No. 729,984. PATENTED JUNE 2, 1903.

H. F. WALLMANN.

COMPOUND INTERNAL COMBUSTION ENGINE.

APPLICATION FILED OCT. 30, 1899.

NO MODEL. 4 SHEETS—SHEET 1.

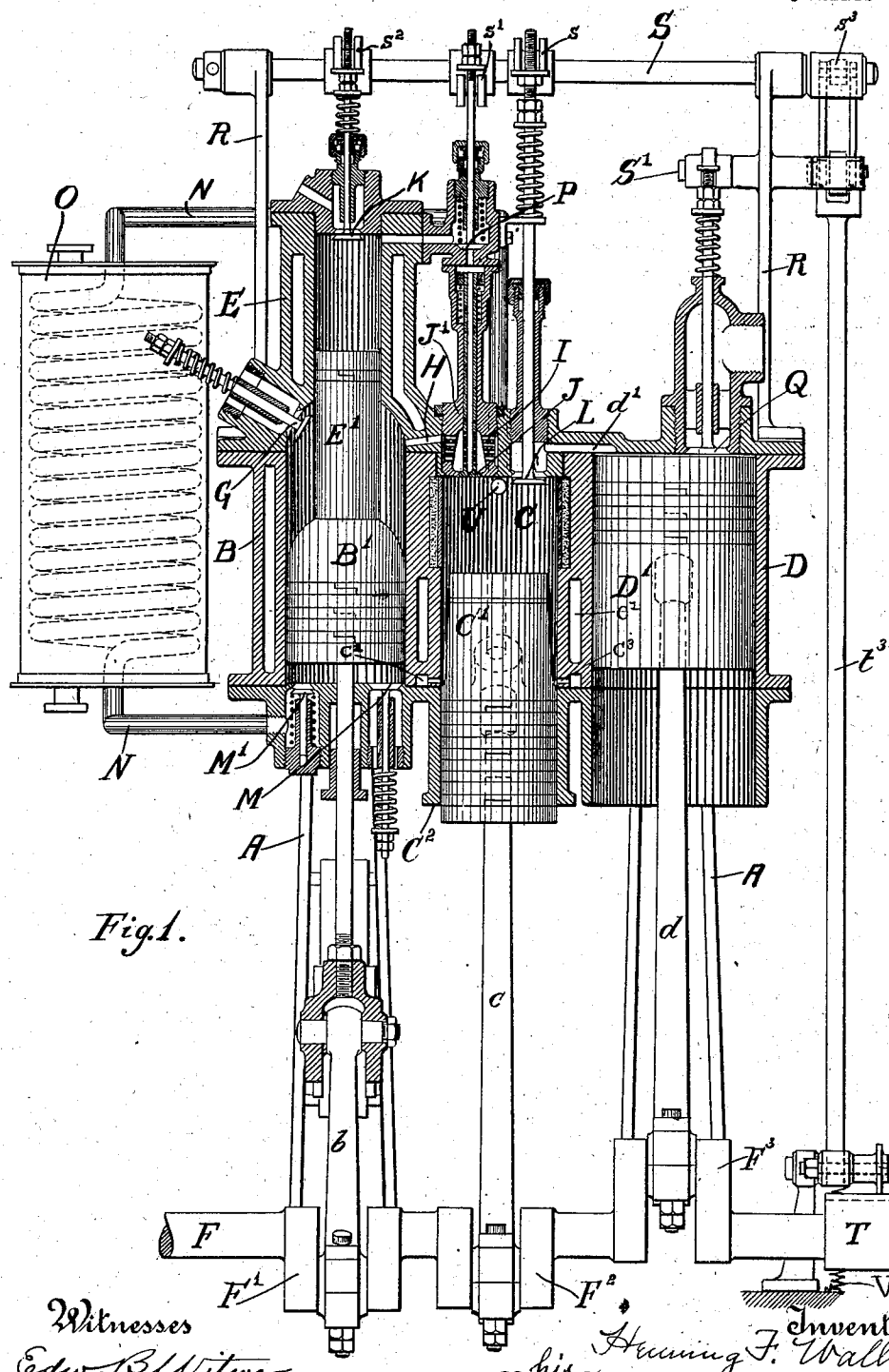


Fig. 1.

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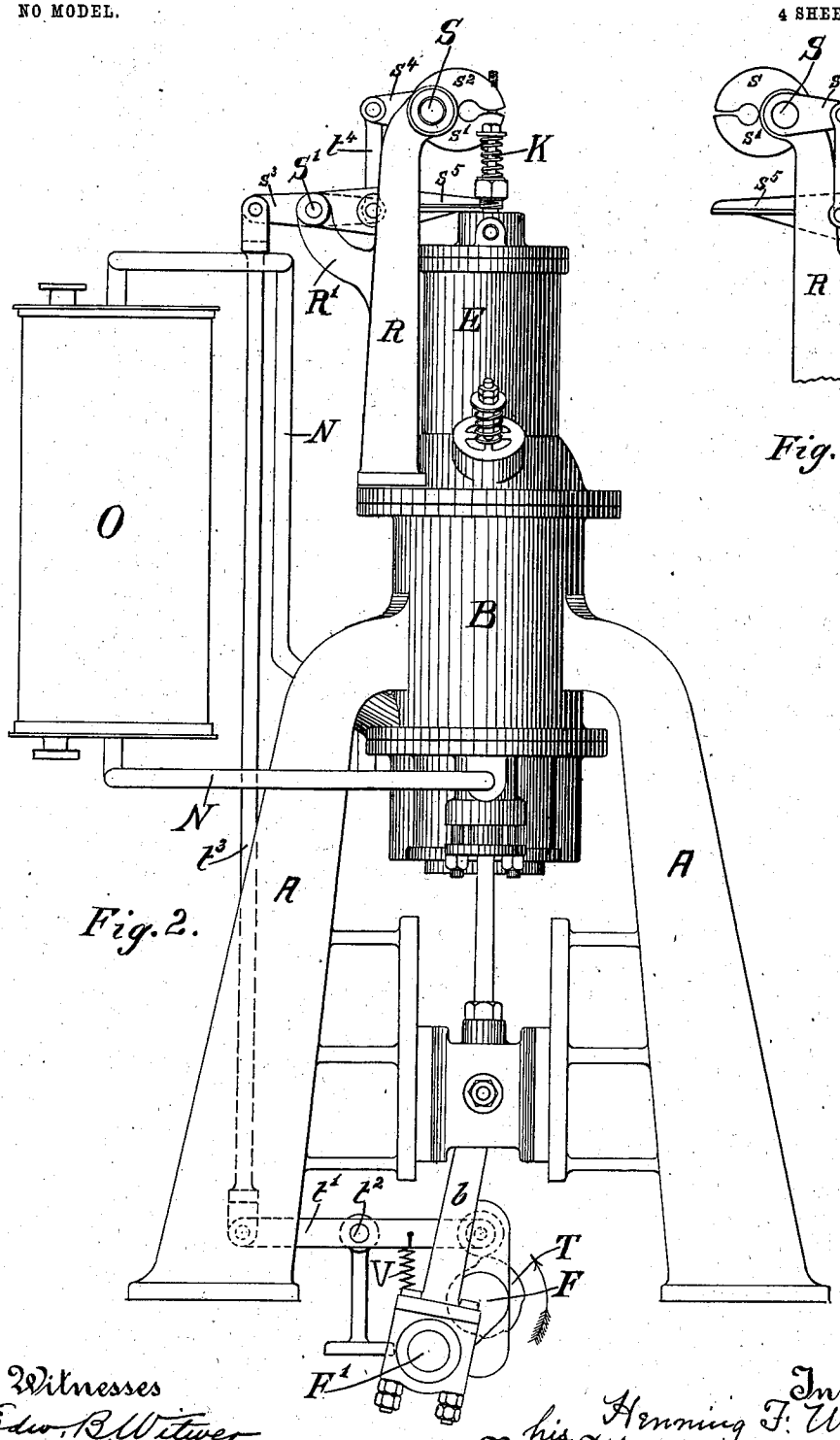


Fig. 2.

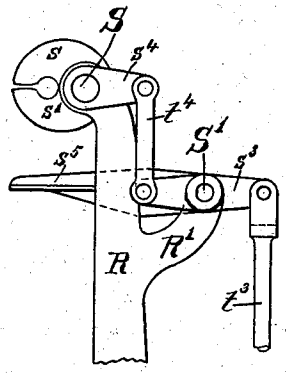


Fig. 3.

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NO MODEL. 4 SHEETS—SHEET 3.

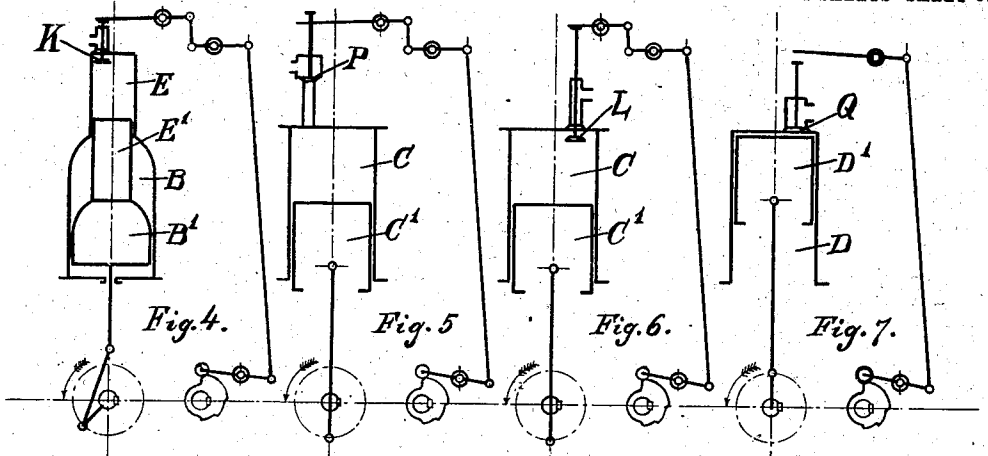


Fig. 4. Fig. 5 Fig. 6. Fig. 7.

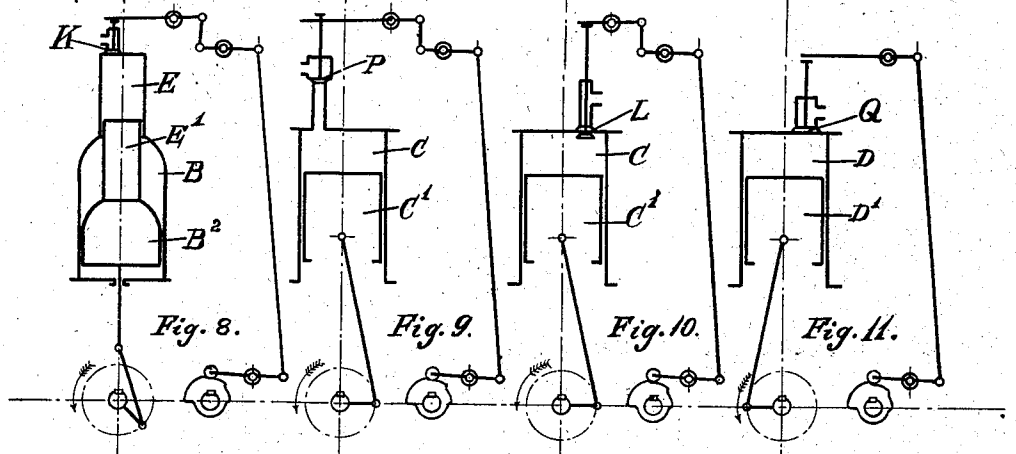


Fig. 8. Fig. 9. Fig. 10. Fig. 11.

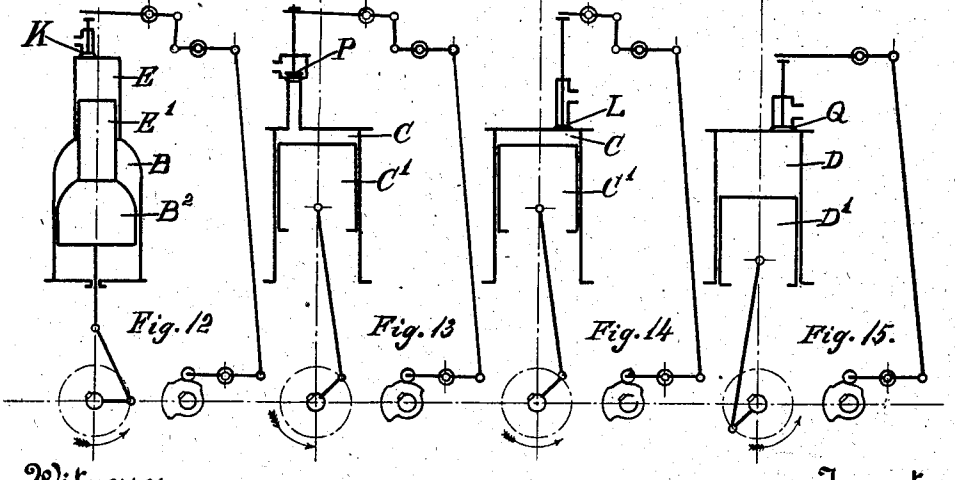


Fig. 12 Fig. 13 Fig. 14 Fig. 15.

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NO MODEL. 4 SHEETS—SHEET 4.

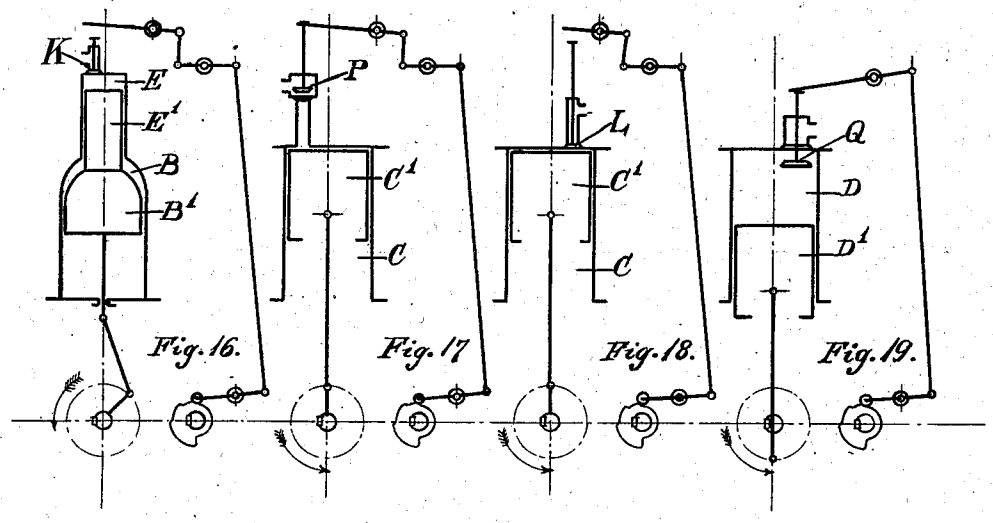


Fig. 16. Fig. 17 Fig. 18. Fig. 19.

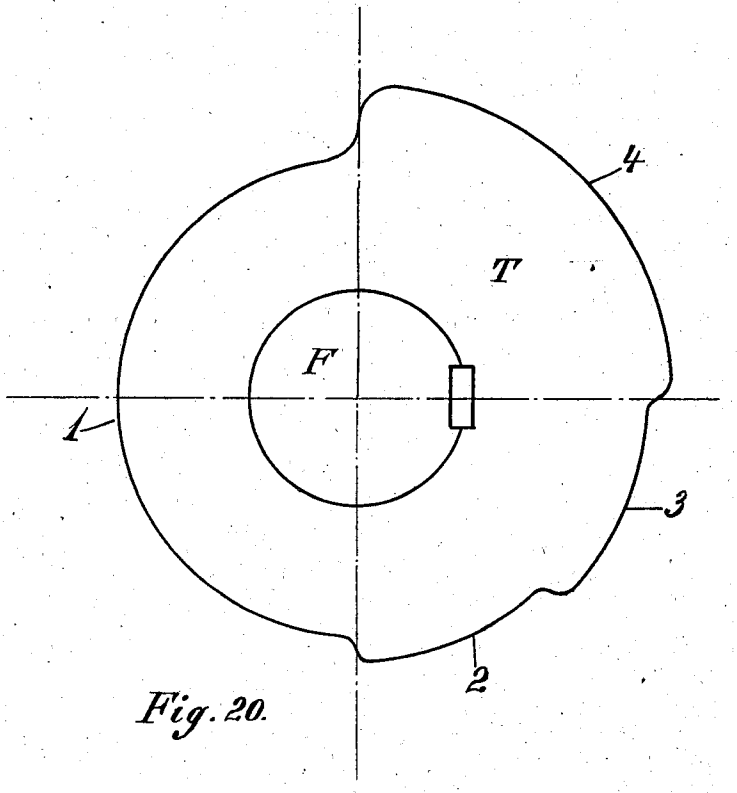


Fig. 20.

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No. 729,984. Patented June 2, 1903.

UNITED STATES PATENT OFFICE.

HENNING FRIEDRICH WALLMANN, OF CHICAGO, ILLINOIS, ASSIGNOR TO THE WALLMANN ENGINE COMPANY, A CORPORATION OF ILLINOIS.

COMPOUND INTERNAL-COMBUSTION ENGINE.

SPECIFICATION forming part of Letters Patent No. 729,984, dated June 2, 1903.

Application filed October 30, 1899. Serial No. 735,301. (No model.)

To all whom it may concern:

Be it known that I, HENNING FRIEDRICH WALLMANN, a citizen of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Compound Internal-Combustion Engines, of which the following is a specification.

My invention relates to internal-combustion engines of the two-cycle type in which a charge of compressed air is mixed in suitable proportions with an inflammable gas or oil vapor ignited and expanded within the combustion-cylinder and made to perform work against the piston at every outstroke of the latter; and my present invention is in the nature of improvements upon the engine forming the subject-matter of a companion application, filed by me on the 11th day of December, 1899, Serial No. 739,962.

These improvements, generally stated, reside in the addition to the engine described in the application above noted of a low-pressure expansion-cylinder adapted to receive and utilize the hot products of combustion from the high-pressure combustion-cylinder, the effectiveness of said hot products being augmented by the admixture therewith while still within the combustion-cylinder of a body of compressed air, which may be furnished from any convenient source, but which in the embodiment of my invention illustrated in the drawings is furnished by an air-compressor connected to and operated from the driving-shaft of the engine. The said body of compressed air is caused to sweep through the entire length of the combustion-cylinder at the completion of the working stroke, thus acting as scavenger for the latter cylinder and at the same time adding to its own effectiveness by the absorption of heat from the hot products of combustion with which it mingles. The said low-pressure expansion-cylinder is therefore, in effect, partly a hot-air engine; but in view of the fact that it also receives and utilizes the expanding gases exhausted from the combustion-cylinder it may properly be termed a "low-pressure" expansion-cylinder, it being borne in mind that by said definition is meant in this case a cylinder in which the effectiveness of the high-pressure exhaust and of a body of compressed air commingled therewith and heated thereby is combined.

The principal objects of my present improvements are increased efficiency and economy in the operation of engines of this general type by the more thorough utilization not only of the expansive effect of the burning gases down nearly or quite to atmospheric pressure, but also of the thermodynamic effect through the conservation and utilization to the fullest practicable extent of the caloricity represented by the fuel employed in the operation of the engine.

In the accompanying drawings I have illustrated one form of engine embodying my present invention, in which—

Figure 1 is an elevation partly in central vertical section. Fig. 2 is a side elevation at right angles to the view shown in Fig. 1. Fig. 3 is a detail of part of the valve-actuating mechanism. Figs. 4 to 19, inclusive, are diagrammatic views illustrating various positions of the valve-actuating mechanism and the valves at different points in the strokes of the pistons; and Fig. 20 is a side view of the triple-stepped valve-actuating cam.

Similar characters of reference refer to similar parts throughout the several views.

A represents a suitable framework supporting at its upper end three cylinders B, C, and D, preferably arranged side by side, as shown. B is a double-acting air-compressor, C a high-pressure combustion-cylinder, and D a low-pressure expansion-cylinder. Located above and in alinement with the air-pump B is a fuel-pump E, the plungers B′ of the air-pump and E′ of the fuel-pump being formed integral or rigidly connected together, so as to move simultaneously under impulses imparted from the crank-shaft F through crank F′ and connecting-rod *b*. Within combustion-cylinder C is the working piston or plunger C′, the latter being connected to and operating the crank-shaft F through the agency of connecting-rod *c* and crank F^2. Within the expansion-cylinder D is another working piston or plunger D′, also connected to and operating the crank-shaft F through

the agency of connecting-rod d and crank F^3. The cranks F^2 and F^3 are set diametrically opposite on the shaft F, while the crank F′ is about forty-five degrees behind the crank F^2.

Referring to the air-pump B, it will be noticed that the presence of the elongated plunger E′, formed directly on the upper face of the air-pump plunger B′, creates an annular air-compression chamber within the cylinder B, to which air is admitted on the suction-stroke through the inlet-valve G and out of which it is forced on the compression-stroke through a port H and a mixing device I, past valve J into the combustion-cylinder C. The cylinder of the fuel-pump E is provided, preferably at its upper end, with an inlet-valve K, normally held closed by a spring, but adapted to open on the suction-stroke and to be positively held open during the initial portion of the discharge-stroke by means and for a purpose hereinafter described.

Referring next to the combustion-cylinder, J is its inlet-valve, and L designates its exhaust-valve. The latter is normally held to its seat by a spring, as shown; but it is positively opened at and during the proper period in the engine's operation to effect the exhaust and scavenging of the combustion-cylinder by suitable mechanism, as hereinafter described. Approximately the upper half of the interior wall of this cylinder is lined with some suitable heat-retaining substance—as compressed asbestos, mica, &c.—while the lower half of the cylinder-wall is cored to form an annular water-jacket chamber c'. Below the water-jacket chamber is another annular chamber c^2, which communicates with the interior of the cylinder at its lower end through a ring of small lateral ports c^3. The piston of the combustion-cylinder is supplied with suitable packing-rings through approximately the lower half of its cylindrical surface, which when the piston is in its lowest position, as shown in Fig. 1, is guided in an annular extension C^2 of the cylinder, and the upper half of the piston is of a reduced diameter and is preferably given a slightly-tapering contour, as shown, its diameter at its upper or inner end being least and gradually tapering outward down to about the middle of the piston. Only the lower and packed half of the piston, therefore, has a sliding contact with the inner wall of the cylinder.

M and M′ designate air inlet and outlet valves, respectively, formed in the lower cylinder-head of the air-pump B, the casing of the valve M′ being tapped by a pipe N, which in the form of a cooling-coil passes through a tank O, through which a flow of cold water is maintained, and at its other end leads into the annular chamber c^2 of the cylinder C.

In order to control the admission of fuel from the fuel-pump E to the combustion-cylinder C, so as to prevent waste of fuel and so that the fuel shall enter the latter cylinder at the right pressure to properly mix with the air supplied through port H, I provide in the passage-way connecting the fuel-pump with the combustion-cylinder and in addition to the regular automatic inlet-valve J of the latter cylinder a positively-actuated controlling-valve P, which by means hereinafter described is opened at a predetermined interval after the closing of the inlet-valve of the fuel-pump and simultaneously with the closing of the exhaust-valve of the combustion-cylinder to admit the compressed fuel into the latter cylinder. This device forms the principal subject-matter of the companion application, Serial No. 739,962, hereinabove referred to, and is not specifically claimed herein. The inlet-valve J of the combustion-cylinder has a hollow stem of considerable length provided with a plurality of lateral ports near its lower end, as shown, and its casing J′ is similarly ported near its lower end opposite the port H, so that the compressed fuel entering through the hollow valve-stem and the compressed air entering through port H will be forced in opposite directions to meet each other in fine sprays through the lateral ports in the valve-stem and its casing, respectively, and will enter the combustion-cylinder past the valve J in a thoroughly-commingled state. Further detailed description of this mixer is not here given, as it is not herein specifically claimed, but forms the subject-matter of a companion application, Serial No. 8,132, filed March 10, 1900.

The low-pressure expansion-cylinder D is connected with the exhaust of the combustion-cylinder C by a port d', and Q is the discharge-valve of the expansion-cylinder. This latter valve is positively actuated in common with the valves K, P, and L by a single cam on the crank-shaft F and suitable intermediate connections, which will now be described.

R R designate a pair of standards mounted on top of the cylinders B and D. In the upper ends of these standards is suitably journaled a horizontal rocker-shaft S. Rigidly secured on this rocker-shaft are three short arms or tappets s, s', and s^2, which at their outer ends engage the stems of the valves L, P, and K, respectively, at the right times to effect the proper actuation of said valves, as hereinafter described. Tappet s is set slightly in advance of tappet s^2, so that it will engage the stem of valve L a little earlier and leave it a little later than the tappet s^2 engages and leaves the stem of valve K, while tappet s' is set to engage and lift valve P at the same instant that tappet s disengages valve L. The rocker-shaft S is positively actuated from the crank-shaft F of the engine through the agency of a triple-stepped cam-disk T on said crank-shaft, said cam-disk engaging and actuating a roller t on one arm of a lever t', pivoted at t^2, Fig. 2, which lever through a connecting-rod t^3 conveys its rock-

ing motion to a lever s^3, fast on one end of a short rocker-shaft S′, journaled in a rearwardly-extending bracket R′ of one of the standards R. The forwardly-extending end of lever s^3 is connected to a rearwardly-extending arm s^4, fast on rocker-shaft S, by a link t^4, all as plainly shown in Fig. 3. On the other end of rocker-shaft S′ is rigidly fixed a tappet s^5, which engages the stem of the exhaust-valve Q of the expansion-cylinder D and which is operated from the cam T through the connections t', t^3, and s^3 in a direction opposite to the movement of the other three tappets s, s', and s^2.

U indicates an igniter located in the upper or inner end of the combustion-cylinder. It may be of any known and approved type and construction and is not, therefore, shown and described in detail.

The operation of my improved engine will be best understood by reference to Figs. 4 to 19, inclusive, which illustrate diagrammatically the various positions of the pistons and valves and the operations taking place in the several cylinders at the commencement of and during the travel of the cam-roller over the four steps or faces of the cam. The highest face (indicated by 4, Fig. 20) extends through ninety degrees, the next highest face (indicated by 3) extends through forty-five degrees, the next to the lowest face (indicated by 2) also extends through forty-five degrees, and the lowest face (indicated by 1) extends through a half-circle, or one hundred and eighty degrees.

Referring now to Figs. 4, 5, 6, and 7 and remembering that in practice the cam T is on the crank-shaft F and of course turns in the same direction as the crank-shaft (see arrows) when the cam-roller mounts the highest face 4 of the cam, pistons E′ and B′ of the fuel and air pumps E and B, respectively, Fig. 4, will have nearly completed their suction-strokes, tappets s^2 will have just engaged the stem of the fuel-inlet valve K, previously opened by suction, to hold the same open for a quarter-turn of the shaft, during the last half of which fuel in the fuel-pump E is idly returned past the open valve to the fuel-reservoir, and piston B′ will have compressed a body of air in and through pipe N and its cooling-coil; piston C′ of combustion-cylinder C, Figs. 5 and 6, will have just completed its downward or working stroke, thereby uncovering ports c^3 and permitting the compressed air in pipe N to scavenge the cylinder; tappet s will have just engaged the stem of exhaust-valve L, thereby opening said valve and permitting the scavenging-blast heated by and commingled with the hot expanding gases to rush into the expansion-cylinder, and tappet s' will have just disengaged the stem of fuel-controlling valve P and permitted said valve to close to its seat; piston D′ of expansion-cylinder D, Fig. 7, will have just completed an upward or exhaust stroke, and tappet s^5 will have just permitted valve Q to close.

Referring next to Figs. 8, 9, 10, and 11, when the cam-roller under the influence of spring V descends from face 4 to face 3 of the cam, pistons E′ and B′, Fig. 8, have already started on their compressing strokes, tappet s^2 has just allowed valve K to close and will permit said valve to remain closed until it is again opened by suction, thereby cutting off further idle return of the fuel to the reservoir, and air is being induced through valve M beneath the piston B′; piston C′, Figs. 9 and 10, is half-way on its inward or upward stroke, having cut off the scavenging-blast through ports c^3; valve L is still open and will remain open one-eighth of a turn of the shaft longer; plunger B′ is completing the scavenging of cylinder C, forcing a blast of air through port H and past valves J and L into the expansion-cylinder, and fuel-controlling valve P is still closed; piston D′, Fig. 11, is half-way down on its expansion or working stroke.

Turning now to Figs. 12, 13, 14, and 15, when the cam-roller under the influence of spring V descends from face 3 of the cam to face 2, pistons E′ and B′, Fig. 12, are half-way up on their compressing strokes, valve K is still closed, and plunger B′ is still drawing in air through valve M; piston C′, Figs. 13 and 14, has completed about five-sixths of its inward or upward stroke; exhaust-valve L has just closed, and simultaneously therewith fuel-controlling valve P has been opened by tappet s' to admit a charge of compressed fuel to the mixing device, (shown in connection with inlet-valve J,) where it meets and commingles with compressed air forced through port H, and the mixture passes through the automatically-opened valve J into the combustion-cylinder; piston D′, Fig. 15, is about five-sixths of the way down on its expansion or working stroke.

Referring finally to Figs. 16, 17, 18, and 19, these diagrams show the relative positions of the plungers and valves at the instant the cam-roller has passed off face 2 onto face 1, the valves all occupying the positions shown in these figures during the next half-revolution of the shaft and cam; pistons E′ and B′, Fig. 16, have completed about five-sixths of their compressing strokes and are compressing and forcing fuel and air through the mixer and into the combustion-cylinder; piston C′, Figs. 17 and 18, has just completed its upward or inward stroke, during the last part of which (after the closing of exhaust-valve L) it coöperated with plungers E′ and B′ in compressing the components of the next charge; piston D′, Fig. 19, has just completed its expansion or working stroke; exhaust-valve Q has just been opened by tappet s^5 and will remain open through a half-revolution of the crank-shaft, or until the piston D′ has completed its upward or ex-

haust stroke. When the crank-shaft has made one-eighth of a turn beyond the position indicated in Diagrams 16, 17, 18, and 19, (at which time plungers E′ and B′ will have completed their upward or compression strokes, piston C′ will be about one-sixth down on its working stroke and piston D′ about one-sixth up on its exhaust stroke,) the igniter U will be operated to fire the charge and effect another working stroke of piston C′, and the hereinabove-described cycle of operations will be repeated.

Both the inlet-valves G and K of the air and fuel pump, respectively, are ordinary automatically-operating puppet-valves opening by suction and closing by spring action; but the closing of the fuel-inlet valve K is delayed by the tappet s^3 while the final scavenging of cylinder C is going on in order that the compression of the components of the next charge may begin simultaneously, or substantially so, and the latter may meet, mix, and enter the combustion-cylinder at the same or substantially the same pressure. The inlet-valve of the combustion-cylinder is opened by the pressure of the incoming charge and is closed by the action of its closing-spring just prior to the ignition of the charge, the valve, if late in closing, being driven hard to its seat by the force of the explosion.

By the improvements hereinabove described, especially the utilization of the heat of the products of combustion (which is usually allowed to go to waste) in augmenting the expansive energy of a body of compressed air in the most direct manner possible—viz., by actual admixture therewith—I believe the efficiency and economy of this class of engines are materially increased, and a considerable saving in the amount of fuel required to produce a given horse-power is effected.

Having thus described my invention and illustrated my preferred embodiment thereof, what I claim as new, and desire to secure by Letters Patent, is—

1. A compound internal-combustion engine, comprising a high-pressure combustion-cylinder, means for supplying air and fuel thereto, a low-pressure expansion-cylinder, means for scavenging the combustion-cylinder, and means for transferring the scavenging-blast, commingled with and heated by the hot expanding gases in the combustion-cylinder, from the latter cylinder to the expansion-cylinder, substantially as described.

2. A compound internal-combustion engine, comprising a high-pressure combustion-cylinder, air and fuel pumps for supplying a combustible charge under pressure thereto, a low-pressure expansion-cylinder, means for scavenging the combustion-cylinder at the end of the working stroke of its piston, and means for transferring the scavenging-blast, commingled with and heated by the hot expanding gases in the combustion-cylinder, from the latter cylinder to the expansion-cylinder, substantially as described.

3. A compound internal-combustion engine, comprising a high-pressure combustion-cylinder, air and fuel pumps for supplying a combustible charge under pressure thereto, a low-pressure expansion-cylinder, an air-pump for scavenging the combustion-cylinder, and means for transferring the scavenging-blast, commingled with and heated by the hot expanding gases in the combustion-cylinder, from the latter cylinder to the expansion-cylinder, substantially as described.

4. In an internal-combustion engine, a combustion-cylinder, and means for scavenging said cylinder from both ends successively, substantially as described.

5. In an internal-combustion engine, the combination with a combustion-cylinder provided with inlet and discharge valves at its inner end, and having a series of lateral ports formed through its walls at its outer end which are uncovered by the piston at the limit of its outward stroke, of a piston having an outer cylindrical packed portion which overruns said lateral ports and an inner portion of reduced diameter which receives the impulse of the ignited charge and reciprocates out of contact with the cylinder-walls, and means for introducing a charge of compressed air to the combustion-cylinder through said lateral ports at the completion of each working stroke, substantially as described.

6. In an internal-combustion engine, in combination a fuel-pump, a high-pressure combustion-cylinder and a low-pressure expansion-cylinder, all having their pistons separately connected to a common crank-shaft, a series of positively-actuated valves controlling both the inlet and discharge functions of said combustion and expansion cylinders, a multiple stepped cam on the crank-shaft, and suitable connections intermediate said cam and said valves, whereby the latter are actuated at the proper times and through the proper intervals to effect the coöperative action of said pump and cylinders in the operation of the engine, substantially as described.

7. In an internal-combustion engine, in combination a combustion-cylinder, a combined fuel-pump and double-acting air-compressor, and suitable valve-controlled connections between said fuel-pump and the combustion-cylinder and between the opposite ends of the air-compressor and the opposite ends of the combustion-cylinder, whereby a stroke of the combined fuel and air pump plunger in one direction acts to scavenge the combustion-cylinder, and its stroke in the opposite direction supplies compressed air and fuel for the next charge, substantially as described.

8. In an internal-combustion engine, in combination a combustion-cylinder, an air-pump for scavenging the combustion-cylinder, a cooling device in the connection be-

tween the air-pump and the combustion-cylinder, an expansion-cylinder, and means whereby the scavenging-blast, commingled with and heated by the products of combustion, is exhausted into the expansion-cylinder before a fresh charge is admitted to the combustion-cylinder, substantially as set forth.

In testimony that I claim the foregoing as my invention I have hereunto subscribed my name in the presence of two witnesses.

HENNING FRIEDRICH WALLMANN.

Witnesses:

SAMUEL N. POND,

J. K. LAMBERT.