employed sixteen cylinders inosculated in pairs, each pair including an intake-cylinder 20 and an exhaust-cylinder 21, which may be placed side by side, having a common explosion-chamber or inosculation 22. In the cylinders are separate pistons 23, 24, connected by rods 25 and pivots 19 to wrists 27, 28 of a two-throw crank-shaft 29. At Figure 3 is shown a row of four cylinders, consisting of two pairs. There are shown at Figures 2 and 4 four of these rows.

As at Figure 2, the rows are evenly spaced, each row being separated from the next by an angle of 45 degrees. There are eight evenly spaced explosions for each revolution of the crank-shaft.

To each crank-wrist 27, 28 are articulated eight rods, connecting it to eight pistons, working in eight cylinders, radiating in the four directions seen at Figure 2. The two middle rows of cylinders are each spaced at an angle of 22½ degrees from a vertical plane intersecting the axis of the crank-shaft. The outer rows radiate at an angle of 67½ degrees from the vertical plane. It will be understood that there are four rows of en-

gine-pistons, four in each row, half of the engine-pistons in each row being connected to one crank-wrist and half to the other. Each row is sub-divided into two pairs, the engine-pistons in one pair moving as a unit in the opposite direction from the engine-pistons in the other pair in the same row.

Figure 4 shows that the pairs of cylinders and their respective engine-heads have an echelon arrangement, agreeing with the alternating arrangement of the pitmen upon the left-hand and the right-hand crank-wrists 27, 28.

The cylinders in each pair form an engine-head 33ª, as seen at Figure 4, two engine-heads in each row, the eight engine-heads being in echelon arrangement. The heads in each radial row may all be cast integral.

The left-hand crank-wrist 27, Figure 3, accommodates the hubs of eight pitmen 25, of which group of pitmen the first and fifth, counting from the right, belong to the engine-head shown, the second and sixth belong to another engine-head, the third and seventh belong to another engine-head, and the fourth and eighth belong to the remaining engine-head. By this arrangement undue separation of the pistons in the engine-head is avoided, and the capacity of each explosion-chamber 22 is kept at a minimum. The invention is, however, not limited to this order of the pitmen upon the crank-shaft, nor to the precise echelon arrangement shown for the engine-heads.

There is a corresponding arrangement of the pitmen of the right-hand crank-wrist 28. Three pitmen of other engine-cylinders may intervene between the pitmen of each pair of cylinders. The piston-rods in each pair may thus be separated to afford this space for the other pitmen. This conduces to shortness and rigidity of the shaft, simplicity, balance and smooth running.

Every down stroke of each piston is a power-stroke, thus placing this simple engine on a par with the sixteen-cylinder, eight-throw, four-cycle engine, with its thirty-two valves, of the prior art. In other words, there are twice as many impulses for each revolution as can be obtained in the common eight-cylinder, eight-throw, four-cycle engine.

In each revolution, each pair of engine-pistons is arrested twice, this arrest occurring at the opposite end of the stroke from the other pair in the same row, Figure 3; there being two arrests in each row at each revolution, making in each revolution eight arrests altogether in the entire system of engine-pistons. These eight arrests occur at intervals of forty-five degrees for smooth running, and the engine is moreover evenly driven by means of the eight evenly spaced impulses at each revolution.

The crank-shaft may be cut from a cylindrical bar to form the crank-wrists and the journals, leaving uncut portions 46 of original diameter to serve as cranks and fly-wheels, and also leaving similar portions 47 at each side of the midway journals 29 for a similar purpose. Upon each crank-pin may be placed a thin-walled split bearing collar or sleeve 48 to reduce friction between the piston-rods and the wrists.

Each row of engine-cylinders is provided with a pair of pumps, which pump charges of mixed gas and air from a carburetor (not shown) through a manifold 50. The pumps in each row form a head 51 between the engine-heads. One pump-piston 52 in each pair serves the left-hand engine-cylinders 20, 21 at Figure 3, and the other pump-piston 53 serves the right-hand engine-cylinders 20, 21. These pump-pistons are driven by means of eccentric-straps 54 from eccentrics 56, 58 which may be formed upon the crank-shaft. The eccentrics are placed between the midway shaft-bearings 29, and conduce to compactness in that they permit relative shortness of the crank-shaft. The pump-eccentric 56 is diametrically opposite the engine crank-wrist 27, and hence the forcing or up stroke of the pump-piston 52 occurs during the explosion or down strokes of the pistons 23, 24. During said up strokes of 52 the drawn-in charge of mixed gas and air is put under pressure, and finally this compressed charge spurts through inlet-ports 55 in the bottom of the engine-cylinder 20, just as said inlet-ports are uncovered at the conclusion of the down stroke of the intake-engine-piston 23. Upon the succeeding down stroke of the pump-piston 52, said ports 55 remain closed, so that such down stroke of piston 52 creates a partial vacuum in the pump-cylinder 61. Near the bottom of the pump-stroke, ports 59 are opened, and a charge enters from the manifold 50.

During the just-mentioned down stroke of pump-piston 52, the companion pump-piston 53 in cylinder 62 rises, and forces the previously-inspired charge to spurt through ports 55 into the intake-cylinder 20 in the main engine-head, and to expel spent gases through inosculation 22 and through exhaust-cylinder 21 and exhaust-port 57, as indicated by arrows at Figure 3.

The pump-cylinders 61, 62 are set or formed within a relatively large head or chamber 51, and are sealed therefrom except for the inlet-ports 59, which are arranged at the bottom or floor 63 of the chamber or compartment; each pump-cylinder being therefore totally sealed from said compartment during nearly the entire up-and-down strokes of the piston.

Both the pump-cylinders and the compartment may be closed by means of a detachable cap 64, having interior cylindrical walls 65 fitted to the tops or edges of the cylinders

61, 62. Said cylinders 65 are headed over at 66 by means of a top which is integral with the cap 64 and co-extensive with said cylinders 65.

The shape of the cap is oblong to correspond with the shape of the pump-head 51, and a transverse space 67 over the pumps forms a communication between the opposite side compartments of this chamber. The manifold 50 opens into the top 68 of said cap 64. The entering mixed gas and air passes down into the transverse passage 67, as shown by the full-line arrows at Figure 3, and then down into the side compartments 63 exteriorly of the pump-cylinders, as shown by dotted arrows, and then enters the indrawing pump through the intake-ports 59, as shown by full arrows.

On the next up stroke, the charge is gradually compressed. As soon as the engine-ports 55 are open, the compressed mixture expands and drives through an outlet 69 in the top of the pump, and down through a chamber 70 and out from a port 71 in the bottom thereof, and into a shallow compartment 72, which surrounds the intake-engine-cylinder 20 and communicates therewith by means of intake-ports 55. The upper end of each pump is enlarged or recessed circumferentially at 73 to permit the escape of the compressed charge through said outlet 69, which is formed in the bottom of this recessed or enlarged portion of the pump-cylinder.

The cubic capacity of the clearance at the top of the pump-cylinder and the chamber or passage 70 is preferably less than the cubic displacement of the pump-piston so that the pressure of the previously pumped-in charge may be raised for example to 10 pounds per square inch at every up stroke of the pump-piston, so as to provide the charge with sufficient energy for driving out the spent charge from the adjoining inosculated cylinders. Said cubic capacity should be so proportioned as to give sufficient draft so that the charge from the carburetor will enter the pump properly, when the piston is in position shown at 52, Figure 3.

The necessary cubic displacement of each pump-piston 52, 53 (which preferably has the same length of stroke as the engine-pistons) may be provided for by making the diameter of the pump-piston considerably larger than that of the engine-piston, as illustrated. The pump-piston displacement may be equal or nearly equal to the displacement of two engine-pistons combined, so that one stroke of the pump-piston may be substantially sufficient to charge both inosculated engine-cylinders. As will be observed at the right-hand portion of 23, the exhaust charge may be all, or nearly all, driven out through the port 57, with a minimum of mixing exhaust gas with fresh gas; this clearness being secured by having reasonably high initial pressure of the charge which spurts through the port 55 and becomes reduced nearly to atmospheric pressure, if the engine is running very slowly, by the time that the exhaust-port 57 is closed by the rising piston 24. It will be understood that the compressed gas may have sufficiently high initial pressure to insure elimination of the exhaust gas without waste of fresh gas. If it is desired to run the engine slowly when the load is small, then the usual butterfly throttle (not shown) which supplies the manifold 50, may be sufficiently closed so that the low-pressure charge drawn in by the pump-piston does not have time to rise to atmospheric pressure, but may still remain at say 10 or 12 pounds absolute pressure when the inlets 59 have been closed by the rising piston 52. Under such partly throttled condition, the piston 52 must rise considerably more in order to bring the pressure of the charge up equal to atmospheric. Thereafter, during the relatively small remainder of its stroke, the piston cannot raise the pressure very high, say only three or four pounds above atmospheric. Hence a relatively small charge of gas will enter the engine-cylinder through the ports 55, and a comparatively small quantity of burned gas will be expelled from the inosculated cylinders, thus reducing the charge of fresh gas when it is desired for the engine to run light, or when the load is light.

It will be seen that by opening and closing said manifold throttle in the usual way, flexibility of the engine operation may be secured. On the other hand, when the throttle is wide open, the engine may be run at high speed, since the pump-pistons 52, 53 will force charges into the inosculated cylinders at sufficient pressure.

The eccentrics 56 are made of large diameter, so as to avoid necessity of providing additional bulky crank-arms for driving the pumps. The great diameter of the eccentrics is not objectionable, because the work done by the pumps is relatively light. The heavy eccentric 56, plus the heavy eccentric-straps 54, tend to counter-balance the heavy crank-wrist 27 and its pitman hubs connected thereto. Moreover, the reciprocating parts 52, 54 of the pump tend to counter-balance the reciprocating parts 23, 24, 25 of the engine. The same is true in respect to the crank 58, etc. which tends to counter-balance the wrist 28, etc. Smooth running may therefore be readily secured.

The two engine-heads and the intervening pump-head, seen at Figure 3, may be cast all in one piece, as shown at Figures 5 and 6; but the pump-caps 64 may be detachable, and the same may be true of the engine-cap 74, 75; the latter having the inosculated engine-portions 22, and being also provided with spark plugs 76 opening into the inosculations; the engine-caps being water-jacketed as shown.

The members 27, 28, 47, 56, 58 of the crank-shaft may be made in one piece, which may be cut down from a single heavy shaft. The pitmen 25 may be slipped onto the wrists 27, 28, or rather upon the bushings 48, and then the ends of the crank-wrists may be set into sockets 77 formed in the end weights 46, which are integral with the end-shafts 29, being joined thereto by integral disk-portions 78; and set-screws 79 may be employed for holding the wrists 27, 28 rigidly connected to the members 46. Said members 46, as well as the members 47, may be shaped to help counterbalance the wrist-pins 27, 28 and their belongings; and extra counterbalancing rim-segments 80 may be secured upon the members 46.

The crank-shaft may be mounted in bearings 81, 82, 83, 84, forming part of a framework, and the shaft may be held in place by detachable members 85. The framework may include supports 86, extending upwardly and outwardly from the shaft-bearings, and carrying at their outer ends four substantially similar sloping beds 87, one for each of the engine-heads seen at Figures 5 and 6, the latter being fastened down upon the beds by bolts 88. These four engine-heads may be similar one to another for economical manufacture, but are placed in the echelon arrangement, seen at Figure 4, to agree with the described arrangement of the pitmen 25 and the eccentric-straps 54. The eccentric-straps may be secured upon the eccentric in any suitable way, as by joining their ends, as indicated at 89, Figure 3.

It will be noted that the chamber 70 extends from the upper or delivery end of the pump down to the intake-ports of the engine-cylinder.

Back-firing dangers are minimized or avoided, since when any engine-cylinder has its inlet-ports open, its outlet-port is also open, and moreover the associated pump-piston closes the port 69, thus shutting off communication and preventing ignition of gas mixture in the manifold and carburetor.

Cooling water may be supplied to the engine-heads through branch pipes 90 each delivering to adjacent engine-heads; and the heated water may be led off through delivery pipe 91.

At Figure 4, the engine-heads marked A B C D are respectively in line with the pump-heads E F G H and also with the opposite engine-heads I J K L.

The pumps, which are arranged in echelon, have their pitmen or eccentric-straps side by side upon the eccentrics, the latter being provided with split anti-friction tubes, bushings or washers 92.

So long as the rows of engine-heads are evenly spaced, the engine may be made with either more or less than the four rows shown; as for example with three rows spaced at 60 degrees, or two rows at 90 degrees, or five rows at 36 degrees, or 8 rows at 22½ degrees.

Variations may be resorted to within the scope of the invention, and portions of the improvements may be used without others.

Having thus described my invention, I claim:

1. An internal combustion engine having a crank-shaft provided with only two wrists, said wrists being diametrically opposite, sixteen cylinders, said cylinders arranged in separated rows which extend longitudinally of the crank-shaft, there being four cylinders in each row, sixteen pistons in said cylinders connected to said wrists, half of the pistons in each row for one crank-wrist and half for the other, the cylinders in each row being divided into two pairs, the cylinders in each pair being side by side and inosculated and having a spark-plug, pitmen connecting four pairs of said pistons to one crank-wrist, pitmen connecting the other four pairs of pistons to the other crank-wrist, all of the rows of cylinders radiating at angles of 45 degrees from one another to secure eight evenly-spaced explosions at each revolution of the crank-shaft, each pair of cylinders forming an engine-head and there being two engine-heads in each row, the engine-heads in the different rows being in echelon or the like arrangement, and the pitmen having corresponding arrangements upon the crank-wrists, there being space between the pitmen in each pair for three other pitmen, and each of said other pitmen belonging to a different engine-head, eccentrics on said shaft for driving the pumps, all of the engine and pump-heads being in echelon, each pump-head having two oppositely-acting pumps, and compression chambers between the pumps and the pairs of engine-cylinders.

2. An engine having a crank-shaft provided with diametrically-opposite wrists, inosculated engine-cylinders having pistons connected to said wrists, said crank-shaft having eccentrics thereon adjoining said wrists, and engine-charging pumps driven by said eccentrics, each eccentric being diametrically opposite to its companion engine-wrist, said eccentrics being of greater diameter than the engine-wrists, each eccentric having a plurality of radial pump-pitmen mounted thereon.

3. An engine having a crank-shaft provided with diametrically-opposite wrists, inosculated engine-cylinders having pistons connected to said wrists, each crank-shaft having eccentrics thereon adjoining said wrists, and engine-charging pumps driven by said eccentrics, each eccentric being diametrically opposite to its companion engine-wrist, said eccentrics being of greater diameter than the engine-wrists, each eccentric having a plurality of radial pump-pitmen mounted thereon, the crank-shaft having

main bearings at its ends and also a main bearing between the engine-wrists said wrists and eccentrics being formed in one piece and cut down from a single heavy shaft.

4. A set of radial rows of engine-cylinders and pump-cylinders for pumping charges thereto, each row including a set of engine-cylinders upon each side of a set of pump-cylinders having pistons, and a crank-shaft for all of the cylinders and including two diametrically-opposite wrists, each connected to half of the engine-pistons, and also including diametrically-opposite integral eccentrics, each connected to half of the pump-pistons, each eccentric being diametrically opposite to its adacent engine-wrist and immediately adjoining the same, said engine-cylinders including inosculated pairs, an engine-cylinder in each pair having an intake port and a chamber being arranged intermediate said intake port and the pump associated with that pair for receiving a compressed charge from the pump during the power strokes of the engine-pistons associated with said pump.

5. A set of radial rows of engine-cylinders and pump-cylinders for pumping charges thereto, each row including a set of engine-cylinders upon each side of a set of pump-cylinders having pistons, and a crank-shaft for all of the cylinders and including two diametrically-opposite wrists, each connected to half of the engine-pistons, and also including diametrically-opposite integral eccentrics, each connected to half of the pump-pistons, each eccentric being diametrically opposite to its adjacent engine-wrist and immediately adjoining the same, said engine-cylinders including inosculated pairs, an engine-cylinder in each pair having an intake port and a chamber being arranged intermediate said intake port and the pump associated with that pair for receiving a compressed charge from the pump during the power strokes of the engine-pistons associated with said pump; each row including engine-heads and also including a pump-head between the engine-heads, each pump-head including two pumps, one for each adjacent engine-head; each intermediate compression chamber being adjacent to its intake engine port.

6. A set of radial rows of engine-cylinders and pump-cylinders for pumping charges thereto, each row including a set of engine-cylinders upon each side of a set of pump-cylinders having pistons, and a crank-shaft for all of the cylinders and including two diametrically-opposite wrists, each connected to half of the engine-pistons, and also including diametrically-opposite integral pump-wrists, each connected to half of the pump-pistons, each pump-wrist being diametrically opposite to its adjacent engine-wrist and immediately adjoining the same, said engine-cylinders including inosculated pairs, an engine-cylinder in each pair having an intake port and a chamber being arranged intermediate said intake port and the pump associated with that pair for receiving a compressed charge from the pump during the power strokes of the engine-pistons associated with said pump, the cubic capacity of said intermediate compression chamber being substantially less than the cubic displacement of the pump-cylinder; the cubic displacement of each pump-piston being about equal to the cubic displacement of the two engine-pistons combined.

7. A set of radial rows of engine-cylinders and pump-cylinders for pumping charges thereto, each row including a set of engine-cylinders upon each side of a set of pump-cylinders having pistons, and a crank-shaft for all of the cylinders and including two diametrically-opposite wrists, each connected to half of the engine-pistons, and also including diametrically-opposite integral eccentrics, each connected to half of the pump-pistons, each eccentric being diametrically opposite to its adjacent engine-wrist and immediately adjoining the same, said engine-cylinders including inosculated pairs, an engine-cylinder in each pair having an intake port and a chamber being arranged intermediate said intake port and the pump associated with that pair for receiving a compressed charge from the pump during the power strokes of the engine-pistons associated with said pump, each pair of inosculated engine-cylinders being cast in one piece with their pump-cylinder, said rows being four in number and set at angles from one another, the four engine-heads being similar to one another and having an echelon arrangement as set forth.

8. The combination of a power-shaft having opposed eccentrics thereon and also having engine-wrists, a series of pumps arranged in echelon and having pistons, eccentric straps placed side by side upon each of said eccentrics and connected to said pump-pistons, said pumps being separated at equally-spaced angular intervals around the power-shaft, and engine-cylinders to which said pumps deliver respectively, said engine-cylinders being placed side by side with the pumps in echelon arrangement and having pistons connected side by side to each engine-wrist of said shaft to drive the same.

9. An internal combustion engine having a crank-shaft provided with only two engine-wrists, said wrists being diametrically opposite, a multiplicity of cylinders, said cylinders arranged in separated rows which extend longitudinally of the crank-shaft, there being four cylinders in each row, pistons in said cylinders, half of the pistons in each row connected to one crank-wrist and half to the other, the engine-cylinders in each row being divided into two pairs, the cylinders in each pair being side by side and inosculated, pit-

men connecting half of said pistons to one engine-wrist, pitmen connecting the other half of said pistons to the other engine-wrist, all of the rows of cylinders radiating at equal angles from one another to secure numerous evenly-spaced explosions at each revolution of the crank-shaft, each pair of cylinders forming an engine-head and there being two engine-heads in each row, the engine-heads in the different rows being in echelon or the like arrangement, and the pitmen having corresponding alternating arrangements upon the crank-wrists, pump-cylinders cast integral with engine-heads in the several rows, and pump-wrists on said shaft for driving the pumps, each wrist being connected to drive a pump in each of said rows.

10. A high-speed reciprocatory balanced automobile-engine having a crank-shaft formed with diametrically-opposed wrists, pairs of inosculated engine-cylinders having pistons directly connected in pairs to each crank-wrist, said cylinders disposed side by side in a plurality of rows lengthwise of the crank-shaft, the cylinders in one row at an angle to the cylinders in another row, a pair of pistons in each row being connected to one crank-wrist and the other pair in the same row being connected to the other crank-wrist, the cylinders, pistons and crank-shaft being organized to secure evenly-spaced power strokes in sufficient number at each revolution of the shaft to produce a continuous torque thereon, and a reciprocating pump grouped with each pair of engine-cylinders for charging them with mixed air and fuel, said pumps having reciprocating pistons and said crank-shaft having additional wrists for the pump-pistons, each pump-wrist being diametrically opposed to its companion crank-wrist, each pump arranged in the same row with its engine-cylinders, and each pump-wrist driving a plurality of pumps, one in each of said cylinder-rows.

11. A high-speed reciprocatory balanced automobile-engine having a crank-shaft formed with diametrically-opposed wrists, pairs of inosculated engine-cylinders having pistons directly connected in pairs to each crank-wrist, said cylinders disposed side by side in a plurality of rows lengthwise of the crank-shaft, the cylinders in one row at an angle to the cylinders in another row, a pair of pistons in each row being connected to one crank-wrist and the other pair in the same row being connected to the other crank-wrist, the cylinders, pistons and crank-shaft being organized to secure evenly-spaced power strokes in sufficient number at each revolution of the shaft to produce a continuous torque thereon, a pump grouped with each pair of engine-cylinders for charging them with mixed air and fuel, said pumps having reciprocatory pistons and said crank-shaft having additional wrists for the pump-pistons, each pump-wrist being diametrically opposed to its companion crank-wrist, each pump arranged in the same row with its pair of engine-cylinders, and each pump-wrist driving a plurality of pumps, one in each of said cylinder-rows, the engine-pistons connected to pitmen which are placed side by side upon each engine-wrist, the pitmen of one pair of pistons alternating with those of another pair upon the same wrist, and pump-pitmen mounted side by side upon the pump-wrist adjoining each engine-wrist.

12. Engine according to claim 11, all of the engine-cylinders being staggered, and the pumps being correspondingly staggered, each pair of cylinders forming a single casting with their companion pump-cylinder, and a base having angularly-disposed faces upon which said castings are secured to form rows of cylinders.

13. A high-speed reciprocatory balanced automobile-engine having a crank-shaft formed with diametrically-opposed wrists, pairs of radiating inosculated engine-cylinders having pistons directly connected in pairs to each crank-wrist, said cylinders disposed side by side in a plurality of rows lengthwise of the crank-shaft, one row at an angle to another, a pair of pistons in each row being connected by a pair of pitmen directly to one crank-wrist and another pair of pitmen in the same row being directly connected to the other crank-wrist, the cylinders being offset in the different rows, a pump grouped with each pair of engine-cylinders for charging them with measured charges of mixed air and fuel, said pumps having reciprocatory pistons and said crank-shaft having additional wrists for the pump-pistons, each pump-wrist being diametrically opposed to its companion engine-wrist, each pump being arranged in the same row with its pair of engine-cylinders, and each pump-wrist driving a plurality of pumps, one in each of said cylinder-rows, the pumps being offset, and pump-pitmen side by side radiating from each pump-wrist.

14. A reciprocatory balanced automobile-engine including a crank-shaft having diametrically-opposed engine-wrists, pairs of inosculated engine-cylinders having pistons with pitmen directly mounted in pairs upon each crank-wrist, said cylinders disposed radially side by side in a plurality of rows lengthwise of the crank-shaft, a pair of pistons in each row being connected to one engine-wrist and the other pair in the same row being connected to the other engine-wrist, and a set of reciprocatory charging pumps one for each pair of engine-cylinders, said pumps having reciprocatory pistons and said crank-shaft having eccentrics forming wrists for pump-piston pitmen, each eccentric being diametrically opposed to the companion engine-wrist, each pump arranged in

the same row with its engine-cylinders, and each eccentric driving a plurality pumps, one in each of said engine cylinder rows.

15. A reciprocatory balanced automobile-engine including a crank-shaft having diametrically-opposed engine-wrists, pairs of inosculated engine-cylinders having pistons with pitmen directly mounted in pairs upon each crank-wrist, said cylinders disposed radially side by side in a plurality of rows lengthwise of the crank-shaft, a pair of pistons in each row being connected to one engine-wrist and the other pair in the same row being connected to the other engine-wrist, and a set of reciprocatory charging pumps one for each pair of engine-cylinders, said pumps having reciprocatory pistons and said crank-shaft having eccentrics forming wrists for pump-piston pitmen, each eccentric being diametrically opposed to the companion engine-wrist, each pump arranged in the same row with its engine-cylinders, and each eccentric driving a plurality of pumps, one in each of said engine-cylinder rows, the engine-pitmen mounted side by side upon the engine-wrists, the pump-pitmen side by side upon the eccentrics, and the engine-cylinders and pump-cylinders being arranged in echelon.

16. A high-speed automobile-engine of the flexible class having a crank-shaft, radial rows of pairs of inosculated cylinders provided with pistons, said crank-shaft having diametrically-opposed engine-wrists, the pistons in each pair being connected to the same wrists, and the pairs of pistons being mutually balanced, the cylinders, pistons and crank-shaft being organized for producing evenly-spaced power strokes in sufficient number at each revolution of the shaft to produce a continuous torque thereon, and each engine-wrist serving for bearing for a plurality of pitmen, diametrically-opposite pump-wrists being also provided on said shaft, and pistons driven by said pump-wrists for charging the engine-cylinders, a plurality of pump-pistons being connected to each pump-wrist.

17. The combination of a crank-shaft, sets of inosculated engine-cylinders, pistons working in said cylinders and driving said shaft, one of the inosculated cylinders in each set having an inlet port, and another thereof in each set having an exhaust port, pumps for mixed air and fuel, one pump for each pair of engine-cylinders, each pump having a cylinder and a piston reciprocating therein and connected to said shaft to be driven thereby, and a source of supply for the pumps, the capacity of each pump being no greater than the combined capacity of its associated engine-cylinders, the delivery of each pump being connected to the inlet port of the engine-cylinder by means of a chambered passage in which the charge is stored in compressed condition preparatory to the opening of said inlet port, two pairs of inosculated cylinders being in line with two pumps, and two other pairs of inosculated cylinders and two other pumps being all in line, and at an angle to the first set; the pumps being between the pairs of cylinders the crank-shaft having two diametrically-opposed wrists each connected to four engine-pistons and two other diametrically-opposed wrists each connected to two pumps; each wrist on said shaft being diametrically opposed to the next; all of the engine-cylinders having an echelon arrangement, and the pumps having corresponding echelon arrangement.

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