Jan. 6, 1931. B. C. STICKNEY 1,787,599

INTERNAL COMBUSTION ENGINE

Filed March 14, 1927 5 Sheets-Sheet 1

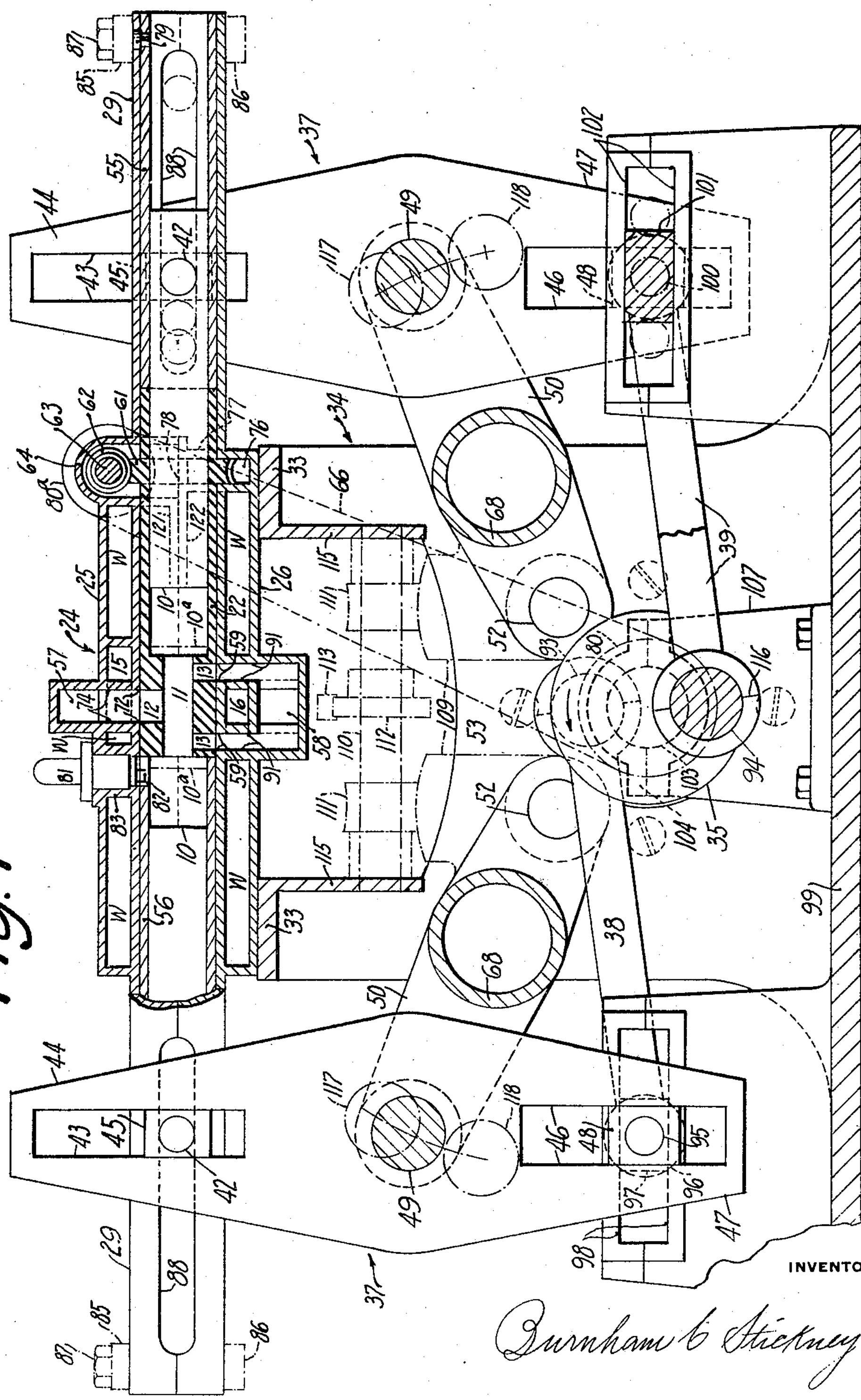

Fig. 1

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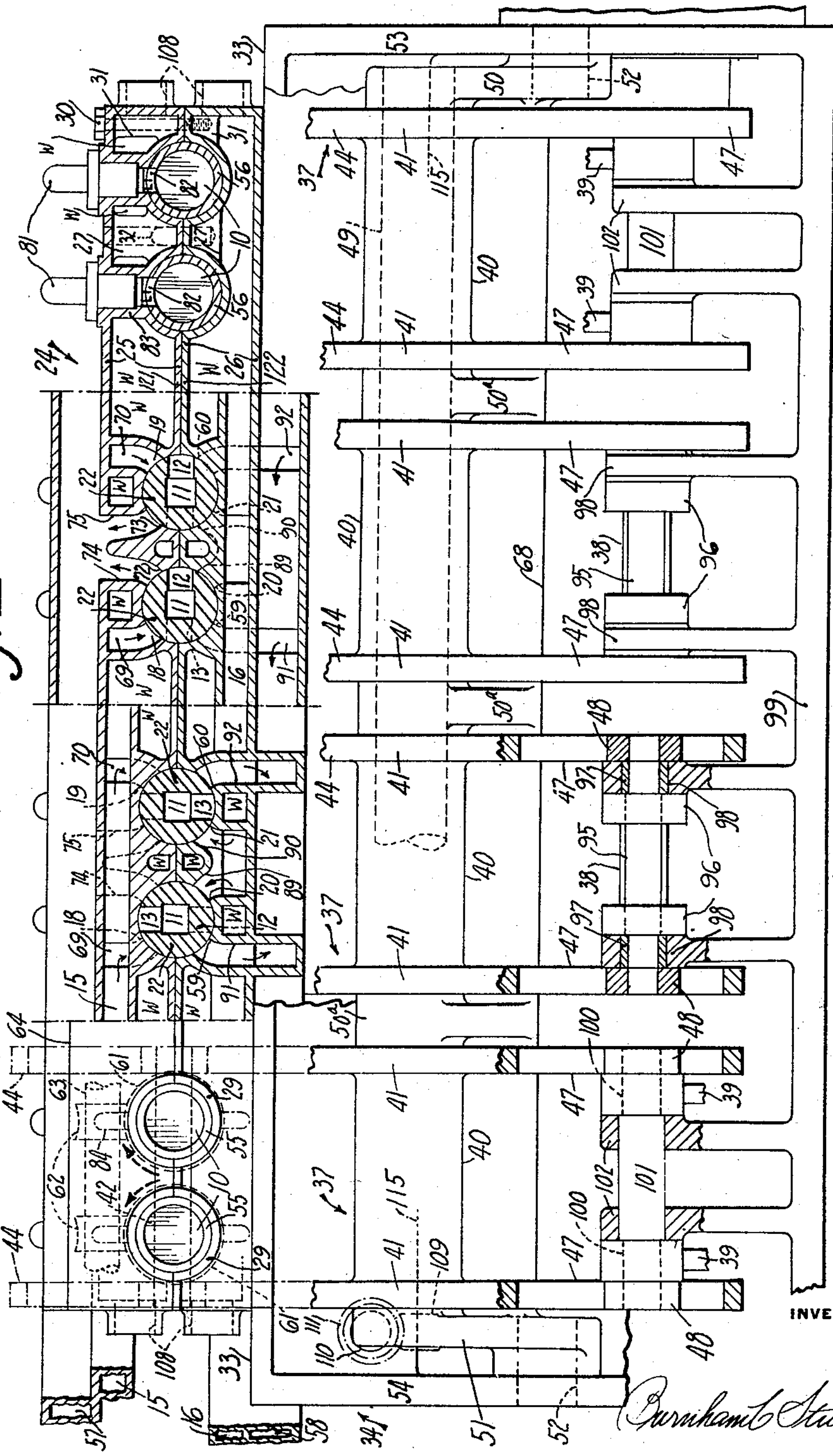
Fig. 2



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INTERNAL COMBUSTION ENGINE

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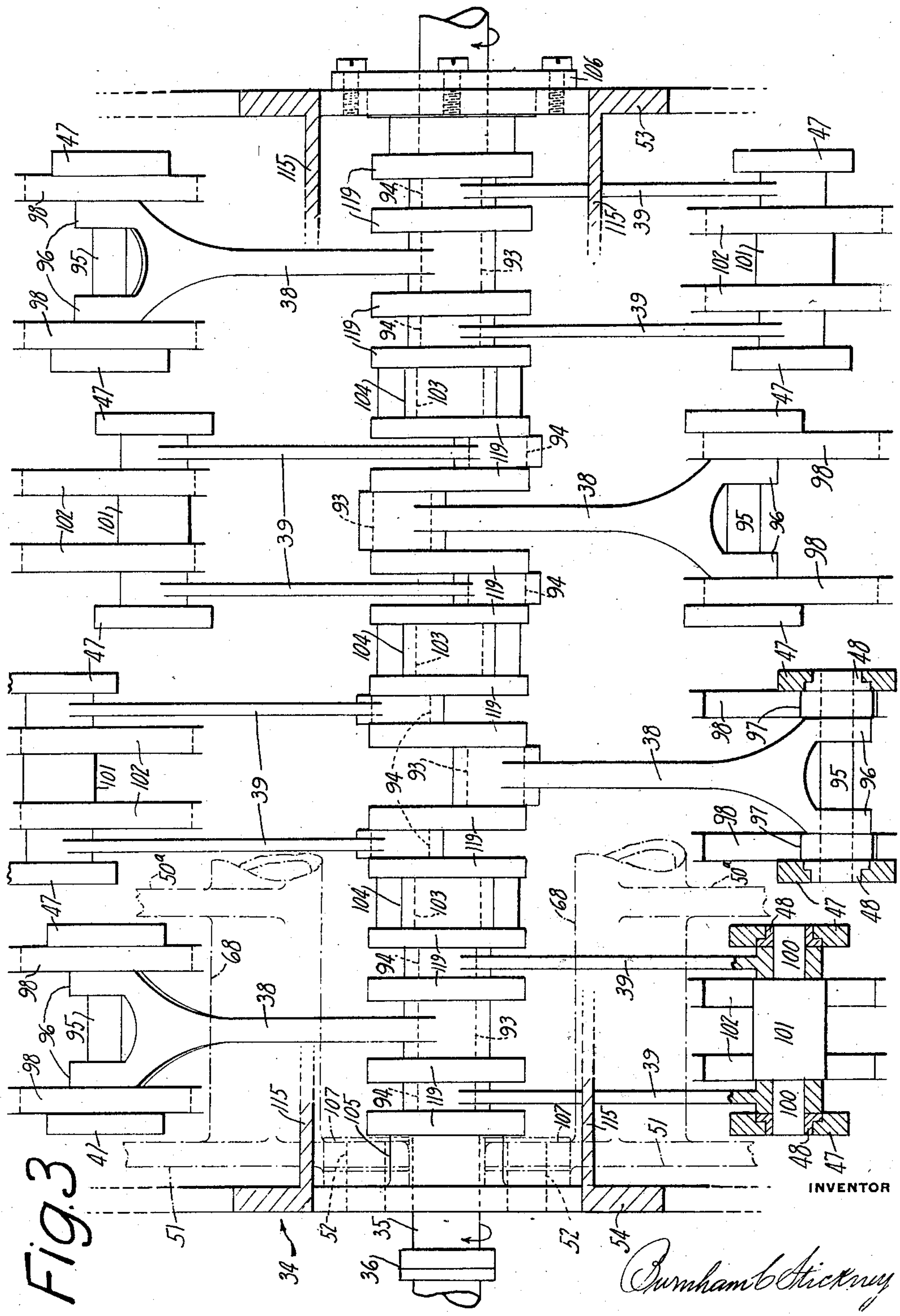

Fig. 3

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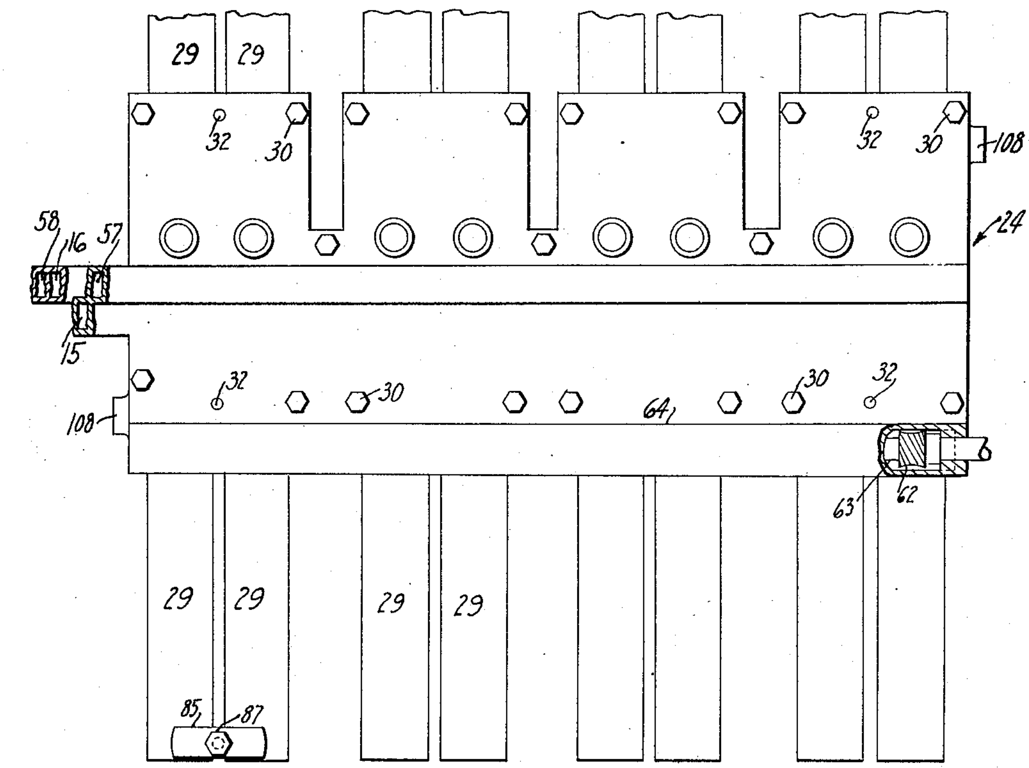

Fig. 4

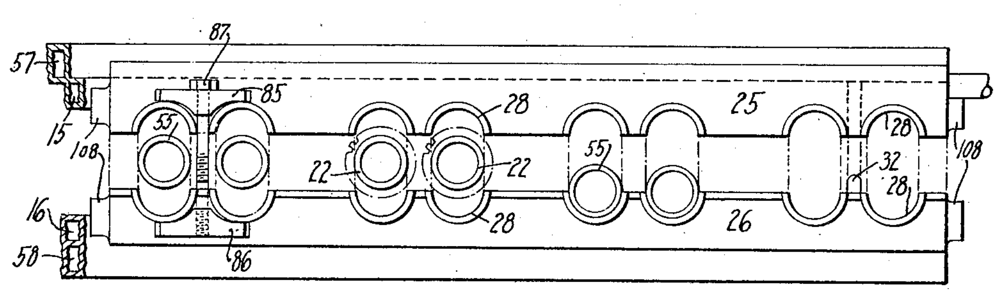

Fig. 5

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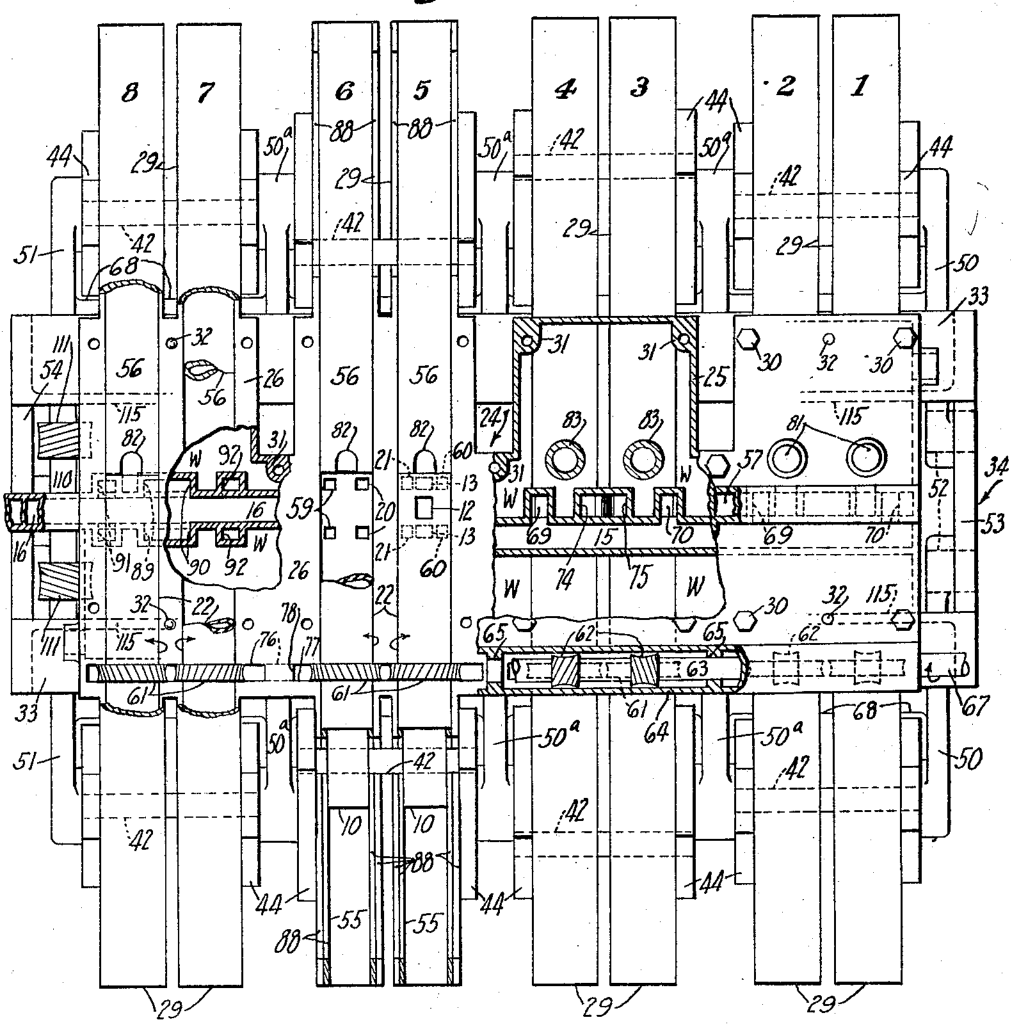
Fig. 6



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Patented Jan. 6, 1931 1,787,599

UNITED STATES PATENT OFFICE

BURNHAM C. STICKNEY, OF HILLSIDE, NEW JERSEY

INTERNAL-COMBUSTION ENGINE

Application filed March 14, 1927. Serial No. 175,336.

This invention relates to internal combustion engines and the valves therefor, and is illustrated as applied to an engine in which oppositely-aligned pistons are connected by driving trains to a common crank-shaft, although certain features of the valve-mechanism are also applicable to engines in which the pistons are not opposed. The invention further relates to improvements in the driving trains, particularly in the means for varying the leverage between the pistons and the crank-shaft, and also to the manner of connecting said means to the crank-shaft.

In the preferred form of the invention the pistons are arranged with their axes horizontal, and the opposed pistons in each pair are articulated to the upper ends of a pair of walking beams, the lower ends of the latter being articulated to pitmen which extend from opposite sides of the engine, along which said walking beams are ranged, to a common crank-shaft. The space between the heads of the pistons of each pair forms the explosion chamber, part of which is defined by a revoluble sleeve or shell which also serves as a rotary valve for opening and closing ports to periodically admit a gas-mixture to the combustion-chamber and to exhaust the burned gas therefrom. This valve may be of a type to enclose the piston and is caused to revolve once for each two revolutions of the crank-shaft, and is furthermore provided with ports which are oppositely arranged for pressure-balancing purposes. The valve or cylinder chest in which said sleeve or shell revolves has similarly arranged opposite intake-ports and also opposite exhaust-ports. The valve for each pair of pistons fits directly in a bore of the cylinder-chest, said bore being of uniform diameter and extending entirely through said chest. The revoluble sleeve or shell is located intermediately of the end portions of said bore, each end portion having fitted therein a fixed sleeve which abuts an end of the revoluble shell. The fixed sleeves and the revoluble shell thus form a pair of colinear cylinders in which the pistons reciprocate. In the preferred arrangement of the sleeves, one fixed sleeve constitutes the cylinder for one piston, while the revoluble shell or sleeve and other fixed sleeve constitute the cylinder for the other piston, which is thus caused to reciprocate in the revolving sleeve or shell, the pistons being cylindrical in form, of small diameter, and of relatively long stroke. By employing the fixed sleeves in conjunction with the revolving sleeve, all the sleeves having a uniform outside diameter, the bore of the cylinder-chest may be uniform in diameter, as already stated. The sleeves having a uniform piston-operating bore, pistons of equal diameters and strokes may be used.

The arrangement of a revolving valve as part of the engine-cylinder conduces to ease and cheapness of manufacture and simplicity of construction and operation, efficiency and durability, and gives the advantage of a rotary valve without the disadvantage that would arise from a revolving valve of larger diameter than the cylinder, as would otherwise be required if the valve and cylinders are to be coaxial. The revolving valve-shell or sleeve is provided with a worm-wheel which meshes with a worm upon a worm-shaft which carries worms for all the valves and is driven by the crank-shaft of the engine. Each revolving valve serves for two pistons, and a single spark-plug also serves for two pistons and their colinear cylinders, thus making a compactly and efficiently arranged engine due to the compactness of the valve itself. The engine-cylinders are amply water-jacketed, and the valve-driving worm-wheels and worms are mounted at the side of the water-jacketing.

The greater part of the usual clearance or compression space is within the inner end portion of the revolving sleeve or valve, and the bore of said sleeve is constricted at said end portion to keep the capacity of the compression space within the required limit. The immediately adjacent portions of the piston-bores in the adjoining fixed sleeve and in the revolving sleeve also form part of the clearance or compression space between the opposite piston-heads. The two piston-bores thus formed may be regarded as being joined by a portion of the revolving sleeve which constitutes the rotary valve proper and which rotates in a valve-chest formed by the surrounding part of the cylinder-chest bore. Intake and exhaust ports in the valve-chest part of said bore are respectively in communication with intake and exhaust manifolds which extend the whole length of the system of engine-cylinders. The ports in the revolving valves, which register periodically with said intake and exhaust ports, are keyed in a manner to avoid unbalanced pressure; there being on one side of each valve a single middle port and upon the diametrically opposite side of said valve two half ports which are in different zones from said middle port. The ports in the valve-chest portion of the aforesaid bore have a corresponding arrangement such that when the large valve-port registers with a large valve-chest port, a passage is opened into an exhaust-manifold above the cylinder-chest. At the same time the small valve-ports open into small conduits which lead to an exhaust-manifold under said cylinder-chest, so that the exhaust passes into both manifolds. Owing to the staggered keying of the opposite ports in the valve, the exhaust-valves open only once in each revolution of the half-speed valve or, in other words, once in every two revolutions of the crank-shaft. It will be understood that when the valve makes a half revolution from an exhaust-port opening position, the exhaust-ports are closed since at this time the single middle valve-port does not open into the two small side exhaust-ports in the chest, nor do the two small side ports in the valve open into the single middle port at the opposite side of the chest. The advantage is gained of having an equal area of uncovered valve-chest wall on opposite sides of the valves, thus avoiding unbalanced pressure without incurring the disadvantage of having the exhaust-port opened at every half revolution of the valve. The foregoing explanation applies likewise to the intake ports of the valve-chest, which are served by the same ports in the revolving valve.

Viewed endwise of the valve-chest bores, there are in the upper portion of each bore circumferentially-spaced large intake and exhaust ports. The large exhaust ports open into straightaway conduits which lead up to an exhaust-manifold which extends transversely of the valve-chest bores along the top of the cylinder-chest casting. Elbow conduits lead from the upper large intake-ports to an intake-manifold which also extends along the top of the engine-casting but at one side of all the exhaust-conduits and below the exhaust-manifold, thus giving, as will appear later on, compactness and simplicity of structure. Running along the bottom of the cylinder-chest there may be an intake-manifold from the sides of which extend L-shaped conduits up to small side intake-ports in the lower portions of the several valve-chest bores. Below the same may be arranged an exhaust-manifold also extending the length of the cylinder-chest and also opening by L-shaped conduits to small side exhaust-ports in said lower portions of the valve-chest bores. The lower intake-manifold extends between the lines of lower exhaust-conduits.

A feature of the invention is that the cylinder-chest structure is made of upper and lower castings. These may be fastened together, each casting having therein a row of transverse semi-cylindrical depressions which, when the castings are secured together, form the aforesaid cylinder and valve chest bores. Each of said castings is complete with its own water-jacketing and its own manifolds and conduits, and the top cylinder-chest section may be lifted off to expose the valves and the fixed sleeves or shells for examination and detachment, and also exposing the line of worm-wheels or the revoluble sleeves, at the inner ends of which said valves are formed. The worm-shaft is mounted in the upper part of the cylinder-chest. Each water-jacketing may have its own inlet and outlet pipes, and hence may be independent of the other water-jacketing. Projecting through the upper water-jacketing, and separated from the water-spaces by surrounding thimbles, are spark-plugs arranged in a row close to the upper exhaust manifold and entering the several explosion-chambers alongside the inner ends of the respective valves, the electrodes extending down through openings in the fixed shells or sleeves which abut said inner ends of the revolving valves. Each spark-plug is thus at the extreme inner end of one piston-bore and serves the opposite piston-bore through the aforesaid central opening or constriction in the revolving valve, which opening or constriction forms part of the compression space of the double-length engine cylinder.

There may be eight pairs of colinearly-arranged pistons making sixteen pistons in all, and these may co-operate with eight walking beams, of which there are four on each side of the engine. Each walking beam is connected to two adjacent pistons; a pin transfixing both of said adjacent pistons and carrying at its ends swivel slides fitting in slots in the upper ends of the walking beam. These pins extend through horizontal slots formed in the walls of tubular projections of the cylinder-chest. Said tubular projections extend beyond the water-jacketed portion of the cylinder-chest, and in them are the outer pistons of the cylinder-chest bores, said outer portions having therein the aforesaid fixed sleeves in which the pistons reciprocate. Coinciding with said slots in said tubular projections, there are slots also formed in said fixed sleeves. Said slots in the tubular projections of the cylinder-chest and in the fixed sleeves avoid interference of the reciprocating piston-pins with said tubular projections and said fixed sleeves, said pins necessarily extending from opposite sides of the pistons. The pistons, by means of said tubular projections, are adequately supported and guided in their reciprocating strokes.

The walking beams are fulcrumed upon a pair of horizontal rods extending the length of the engine, these rods being adjustable up and down, to shift the walking beams, to vary the leverage of the pistons upon the crank-shaft, and thus alter the length of strokes of the pistons. The lower ends of the walking beams are also slotted and the lower slots co-operate with slides, which are swiveled upon the ends of transverse pins, on which fit the outer ends of pitmen, which extend inwardly to the crank-pins of the crank-shaft.

The rods upon which the walking beams are fulcrumed, are mounted upon arms which swing about fulcrums located in end walls of the engine-frame and close to the crank-shaft-axis, to keep down the width of the engine. The arms at each end of a rod are joined by a tubular bar, which, in order to clear the crank-shaft and pitmen, joins said arms at points intermediate their fulcrums and shaft-supporting ends. Each tubular bar with the arms at each end, forms a walking-beam shifting frame. For shifting the frames simultaneously, one arm of each frame has a worm-wheel-sector. Each sector meshes with a worm or a single transverse shaft which is revolved by means of a rack and pinion. The rack may be driven by means of a lever or other device convenient to the driver of the engine.

Preferably each walking beam consists of a pair of spaced-apart plates joined by a hub, each pair straddling two adjacent engine-cylinders on one side of the engine, so that two adjacent pairs of opposed pistons, the two piston-pins transfixing the adjacent pistons, the two walking beams, and the pitmen connected thereto form a crank-shaft-revolving unit.

To conduce to smoother running of the crank-shaft, there is employed, in each such unit on one side, a single pitman connected to one of the walking beams, and on the other side a pair of pitmen connected to the other walking beam. The crank-pin ends of the pair of pitmen straddle the crank-pin end of the single pitman, thereby tending to reduce pounding of the crank-shaft by avoiding the effect of a couple, which, due to the simultaneous thrusts of single pitman on each side of the crank-shaft, would tend to skew said shaft. The wrists or cross-head pins at the outer ends of the pitmen work in horizontal ways, whereby the pitmen are guided at said outer ends, while up-and-down adjustments of the walking beams are at the same time permitted.

The crank-shaft may be cut from a single shaft without forging, the same having a series of eccentric cylindrical millings, whereby adjacent original sections of the shaft are joined by wrists formed by said millings, upon which are articulated the inner ends of the pitmen. The driving train from the engine-pistons to the crank-shaft, as herein provided for, permits the use of a very short crank, inasmuch as the pitmen in each of the four aforesaid crank-shaft driving units are always driven in opposite directions from opposite sides of the axis of the crank-shaft. By reason of the short cranks, the crank-shaft may be inexpensively and accurately cut from a shaft which is originally of very small diameter as compared to a shaft from which a crank-shaft of the usual large throw would have to be cut. The uncut webs of the original shaft may be relatively thin, thus keeping down the overall length, and thereby conducing to compactness. The uncut webs may also serve to a certain extent as small fly-wheels, thus conducing to even running of the engine, particularly since they are spaced at short intervals along the shaft. The crank-shaft has the usual intermediate bearing journals, preferably three, one between every two adjacent sets of the crank-pins for the several aforesaid crank-shaft-revolving units.

Other features and advantages will hereinafter appear.

In the accompanying drawings,

Figure 1 is a sectional view taken transversely of the engine through one of the crank-shaft-driving units.

Figure 2 is a part-sectional side elevation of the engine, showing at one place an end view of the cylinders, at another place a section through the closed valves, at another place a section through the valves in a different position and showing other portions of the valve-chest, and at another place through the engine-cylinders near the fixed sleeve inner ends at a place where the spark-plugs enter the cylinders. Other portions of said Figure 2 show different views of the walking beams, their supports and the parts articulated therewith.

Figure 3 is a sectional plan view, showing the crankshaft and its bearings, and also the arrangement of the four sets of pitmen, etc.

Figure 4 is a top plan view of the cylinder-chest, showing the manifolds, the water-jacketed main part of the chest, and the manner of retaining the valve-rotating shaft in said main part.

Figure 5 shows the upper casting detached from the lower casting of the engine, showing also diagrammatically the cylinder linings or fixed sleeves and valve sleeves, and the valve-revolving worm-wheels, etc.

Figure 6 is a part-sectional plan view of the engine, similar to Figure 4, but showing in detail some of the manifolds and conduits, the valve-driving gearing, the water-jacketing, the pins which transfix the pistons, the walking beams, the pitmen, etc.

The invention is shown as applied to an internal combustion engine in which pistons 10 operate in pairs. The engine is intended to operate on the usual four-stroke cycle. The pistons of each pair have colinear movements in opposite directions to and from a clearance or compression space 11, which is between and is common to two opposite and colinear cylinders in which the pistons move. Features of the invention embodied in said cylinders will be presently described in detail. It may be briefly stated at this point, however, that a portion of the colinear cylinders, which portion includes the larger part of the compression space 11, is revoluble, and has ports 12 and 13 opening from said compression (or clearance) space for admitting and discharging gas into and from the cylinders.

Fuel is admitted into each pair of colinear cylinders from an upper intake manifold 15 and a lower intake manifold 16 when the revoluble cylinder-ports 12 and 13 are in register with intake ports 18, 19, 20 and 21 (Figure 2), which, as will be presently described in detail, communicate with said manifolds. The revoluble cylinder-portion, hereinafter called the revoluble sleeve 22, controls, by means of the ports therein, the period of intake of the fuel-charge and also controls the period during which an exploded charge is expelled from the cylinders. The revoluble sleeve 22, or, in other words, the ported portion thereof thus forms a valve, and such a valve is provided for each pair of colinear pistons.

In the engine herein shown there are eight pairs of pistons, making sixteen pistons in all. It will be understood that the invention is not limted to this particular number of pistons and corresponding cylinders. There may be as few as eight pairs of pistons and cylinders, the equivalent of the usual four-cylinder engine, or the pairs of pistons and cylinders may be increased to as many as desired. Each revoluble sleeve 22 of the several cylinders is revolubly fitted within a bore formed in a cylinder-chest generally indicated by the number 24. It is a feature of the invention that said cylinder-chest 24 is made in two separable portions, an upper portion 25 and a lower portion 26, for the purpose of facilitating the manufacturing and assembling of said cylinder-chest and related parts. By making the cylinder-chest in two portions, which are joined along a plane passing through the axes of all the cylinder-bores, the molding and the machining of the cylinder-chest are substantially simplified. It will also be apparent that by reason of the separable cylinder-chest-portions, the inspection, assembly or removal of the revoluble cylinder-portions in said chest is facilitated. Each cylinder-chest-portion is water-jacketed for the usual purpose of dissipating the heat of combustion, so that the cylnders do not become overheated. It is a further feature of the invention that by keeping the water-jacketing of the two cylinder-chest-portions separate, the use of the otherwise necessary gasket between said portions is avoided. The water-spaces formed by the water-jacketing of the cylinder-chest are indicated wherever they appear in the drawings by the letter W. Figure 5 shows the cylinder-chest-portions separated, and it will be seen in said Figure 5 that each cylinder-chest-portion includes semi-cylindrical portions 28 of the bores in which the cylinders proper are retained. As shown in Figures 1, 4 and 6, said bores extend beyond the water-jacketed portion of the cylinder-chest, so as to provide for bearings of ample length for the pistons 10. In order that the bores may be thus extended, the cylinder-chest is extended beyond its water-jacketed portion in the form of tubes 29, said tubes being, of course, split along the plane in which the cylinder-chest-portions are joined.

The bores of the cylinder-chest are of even diameter throughout to facilitate machining. The separate portions of the cylinder-chest may be fastened together by bolts 30, which, as shown in Figure 2, pass through clearance holes in the upper cylinder-chest-portion, and are threaded into the lower cylinder-chest-portion. The clearance and thread-holes for said bolts are formed in suitable bosses 31. Said holes are thus separated by the walls formed by said bosses from the adjoining water-spaces in the cylinder-chest-portions. By means of dowels 32, lateral displacement of the cylinder-chest-portions relatively to one another is prevented, and said portions may be accurately relocated with respect to one another whenever they are separated after the bores have been machined. The dowel-holes are formed in bosses 27, which separate said holes from adjoining water-spaces. The bores may be roughly machined in each separate cylinder-chest-portion, but the final finishing of the bores is preferably done when the two cylinder-chest-portions are bolted and doweled together. The assembled cylinder-chest may be mounted and secured upon platforms 33 formed in a frame generally indicated by the number 34, in which, as shown particularly in Figure 1, other portions of the engine, to be described, are mounted. Said frame 34 may be elaborated or modified according to any desired practice, as, for example, to include an inclosure for retaining lubricating oil. The frame 34 herein illustrated serves mainly to keep the various portions of the engine in proper relation to one another.

The pistons 10 are operatively connected to the usual crank-shaft 35, which may be connected to the car, or other mechanism which the engine is intended to operate, by means of the usual clutch which is conventionally indicated in Figure 3 at 36. For operatively connecting the pistons 10 and the crank-shaft 35, there are connected to the pistons walking beams generally indicated by the number 37. Said walking beams are in turn connected to the crank-shaft by pitmen 38 and 39, and in a manner which forms a feature of the invention to be described later on.

Piston-operating cycles take place in recurring sequence with respect to the several pairs of colinear cylinders. According to the usual practice, one pair of pistons is operated in a power-stroke, while another pair of pistons moving in the same direction, and at the same time, sucks fuel into its cylinders. Similarly, the exhaust stroke of the first pair of pistons is accompanied by a compression stroke of the second pair of pistons. Hence, there are always two pairs of pistons operating in similar directions at the same time. Pistons which are operated in similar directions at the same time operate in two sidewise adjoining cylinders, so that each two pistons which move in unison in similar directions may operate on and be operated by one walking beam 37. By this arrangement the number of pitmen or pairs of pitmen, as will presently appear, is only one-half the number of pistons. Each walking beam 37, in order to serve two similar pistons, is formed as indicated in Figures 2, 3 and 6. As shown particularly in Figure 2, each walking beam includes an elongated hub 40, which connects two spaced-apart plates 41. Said plates and hub form a double walking beam, which straddles the pair of cylinders for the adjacent similar pistons which said walking beam serves. The pistons of each adjacent pair are transfixed by a common wrist-pin 42, the ends of which project into slots 43 formed in upper arms 44 of the walking beam (see Figure 1). Sliding blocks 45, which operate in said upper arm-slots and at the same swivel about the ends of the piston-wrist-pins 42, are for the purpose of making and completing operative connection between said upper arms 44 and the pistons which said arms of the walking beam straddle. In a similar manner slots 46 in lower arms 47 of each double walking beam have fitted therein sliding blocks 48, which are swiveled upon the ends of cross-head pins, which will be further described, said lower arms 47 being in this manner connected to the crank-shaft pitmen 38 and 39. Said cross-head pins are constrained to move horizontally in a manner also to be described in detail later on. By reason of the sliding blocks 45 and 48, and the slots and the walking beams, there may be the necessary endwise displacement of said blocks relatively to said walking beams, said endwise displacement being due to the transverse reciprocating movement of said blocks as the walking beams oscillate about a given center. The slots 43 and 46 of the walking beams are of such extent that the fulcrum of the walking beams may be shifted to change the stroke of the pistons in the manner disclosed in my Patent No. 1,753,159, April 1, 1930. By thus changing the stroke of the pistons, the power of the engine may be varied without the wasteful use of gas. As also shown in said co-pending application, there may be a change in the compression space capacity, proportionate to the change in piston-stroke, so that irrespective of the length of stroke there will always be the required degree of compression. In order that the fulcrum of the walking beams may shifted, the entire walking beams are shifted bodily, and are for this purpose fulcrumed upon a shiftable rod 49 mounted between swingable arms, which may be designated as an arm 50 at the front end of the engine and an arm 51 at the rear end of the engine. Said front and rear arms are swung upon studs 52 projecting inwardly from the front and rear walls 53 and 54, respectively, of the engine-frame 34. To keep down the over-all width of the engine, said studs 52 are located close to the axis of the crank-shaft 35. In order that a member 68 connecting each pair of the front and rear arms 50 and 51 may be clear of said crank-shaft 35, and the pitmen connected thereto, said member joins said arms at points intermediate of their fulcrums and the rod 49 which supports the walking beams. Said member 68, as shown in Figure 1, may be hollow to keep down weight. Each pair of front and rear arms 50 and 51 connected by the member 68, and supporting at their outer ends the fulcrum-rod 49, forms a frame in which the walking beams on one side of the engine are supported, and whereby said walking beams may be shifted bodily to change the stroke of the pistons. Means for simultaneously shifting the two frames, one on each side of the engine, will be described later. The fulcrum-rod 49 of each of said frames is also supported at several places between the outer arms 50 and 51 by intermediate arms 50^a, which also serve to space the walking beams along said rod. Said intermediate arms 50^a project from the outer arm-connecting member 68 of said frame.

Having indicated the general features of the means for connecting the pistons to the crank-shaft, and before describing said means in further detail, the cylinders in which said pistons operate will be at this time further described. As shown in Figure 1, the pistons are cylindrical in form, and elongated enough, so that they have a sufficient extent of bearing in their respective cylinders. According to the present embodiment of the invention, each right-hand piston reciprocates in a cylinder formed by the bore of the revoluble sleeve 22 and the bore of a fixed sleeve 55, the bores of said sleeves being exactly and truly aligned and of equal diameters, and the fixed sleeve 55 being fixed in the surrounding right-hand tube 29 of the cylinder-chest. The cylinder for each opposite or left-hand piston is formed by the bore of a fixed sleeve 56, which, as shown in Figure 1, extends from the inner end of the revoluble sleeve 22 to the outer end of the surrounding left-hand tube 29 of the cylinder-chest. Each revoluble sleeve 22 thus is between opposite ends of fixed sleeves 55 and 56. To keep the cubic capacity of the compression space 11 within the required limit, the bore of the revoluble sleeve 22 is constricted at the portion along which are disposed the ports 12 and 13, to an area, which, as shown in Figure 2, is square in section, although said area may, instead, be circular in section.

For convenience of illustration the revoluble sleeve-ports 12 and 13, in register with ports 72 and 59, respectively, in the cylinder-chest, are shown in Figure 1 as being projected upon a vertical plane. In reality, said ports 12 and 13, when in register with cylinder-chest-ports, are inclined from a vertical plane, as will be evident from an inspection of Figure 2. Said ports 72 and 59, shown in Figure 1, are exhaust ports, the upper port 72 leading into an exhaust manifold 57, and the lower port 59 leading into a lower exhaust manifold 58. The revoluble sleeve-ports 12 and 13 are disposed on diametrically opposite sides of said revoluble sleeve in a manner indicated in Figure 1, for the purpose of avoiding the effect of the otherwise unbalanced pressure within said revoluble sleeve. It may be seen that pressure reacting against the valve-chest wall through the port 12 is exactly and oppositely balanced by the pressure reacting against the opposite valve-chest wall through the ports 13, the ports 13 each being half the area of the single port 12 and staggered or offset in respect to said port 12. The reason for staggering the ports 13 relatively to the port 12 is to provide that none of said ports 12 and 13 shall open their corresponding intake and exhaust ports more than once in a single revolution of the revoluble sleeve 22.

It is a feature that the ports in the revoluble cylinder, sleeve or shell 22 are opposed, to secure internal-pressure-balance of the exploding gas. Outward pressure of the gas against any portion of the wall of the revolving sleeve or shell tends to force that portion against the inner surface of the chest 24, but undue friction from this cause is avoided by equal outward pressure of the gas upon the opposite portion of the wall of the revolving shell. This gas-pressure-balance is preserved, notwithstanding the cutting away of a portion of the wall to form a port, inasmuch as the opposite wall of the revolving shell is equally cut away. For speed of port opening and closing, and for amplitude of port-opening, the shell 22 preferably has a single complete system of porting, and one revolution of the shell serves a complete cycle of operations of the engine; the cycle in this illustration being intake, compression, explosion and exhaust. Preferably the shell-porting is common, viz., it co-operates with both intake and exhaust ports of the chest. The shell and the chest portings are co-ordinated so that, in each revolution of the shell, there is only one intaking of fuel and only one exhausting of spent gas. Such co-ordination includes the provision of one-half of the common porting in one side wall and the other half in the opposite side wall of the revolving shell. In other words, the opposing of the portings is made feasible by using two half-portings which are diametrically opposed to each other to secure pressure-balance, instead of using a single full-size port without pressure-balance. In the chest there are two opposed half-ports for intake, and likewise two opposed half-ports for exhaust. All of these half-ports in the chest lead to suitable manifold groups.

In each revolution, each of the opposed fractional portings of the common shell passes the location of each one of the fractional intakes in the chest, and also passes the location of each one of the fractional exhausts in the chest, but without intaking or exhausting more than once in each revolution. This co-ordination includes the keying of the shell-portings relatively to the chest-portings; that is, the opposed portings of the revolving shell 22 are placed in different zones or belts from each other, whereby each of the opposite shell-portings is keyed. In each revolution they can once only open the chest-intake portings, and once only open the chest-exhaust portings. The intake half-porting on one side of the chest is not in the same zone with the intake half-porting on the opposite side of the chest; and the same is true of the common shell or sleeve portings. Hence the shell 22 can open the chest-intake ports only once in each revolution. The exhaust half-ports in the opposite sides of the chest immediately precede the intake half-ports, and are similar thereto in contour and zoning or keying. Hence the common portings in the revolving shell can open the chest-exhaust ports only once in each revolution. Thus there is secured pressure-balance, speed, and amplitude of porting. If desired, the porting on one side of the revolving shell may be sub-divided into quarter-ports 13, 13, and the half-port (12) zone may occur between the quarter port (13) zones; and the chest-portings may be correspondingly placed, as illustrated, thus affording great nicety of pressure-balance, especially useful if the shell is short relatively to its diameter, and more especially if the type of revolving ported sleeve or shell is so short as not to surround the piston at all, but merely encloses the usual combustion-chamber or compression-space.

It is in order that the revoluble sleeve-ports 12 and 13 may register periodically with the intake and exhaust ports from the valve-chest, that the revoluble sleeve 22 is rotated. According to the usual practice of opening and closing the intake and exhaust ports once in every two revolutions of the crankshaft, said revoluble sleeve 22 is rotated at half the speed of the crank-shaft. Each revoluble sleeve, in order that it may be thus rotated, may have formed thereon a gear 61, which may be driven by another gear 62, mounted on a shaft 63, extending transversely of the several revoluble sleeves 22. The shaft 63 may be journaled in a housing 64, which, as shown in Figure 1, may form part of the upper cylinder-chest-portion 25 and extend the full length thereof. In order that the shaft may be journaled in said housing, there may be formed between the longitudinal walls of said housing, as indicated in Figure 6, transverse webs 65, which may be bored to receive the shaft 63. Means for connecting the revoluble sleeve-driving shaft 63 to the crank-shaft may be in the form of the usual transmission chain, indicated at 66, Figure 1, and running over the usual gears 80 and 80^a. In order to be driven by means of said chain, one end of the sleeve-rotating shaft 63 may project beyond the cylinder-chest, as indicated at 67, Figure 6. It will be understood that the relative diameters of the gears 80 and 80^a depend upon the relative speeds of the crank-shaft and revoluble sleeve-driving shaft 63, the speed of the latter depending upon the relative proportions of the gears 62 thereon and the gears 61 on the revoluble sleeves; all of said diameters, speeds and proportions being designed so that said revoluble sleeves rotate at one-half the crank-shaft speed.

The arrangement of the intake and exhaust ports in the cylinder-chest-bores in respect to the cylinder-ports 12 and 13, and also in respect to the intake and exhaust manifolds, will now be described. As already mentioned, two pairs of opposed cylinders, of which like pistons on each side of the engine operate in unison, are arranged so that said pairs are adjacent to one another, as shown particularly in Figure 2. As already stated, there is an intake manifold 15 in the upper portion 25 of the cylinder-chest, and another intake manifold 16 in the lower portion 26 of the cylinder-chest. The upper intake manifold communicates with the intake ports 18, 19 in the upper sides of the cylinder-chest-bores by means of conduits 69 and 70, said conduits being L-shaped, because the upper intake manifold 15 is offset to one side of the ports 18 and 19 communicating therewith. Said ports 18 and 19 are arranged in the path of the single large or full-area port 12, which is formed in the revoluble sleeve 22. In a similar manner, the intake ports 20 and 21 in the lower sides of the cylinder-chest-bores are disposed in the path of the ports 13 of the revoluble sleeve. The upper exhaust manifold 57 extending longitudinally along the top of the upper portion of the cylinder-chest communicates with exhaust ports 72 and 73 in the upper sides of the cylinder-chest-bores.

It is a feature of the arrangement of the exhaust ports 72 and 73 that substantially straight-away passages 74 and 75 therefrom merge into each other as said passages open into the upper exhaust manifold 57. Said feature is best shown in connection with the third pair of colinear cylinders from the left of Figure 2. In a similar manner, passages 89 and 90 from the lower intake ports 20 and 21 merge into one another as they are directed toward the lower intake manifold 16. A view of said intake passages as they thus merge into the lower intake manifold is best shown in connection with the second pair of colinear cylinders, from the left, in Figure 2. Viewing the individual pairs of colinear cylinders endwise, as in Figure 2, there are between the cylinders of each of said pairs and in the upper portion of the cylinder-chest, the exhaust ports 72 and 73 and passages 74 and 75; intake ports 18 and 19 and passages or conduits 69 and 70 being at the outer sides of said each pair of cylinders. In the lower portion of the cylinder-chest the ports 20 and 21 and passages 89 and 90 disposed between the cylinders of each pair of colinear cylinders are for intake, while the ports 59 and 60 and passages 91 and 92 disposed on the outer side of said cylinders are for exhaust. The lower intake passages 89 communicate with the lower intake manifold 16, which extends along and within the lower cylinder-chest portion between opposite rows of said lower intake passages. Similarly, the lower exhaust passages 91 and 92 communicate with the lower exhaust manifold 58, which extends along the bottom of said lower cylinder-chest-portion and is between opposite rows of said lower exhaust passages. In this manner, intake ports are arranged on diametrically opposite sides of the several cylinder-chest-bores, and the exhaust ports are also so arranged. Due to what may be called the reverse diagonal arrangement of the ports of one cylinder in respect to the arrangement of similar ports in an adjacent cylinder, as just described, it is necessary that the revoluble sleeves 22 of each pair of colinear cylinders rotate in opposite directions, as indicated by the arrows in Figure 2. This is readily accomplished by inclining the helices of the revoluble sleeve-gears 61 and the corresponding driving gears 62 for the paired revoluble sleeves in opposite directions, as indicated in Figure 6.

The inner sides of the housing 64 for the sleeve-driving shaft may extend straight downwardly to the bottom of the cylinder-chest-portion in which said housing is formed. The space thus formed, and not occupied by the sleeve-driving gearing therein, may be filled with lubricant. The lower cylinder-chest-portion may have a trough 76 extending longitudinally thereof for clearing the gears 61 on the several rotary revoluble sleeves 22. The sides of said trough may be finished to form bearings for the sides of the revoluble sleeve-gear 61, and thus serve to retain the revoluble sleeves 22 longitudinally of their respective bores in the cylinder-chest. The side wall 77 of the lower cylinder-chest-portion, which side wall also is a side wall of said trough 76, may be tied to the main body of said lower cylinder-chest-portion at several places along its upper edge, by webs 78, which bridge the top of said trough.

To insure retention of the fixed sleeves 55 and 56 longitudinally of their bores, suitable means may be used, as, for example, a key 79, Figure 1, which may be driven through the wall of a fixed sleeve and the wall of the cylinder-chest-tube 29, in which said fixed sleeve is retained.

Each pair of colinear cylinders being served by a common rotary valve embodied in the revoluble sleeve 22, is also served by a common ignition plug 81. As shown in Figure 1, the electrodes of said ignition plug, which projects through the top of the upper cylinder-chest-portion, are just outside the bore in which the left-hand piston, as seen in Figure 1, reciprocates. An opening 82 in the fixed sleeve 56, in which said piston reciprocates, is opposite the opening in the upper cylinder-chest-portion through which said ignition plug is inserted. The extreme positions of the piston-heads at the end of an inward or compression stroke are represented by the broken lines 10^a, Figure 1. In order that the left-hand pistons may not cover the electrodes at the end of said stroke, the piston-heads of the left-hand pistons must not pass entirely beyond the openings 82 through which the ignition-plug electrodes communicate with the several compression chambers 11. In other words, according to the arrangement of parts shown in Figure 1, the extreme position reached by the piston-head of each left-hand piston must be such as to leave sufficient room between said piston-head and the end of the revoluble sleeve 22, to afford communication between the ignition-plug electrodes and the compression chamber 11 for proper ignition of the charge in said compression chamber. As shown in Figures 1, 2 and 6, the openings in the upper cylinder-chest in which the ignition plugs are inserted are formed in thimbles 83, which separate said openings from the surrounding water-spaces in said upper cylinder-chest-portion.

The semi-cylindrical portions of the tubes 29 of the separate cylinder-chest-portions may be stiffened by having ribs cast integral with said semi-cylindrical portions, and said ribs, sectionally, may be of the form indicated at 84, Figure 2, and extend longitudinally of said portions almost to the end thereof. The use of these ribs is optional. Said semi-cylindrical portions of the tubes, however, should be clamped together at their ends to secure rigidity. Suitable clamping means for this purpose may consist, as shown in Figures 4 and 5, of an upper bar 85 and a lower bar 86, said bars spanning a pair of sidewise adjacent tubes 29, and being drawn together to clamp said tube-portions together by a screw 87, which has a clearance hole in the upper bar 85, and is threaded into the lower bar 86.

As previously mentioned, each walking beam 37 is connected to a pair of sidewise adjacent pistons by means including the transverse wrist-pin 42 which transfixes said pistons. To clear said pin as it reciprocates back and forth, the walls of the fixed sleeves 55 and 56 and the cylinder-chest-tubes 29 have slots indicated in Figures 1 and 6 by the number 88. In Figure 1 the slots 88 are shown as forming a bearing for the pins 42. Said slots, however, may clear said pins if they are fixed in their respective pistons.

The lower arms 47 of the several walking beams 37 are connected to the outer ends of the pitmen 38 and 39. A novel feature of the invention is in the arrangement and construction of said pitmen in respect to the walking beams and crank-shaft. Due to the simultaneous operation of the oppositely-disposed pistons 10 an explosion stroke in a pair of colinear cylinders, in which said pistons operate, reacts simultaneously upon said pistons. By means of the walking beams 37 and the pitmen to be described, the power thus developed is applied at diametrically opposite sides of the crank-shaft for the purpose of balancing the engine and securing smooth running of the crank-shaft. The aforesaid novel feature of the present invention, which conduces still further to smooth running of the crank-shaft, is an arrangement of crank-pins and pitmen, whereby the opposite thrusts, which said crank-shaft receives from or imposes upon the pitmen connected thereto, are applied in such manner as to avoid the effect of the mechanical couple, which heretofore, whenever oppositely-working pitmen were used, tended to skew the shaft.

According to the present arrangement of the crank-pins, and considering one pair of opposite walking beams alone, a single crank-pin 93 on one side of the crank-shaft is connected to one of said walking beams on one side of the engine by a single pitman 38. Straddling said single crank-pin 93 is a pair of diametrically opposite crank-pins 94, which are connected to the walking beam on the other side of the engine by means of two pitmen 39. The two opposite walking beams, each serving two sidewise adjacent pistons, as already explained, constitute, with said pistons and the pitmen 38 and 39, just described, a crank-shaft driving unit. In the engine herein shown, there are four such units, since there are sixteen pistons. In respect to the several pairs of pitmen 39 and the several single pitmen 38, they may be arranged along each side of the crank-shaft axis in the manner shown in Figure 3. According to said figure, there are at the near side of the crank-shaft axis four walking beams, of which only the lower arms 47 are indicated. The two middle walking beams at said near side are each connected to a single pitman 38, and the two outer ones are each connected to doubled pitmen 39. On the other side of the crank-shaft axis of the four walking beams indicated by their lower arms 47 thereof, the two outer ones are connected to a single pitman 38, and the two inner ones are connected to doubled pitmen 39. The walking beams are all alike in form. A walking beam that is connected to a single pitman 38 is connected to said pitman by means of a cross-head-pin 95 and the previously-mentioned sliding block 48 guided in the aforesaid slots 46 of the lower walking beam arms 47. Said cross-head-pin extends transversely of a bifurcated outer end 96 of said single pitman, and is constrained to reciprocate horizontally by means of cross-head-blocks 97 guided in ways 98, projected upwardly from the bed 99 of the engine-frame 34. Each cross-head-block 97, of which there are two for each cross-head-pin 95, is disposed, as shown in figures 2 and 3, between an adjacent sliding block 48 and a branch of the bifurcated end 96 of the single pitman 38.

Each walking beam that is connected to a pair of pitmen 38 is connected to said pitmen by means of cross-head-pins 100, which may be formed at opposite ends of a cross-head-block 101 that is constrained to reciprocate horizontally in ways 102 that are similar to the ways 98, just described. The outer ends or heads of said pairs of pitmen 38 fit said cross-head-pins 100, and each end or head is disposed, as shown in Figures 2 and 3, between an adjacent walking-beam sliding block 48 and an end of its cross-head-block 101.

Four sets of opposite crank-pins, each set consisting of the single crank-pin 93 and the two opposite crank-pins 94, are arranged in quadrature, as viewed endwise of the crank-shaft. Longitudinally of the crank-shaft the order of quadrature corresponds to the order in which similar strokes of the operating cycles occur throughout the eight pairs of colinear cylinders. For eight pairs of cylinders numbered from 1 to 8, as shown in Figure 6, and with each single crank-pin 93 or pair of crank-pins 94 serving two pistons, in the manner explained, the firing order for the arrangement of the engine, herein shown, is 1—5—8—4—2—6—7—3.

Between each two adjacent sets of crank-pins 93 and 94 there may be crank-shaft-journal 103, which may rotate in a bearing 104 extending upwardly from the bed 99 of the engine-frame. The rear journal of the crank-shaft may have a bearing 105 formed in the rear wall 54 of the engine-frame. The front crank-shaft-journal has a bearing 106, which removably fits an opening in the front engine-frame wall 53 and through which opening the crank-shaft may be inserted and withdrawn. To facilitate the insertion and removal of the crank-shaft the intermediate bearing-standards 107 are detachably secured to the engine-frame bed 99. The inner ends or heads of the pitmen are split in the usual manner, the split being conventionally indicated at 116, Figure 1.

The circumferential extent of the several ports in the revoluble sleeve 22 and also of the intake and exhaust ports in the cylinder-chest-bores may be proportioned according to any desired practice of opening and closing the intake and exhaust ports. The extent, longitudinally of the cylinders, of the intake and exhaust ports should not be less than the corresponding extent of the revoluble sleeve-ports co-operating therewith. It will be apparent that the intake and exhaust ports in the cylinder-chest-bores may be easily made to the required size, because easy access is had to said ports by reason of the separable cylinder-chest-portions, which, in this respect alone, afford a substantial advantage conducing to ease and economy of manufacture.

Each cylinder-chest-portion has its own water inlet and outlet, an inlet and outlet being preferably disposed at diagonally opposite corners of the cylinder-chest-portion in which they are formed. Said inlets and outlets are indicated by the number 108 and are connected to the usual radiator (not shown). On account of the outlets in each cylinder being at substantially the same level, a pump (not shown) should be used to insure proper water circulation.

For shifting the walking beams simultaneously to change the positions of their fulcrum-rods 49 in respect to the aforesaid cross-head-pins and piston-wrist-pins, and thus change the stroke of the pistons, the aforementioned frames in which said rods are supported are shifted simultaneously. For doing this, each rear arm 51 of said frames may have formed or mounted thereon, concentric with its fulcrum-stud 52, a worm-sector 109. By means of said sectors and a shaft 110, having worms 111 meshing with said sectors, said walking-beam supporting frames may, by rotating said shaft, be moved simultaneously in a manner similar to that described in my aforesaid Patent No. 1,753,159. Said shaft may have a gear 112 meshing with a pinion 113 (Figure 1), which may be connected to an external lever or wheel (not shown), so that said shaft may be easily controlled from any desired point or station. Said shaft 110 may be journaled in webs 115, which extend lengthwise of the engine-frame and serve also to stiffen said frame.

In Figure 1 the walking-beam fulcrum-rods 49 are shown in such position that the stroke of the pistons is equal to the throw of the crank-shaft. The dotted circles 117 indicate the extent to which said fulcrum-rods may be shifted for shorter piston-strokes. The extent to which the fulcrum-rods may be shifted for longer piston-strokes is indicated by the dotted circles 118.

Owing to the short throw of the crank-arms, the crank-shaft may be formed from a cylindrical rod instead of the usual forging. The eccentric cylindrical millings which form the several crankpins 93 and 94 are separated from one another and from adjacent crank-shaft-journals by webs 119 left by the uncut portions of said rod. Said webs, distributed along the shaft, act as small fly-wheels and conduce to this extent to smooth running of the crank-shaft.

As will be seen in Figure 2, the cylinders are not evenly spaced individually, but are spaced evenly in pairs, each pair having those cylinders in which the pistons, as already explained, move simultaneously in the same direction. The extent to which the several pairs of adjacent cylinders are spaced apart and the arrangement of walking beams, pitmen, crank-pins and crank-bearings are mutually dependent upon each other. Each may, within the scope of the invention, be modified somewhat to suit the other. The cylinder-spacing and arrangement of the walking beams, etc., as illustrated herein affords a compact engine, easily assembled, and having parts easy of access for repairs, replacement or adjustment.

The intake manifolds 15 and 16 may be connected to the usual carburetor (not shown). For high speeds of operation fuel may be forced into the several cylinders by means of a blower or supercharger (not shown), so that a full charge of fuel is supplied to the cylinders at said high speeds.

The exhaust manifolds are connected to the usual muffler, or may discharge into the atmosphere.

The upper and lower cylinder-chest-portions 25 and 26, respectively, are so joined that the bottom surface of the lower wall 120 (Figures 1 and 2) of the upper cylinder-chest-portion makes close contact with the upper surface of the upper wall 121 of the lower cylinder-chest-portion, each of said surfaces being machined to a plane for this purpose. The portions of the bores within the water-jacketed portions of the cylinder-chest are formed in tubes 122 of which the aforesaid outer tubes 29 may be regarded as extensions. The aforesaid intake and exhaust passages are at about the middle of said tubes 122 and extend therefrom radially toward the several aforesaid exhaust and intake manifolds. All of said passages, semi-cylindrical portions of said tubes, walls and manifolds are cast integral with their respective cylinder-chest-portions, and may, by reason of the novel arrangement thereof, as herein set forth, be cast without the use of complicated patterns and molds.

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, including a bored chest, a lining in the bore of said chest, said lining forming a pair of colinear cylinders and consisting of stationary end-portions, and a revoluble intermediate portion, part of said intermediate portion forming a compression space common to a pair of opposed pistons working in said cylinders, the compression-space part of said intermediate portion having ports co-operating with intake and exhaust ports formed in said bore, and means for revolving said intermediate portion to cause its ports to periodically register with said intake and exhaust ports.

2. In an internal combustion engine including a pair of oppositely-aligned pistons, a cylinder-chest therefor having a bored tube, two sleeves fitting the bore and being fixed therein, each of said sleeves extending from the ends of said tube toward the middle portion of the lengthwise extent of said tube, and a revoluble sleeve in said middle portion revolubly fitting said bore, said fixed and revoluble sleeves forming a pair of colinear cylinders in which said pistons may reciprocate in opposite directions, a portion of said revoluble sleeve forming a common compression or clearance space which includes a portion of said revoluble sleeve, said portions of said revoluble sleeve having ports co-operating with intake and exhaust ports formed in said tube.

3. In an internal combustion engine including a pair of oppositely-aligned pistons,

a cylinder-chest therefor having a bored tube, two sleeves fitting the bore and being fixed therein, each of said sleeves extending from the ends of said tube toward the middle portion of the lengthwise extent of said tube, and a revoluble sleeve in said middle portion revolubly fitting said bore, said fixed and revoluble sleeves forming a pair of colinear cylinders in which said pistons may reciprocate in opposite directions, a portion of said revoluble sleeve forming a common compression or clearance space which includes a portion of said revoluble sleeve, said portion of said revoluble sleeve having ports co-operating with intake and exhaust ports formed in said tube, the cylinder-chest including water-jacketing which separates said tube from the exterior of the cylinder-chest, said chest also including passages formed therein and connecting the tube intake and exhaust ports to said exterior of said chest.

4. In an internal combustion engine including a pair of oppositely-aligned pistons, a cylinder-chest therefor having a bored tube, two sleeves fitting the bore and being fixed therein, each of said sleeves extending from the ends of said tube toward the middle portion of the lengthwise extent of said tube, and a revoluble sleeve in said middle portion revolubly fitting said bore, said fixed and revoluble sleeves forming a pair of colinear cylinders in which said pistons may reciprocate in opposite directions, a portion of said revoluble sleeve forming a common compression or clearance space which includes a portion of said revoluble sleeve, said portion of said revoluble sleeve having ports co-operating with intake and exhaust ports formed in said tube and disposed in the path of the revoluble sleeve-ports.

5. An internal combustion engine including a plurality of pairs of oppositely-aligned pistons, a cylinder-chest therefor having a plurality of bored tubes, one for each pair of pistons, two sleeves in the bore of each tube, said sleeves fitting said bore and being fixed therein, said sleeves extending from opposite ends of their tube toward the middle portion thereof, and a plurality of revoluble sleeves, one for each tube and revolubly fitted in said middle portion thereof, the fixed and revoluble sleeves in each tube forming a pair of colinear cylinders in which a pair of said pistons may reciprocate in opposite directions from and toward a common compression or clearance space which includes a portion of the revoluble sleeve, the compression-space portion of each revoluble sleeve having ports co-operating with intake and exhaust ports formed in its respective tube, the cylinder-chest including water-jacketing which separates said tubes from the exterior of the cylinder-chest, said chest also including passages connecting the several intake and exhaust tube ports to the exterior of said chest.

6. An internal combustion engine including a plurality of pairs of oppositely-aligned pistons, a crank-shaft, a cylinder-chest for said pistons, said chest having a plurality of bored cylinder-tubes, one for each pair of pistons, and a plurality of revoluble sleeves, one for each tube revolubly fitted therein, the revoluble sleeve in each tube forming part of a pair of colinear cylinders in which a pair of said pistons may reciprocate in opposite directions from and toward a common compression or clearance space which includes a portion of the revoluble sleeve, the compression-space portion of each revoluble sleeve having ports co-operating with intake and exhaust ports formed in its respective tube, the compression-space portion of each revoluble sleeve also being constricted to limit the cubic capacity of the compression or clearance space.

7. An internal combustion engine including a cylinder-chest having a pair of parallel, side-by-side bores, two revoluble sleeves, one in each bore, each sleeve serving as a piston-cylinder, a compression or clearance space in each cylinder, said space including part of the revoluble sleeve, said part of the sleeve having ports at diametrically-opposite sides thereof co-operating with intake and exhaust ports formed in the cylinder-chest bore in which it revolves, each bore having intake ports disposed at diametrically-opposite sides thereof, said each bore also having exhaust ports disposed at diametrically-opposite sides thereof, but spaced circumferentially from the intake ports of said each bore, the direction in which the ports are thus spaced circumferentially in one bore being opposite to the direction of said spacing in the other bore, the opposite intake ports and the opposite exhaust ports of each bore being diagonally arranged in respect to a plane through the axes of said bores so that on one side of said plane there are two exhaust ports, one for each bore, inclined toward each other, and on the opposite side of said plane two intake ports, one for each bore, also inclined toward each other, exhaust passages leading from said exhaust ports, and intake passages leading from said intake ports, the exhaust passages due to the inclination of the exhaust ports merging into one another, the intake passages due to the inclination of the intake ports also merging into one another, the remaining intake and exhaust ports of said bores on each side of said plane also having intake and exhaust passages respectively, said remaining ports and their passages being disposed at the outer sides of the pair of bores on account of the aforesaid diagonal arrangement of all the ports.

8. An internal combustion engine including a cylinder-chest having a pair of parallel, side-by-side bores, two revoluble sleeves, one in each bore, each sleeve serving as a piston-

cylinder, a compression or clearance space in each cylinder, said space including part of the revoluble sleeve, said part of the sleeve having ports at diametrically-opposite sides thereof co-operating with intake and exhaust ports formed in the cylinder-chest bore in which it revolves, each bore having intake ports disposed at diametrically-opposite sides thereof, said each bore also having exhaust ports disposed at diametrically-opposite sides thereof, but spaced circumferentially from the intake ports of said each bore, the direction in which the ports are thus spaced circumferentially in one bore being opposite to the direction of said spacing in the other bore, the opposite intake ports and the opposite exhaust ports of each bore being diagonally arranged in respect to a plane through the axes of said bores so that on one side of said plane there are two exhaust ports, one for each bore inclined toward each other, and on the opposite side of said plane two intake ports, one for each bore also inclined toward each other, exhaust passages leading from said exhaust ports, intake passages leading from said intake ports, the exhaust passages due to the inclination of the exhaust ports merging into one another, the intake passages due to the inclination of the intake ports also merging into one another, the remaining intake and exhaust ports of said bores, on each side of said plane, also having intake and exhaust passages respectively, said remaining ports and their passages being disposed at the outer sides of the pair of bores on account of the aforesaid diagonal arrangement of all the ports, an intake manifold and an exhaust manifold with which the intake and exhaust passages respectively on one side of said plane communicate, and another intake manifold and another exhaust manifold with which the intake and exhaust passages on the opposite side of said plane communicate.

9. An internal combustion engine including a cylinder-chest having a pair of parallel, side-by-side bores, two revoluble sleeves, one in each bore, each sleeve serving as a piston-cylinder, a compression or clearance space in each cylinder, said space including part of the revoluble sleeve, said part of the sleeve having ports at diametrically-opposite sides thereof co-operating with intake and exhaust ports formed in the cylinder-chest bore in which it revolves, each bore having intake ports disposed at diametrically-opposite sides thereof, said each bore also having exhaust ports disposed at diametrically-opposite sides thereof, but spaced circumferentially from the intake ports of said each bore, the direction in which the ports are thus spaced circumferentially in one bore being opposite to the direction of said spacing in the other bore, the opposite intake ports and the opposite exhaust ports of each bore being diagonally arranged in respect to a plane through the axes of said bores so that on one side of said plane there are two exhaust ports, one for each bore inclined toward each other, and on the opposite side of said plane two intake ports, one for each bore also inclined toward each other, exhaust passages leading from said exhaust ports, intake passages leading from said intake ports, the exhaust passages due to the inclination of the exhaust ports merging into one another, the intake passages due to the inclination of the intake ports also merging into one another, the remaining intake and exhaust ports of said bores on each side of said plane also having intake and exhaust passages respectively, said remaining ports and their passages being disposed at the outer sides of the pair of bores on account of the aforesaid diagonal arrangement of all the ports, an intake manifold and an exhaust manifold with which the intake and exhaust passages respectively on one side of said plane communicate, and another intake and another exhaust manifold with which the intake and exhaust passages on the opposite side of said plane communicate, said passages and manifolds being formed integral with said cylinder-chest.

10. An internal combustion engine including a cylinder-chest having a pair of parallel, side-by-side bores, two revoluble sleeves, one in each bore, each sleeve serving as a piston-cylinder, a compression or clearance space in each cylinder, said space including part of the revoluble sleeve, said part of the sleeve having ports at diametrically-opposite sides thereof co-operating with intake and exhaust ports formed in the cylinder-chest bore in which it revolves, each bore having intake ports disposed at diametrically-opposite sides thereof, said each bore also having exhaust ports disposed at diametrically-opposite sides thereof, but spaced circumferentially from the intake ports of said each bore, the direction in which the ports are thus spaced circumferentially in one bore being opposite to the direction of said spacing in the other bore, the opposite intake ports and the opposite exhaust ports of each bore being diagonally arranged in respect to a plane through the axes of said bores so that on one side of said plane there are two exhaust ports, one for each bore inclined toward each other, and on the opposite side of said plane two intake ports, one for each bore also inclined toward each other, exhaust passages leading from said exhaust ports, intake passages leading from said intake ports, the exhaust passages due to the inclination of the exhaust ports merging into one another, the intake passages due to the inclination of the intake ports also merging into one another, the remaining intake and exhaust ports of said bores on each side of said plane also having

intake and exhaust passages respectively, said remaining ports and their passages being disposed at the outer sides of the pair of bores on account of the aforesaid diagonal arrangement of all the ports, an intake manifold and an exhaust manifold with which the intake and exhaust passages respectively on one side of said plane communicate, and another intake manifold and another exhaust manifold with which the intake and exhaust passages on the opposite side of said plane communicate, said passages and manifolds being formed integral with said cylinder-chest, said cylinder-chest consisting of two separable parts which are joined at said plane.

11. An internal combustion engine including a two-part cylinder-chest having a plurality of parallel, side-by-side bores, the parts of said cylinder-chest being longitudinally divided and separable and joined at a plane in which lie the axes of said bores, a plurality of revoluble sleeves, one in each bore, each sleeve serving as a piston-cylinder, a compression or clearance space in each cylinder, each sleeve having ports at diametrically-opposite sides thereof co-operating with intake and exhaust ports formed in the cylinder-chest bore in which it revolves, exhaust passages in each chest part leading from the exhaust ports of the several bores, and intake passages in each chest part leading from the intake ports of the several bores; each chest part having a complete closed intake manifold and a complete closed exhaust manifold.

12. An internal combustion engine including a two-part cylinder-chest having a plurality of parallel, side-by-side bores, the parts of said cylinder-chest being longitudinally divided and separable and joined at a plane in which lie the axes of said bores, a plurality of revoluble valve-members, one in each bore, each valve-member having ports at diametrically-opposite sides thereof co-operating with intake and exhaust ports formed in the chest bore in which it revolves, each bore having intake ports disposed at opposite sides thereof, and also having exhaust ports disposed at opposite sides thereof but spaced from the intake ports of said each bore, the intake and exhaust ports of each of the bores in each cylinder-chest part having intake and exhaust passages, respectively, a complete closed intake manifold and a complete closed exhaust manifold for one cylinder-chest part and communicating respectively only with the intake and exhaust passages therein, and another complete closed intake manifold and another complete closed exhaust manifold for the other cylinder-chest part and communicating respectively with the intake and exhaust passages only in said other cylinder-chest part.

13. An internal combustion engine including a two-part cylinder-chest having a plurality of pairs of parallel, side-by-side bores, the parts of said cylinder-chest being separable and joined at a plane passing through the axes of said bores, a plurality of revoluble sleeves, one in each bore, each sleeve serving as a piston-cylinder, a compression or clearance space in each cylinder, said space including part of the revoluble sleeve, said part of each sleeve having ports at diametrically-opposite sides thereof co-operating with intake and exhaust ports formed in the cylinder-chest bore in which it revolves, each bore of a pair of bores having intake ports disposed at diametrically-opposite sides thereof, said each bore also having exhaust ports disposed at diametrically-opposite sides thereof but spaced from the intake ports of said each bore, the opposite intake ports and the opposite exhaust ports of each bore of a pair being diagonally arranged in respect to the plane at which said parts of the cylinder-chest are joined, a complete closed intake manifold and a complete closed exhaust manifold for one cylinder-chest part and communicating respectively only with the intake and exhaust ports therein, and another complete closed intake manifold and another complete closed exhaust manifold for the other cylinder-chest part and communicating respectively only with the intake and exhaust ports in said other cylinder-chest part, said manifolds being formed integral with their respective cylinder-chest parts, each cylinder-chest part having its own closed complete water-jacketing.

14. An engine including a revoluble cylinder, a piston reciprocating in said cylinder, a bored chest in which said cylinder revolves, said cylinder having a clearance-portion, said clearance-portion having a single system of opposed fractional ports in different zones, each being both an intake and an exhaust port, opposed fractional intake-ports and opposed fractional exhaust-ports formed in different zones in said chest, and means for causing said cylinder to make one complete revolution for every complete cycle of operations of the engine, to cause its opposed fractional ports to register co-ordinately first with the fractional intake ports and then with the fractional exhaust ports of said chest.

15. An engine including a revoluble shell, a reciprocating piston, a chest in which said shell revolves, said shell provided with opposed portings to secure internal-pressure-balance, said portings forming a single complete system common to both intake and exhaust, and means to revolve said shell once for each complete cycle of operations of the engine, said chest having a system of exhaust portings co-ordinated with the shell-portings, and said chest also having a system of intake-portings co-ordinated with said shell-portings, so that, in each revolution of the shell, there occurs only one intak-

ing and only one exhausting, said shell having its said porting-capacity divided equally between said opposed common ports, each common port having a fraction of the entire porting-capacity for both intake and discharge, the chest having its intake-portings opposed for simultaneous admission, and the intake-capacity of the chest being divided equally among its said portings, said chest having also its exhaust-ports opposed for simultaneous exhaust, the exhaust-capacity of said chest being equally divided among said exhaust-ports, the respective shell and chest ports being keyed by means of the location of the opposed common shell-ports in different belts or zones and by a co-ordinated location of each of the fractional intake ports and fractional exhaust-ports in the chest, to enable the common shell-ports to pass idly by one set of intake and exhaust chest-portings and to register with the other set of intake and exhaust chest-portings in each revolution.

16. An engine including a revoluble shell, a reciprocating piston, a chest in which said shell revolves, said shell provided with opposed portings to secure internal-pressure-balance, said portings forming a single complete system common to both intake and exhaust, and means to revolve said shell once for each complete cycle of operations of the engine, said chest having a system of portings co-ordinated with the shell-portings, so that, in each revolution of the shell, there occurs only one intaking and only one exhausting, said shell having its said porting-capacity divided equally between said opposed ports, each port having a fraction of the entire porting-capacity for either intake or discharge, the chest having opposed intake-ports for simultaneous admission, and the intake-capacity of the chest being divided equally among said ports, said chest having also opposed exhaust-ports for simultaneous exhaust, the exhaust-capacity of said chest being equally divided between said exhaust-ports, the respective shell and chest ports being keyed by means of the location of the opposed shell-ports in different belts or zones and by a co-ordinated location of each of the fractional intake and exhaust ports in the chest, to enable the shell-ports to pass idly by one set of chest-portings and to register with the other set of chest-portings in each revolution, said shell having on one side a common porting in one zoning and having on the other side a common porting in different zoning, said chest having intake-portings at its opposite sides, one in one zoning and one in the other, and said chest also having exhaust-portings on its opposite sides, one in one zoning and one in the other.

17. An engine including a revoluble shell, a reciprocating piston, a chest in which said shell revolves, said shell provided with opposed portings to secure internal-pressure-balance, said portings forming a single complete system common to both intake and exhaust, and means to revolve said shell once for each complete cycle of operations of the engine, said chest having a system of portings co-ordinated with the shell-portings, so that, in each revolution of the shell, there occurs only one intaking and only one exhausting, said shell having its said porting-capacity divided equally between said opposed ports, each port having a fraction of the entire porting-capacity for either intake or discharge, the chest having opposed intake-ports for simultaneous admission, and the intake-capacity of the chest being divided equally among said ports, said chest having also opposed exhaust-ports for simultaneous exhaust, the exhaust-capacity of said chest being equally divided between said exhaust-ports, the respective shell and chest ports being keyed by means of the location of the opposed shell-ports in different belts or zones and by a co-ordinated location of each of the fractional intake and exhaust ports in the chest, to enable the shell-ports to pass idly by one set of chest-portings and to register with the other set of chest-portings in each revolution, said shell having on one side a common porting in one zoning and having on the other side a common porting in different zoning, said chest having intake-portings at its opposite sides, one in one zoning and one in the other, and said chest also having exhaust-portings on its opposite sides, one in one zoning and one in the other, the porting on one side of the shell being sub-divided into quarter-ports, and the half-port zone of the shell occurring between the quarter-port zones, and the chest-portings being correspondingly placed.

18. An internal combustion engine including a plurality of pairs of pistons, the pistons in each pair being colinear, a crank-shaft driven by the pistons, a cylinder-chest for said pistons, said chest having a plurality of bored cylinder-tubes, one tube for each pair of colinear pistons, and a plurality of revoluble sleeves, one fitted in each tube, the revoluble sleeve in each tube forming one of colinear cylinders in which a colinear pair of said pistons reciprocate oppositely to each other from and toward a common compression or clearance space which includes a portion of the revoluble sleeve, the compression-space portion of each revoluble sleeve having ports co-operating with intake and exhaust ports formed in its respective tube, and means operatively connecting said revoluble sleeves and crank-shaft for rotating said sleeves and thereby causing their ports to periodically register with said intake and exhaust ports.

19. An internal combustion engine including a plurality of pairs of pistons, the pis-

tons in each pair being colinear, a crank-shaft driven by the pistons, a cylinder-chest for said pistons, said chest having a plurality of bored cylinder-tubes, one tube for each pair of colinear pistons, and a plurality of revoluble sleeves, one fitted in each tube, the revoluble sleeve in each tube forming one of colinear cylinders in which a colinear pair of said pistons reciprocate oppositely to each other from and toward a common compression or clearance space which included a portion of the revoluble sleeve, the compression-space portion of each revoluble sleeve having ports co-operating with intake and exhaust ports formed in its respective tube, means operatively connecting said revoluble sleeves and crank-shaft for rotating said sleeves and thereby causing their ports to periodically register with said intake and exhaust ports, and a plurality of ignition plugs, one for each pair of colinear cylinders, each of said ignition plugs being so disposed that its respective electrodes are in communication with the compression or clearance spaces of its pair of colinear cylinders.

20. An internal combustion engine including a crank-shaft, a piston connected to said crank-shaft, a revoluble shell enclosing a compression space, a chest enclosing said shell and having an inner wall within which said shell revolves, said shell having a set of complementary portings opposed for pressure-balancing purposes, the porting at one portion of the circumference of said shell being out of the circumferential zone of the opposed complementary porting, correspondingly disposed complementary intake portings succeeded by complementary exhaust portings all formed in said inner wall of said chest and located to effect co-operative registration of said shell-portings with each of the intake and exhaust portings in said chest-wall only once in each cycle of two revolutions of the crank-shaft, whereby the shell-portings may pass idly by the chest-portings at appropriate portions of the shell revolution, and means connecting said shell and crank-shaft, whereby said shell is revolved to cause registration of the shell-ports only once in each cycle with the intake and exhaust ports in said chest-wall.

21. An engine including a reciprocating piston and a revoluble valve-member, a bored chest in which said valve-member revolves, said valve-member provided with opposed fractional ports, each of which is common to both intake and exhaust, said ports in different zones, opposed fractional intake-ports and opposed fractional exhaust-ports being formed in correspondingly different zones in said chest, said valve-ports being keyed with said chest-ports, and means for revolving said valve in a single plane to cause its said fractional common ports to register first with fractional exhaust-ports of said chest and then with fractional intake-ports of said chest.

22. An internal combustion engine including a revoluble valve, a piston, a chest to which said valve is fitted and in which it revolves, said valve enclosing a compression space, said valve having a single common port of given area disposed in one zone opposite to two half-area common ports in other zones for pressure-balancing purposes, a set of intake-ports correspondingly formed and zoned in said chest, a set of exhaust-ports also correspondingly formed and zoned in said chest, the ports in said valve being co-operative with both said intake-ports and said exhaust-ports, and means for revolving said valve to cause its opposite common ports in each cycle to register first with said exhaust-ports and then with said intake-ports, at one portion of the revolution of said valve, and to pass idly by both said exhaust-ports and said intake-ports at another portion of the revolution of said valve.

23. An internal combustion engine, including a crank-shaft, a revoluble shell, a piston connected to said crank-shaft, a chest in which said shell revolves, said shell having fractional ports oppositely disposed for pressure-balancing purposes, and staggered in different zones, said ports common to both intake and exhaust, said chest having similarly-disposed and staggered opposite intake-ports and opposite exhaust-ports formed in said chest to effect co-operative registration of ports only once in each revolution of the shell, and means connecting said shell and crank-shaft whereby said shell is revolved to cause its ports to register successively with said intake and exhaust ports only once in each revolution of said shell.

24. An internal combustion engine including a two-part cylinder-chest having a plurality of parallel side-by-side bores, the parts of said cylinder-chest being divided longitudinally of said bores and separable and joined in a plane in which lie the axes of said bores, and a plurality of revoluble valves, one in each bore, each valve having ports co-operating with intake and exhaust ports formed in the cylinder-chest bore in which it revolves, each of said chest parts having an integral complete closed manifold which is out of communication with the porting in the other chest part.

25. An internal combustion engine including a two-part cylinder-chest having a plurality of parallel side-by-side bores, the parts of said cylinder-chest being divided longitudinally of said bores and separable and joined in a plane in which lie the axes of said bores, and a plurality of revoluble valves, one in each bore, each valve having ports co-operating with intake and exhaust ports formed in the cylinder-chest bore in which it revolves, each of said cylinder-chest parts hav-

ing complete closed manifolds, co-operative with said ports, the manifolds in each part being out of communication with the porting in the other part.

26. An internal combustion engine including a two-part cylinder-chest having a plurality of parallel side-by-side bores, the parts of said cylinder-chest being divided longitudinally of said bores and separable and joined in a plane in which lie the axes of said bores, and a plurality of revoluble valves, one in each bore, each valve having ports co-operating with intake and exhaust ports formed in the cylinder-chest bore in which it revolves, each of said revoluble valves forming an engine-cylinder in which the piston reciprocates, each chest part having a complete closed manifold for only the ports in said part, and each part having a complete closed water-jacket.

27. An internal combustion engine including a revoluble valve, a chest to which said valve is fitted and in which it revolves, said valve having a common port disposed in one zone opposite to a common port in another zone, intake-ports correspondingly formed and zoned in said chest, exhaust-ports also correspondingly formed and zoned in said chest, each port in said valve being usable for both intake and exhaust, and means for revolving said valve to cause its opposite common ports, at one portion of the revolution of said valve, to register first with said exhaust-ports and then with said intake-ports, and at another portion of the revolution of said valve to pass idly by both said exhaust-ports and said intake-ports.

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