D. I. TWITCHELL.

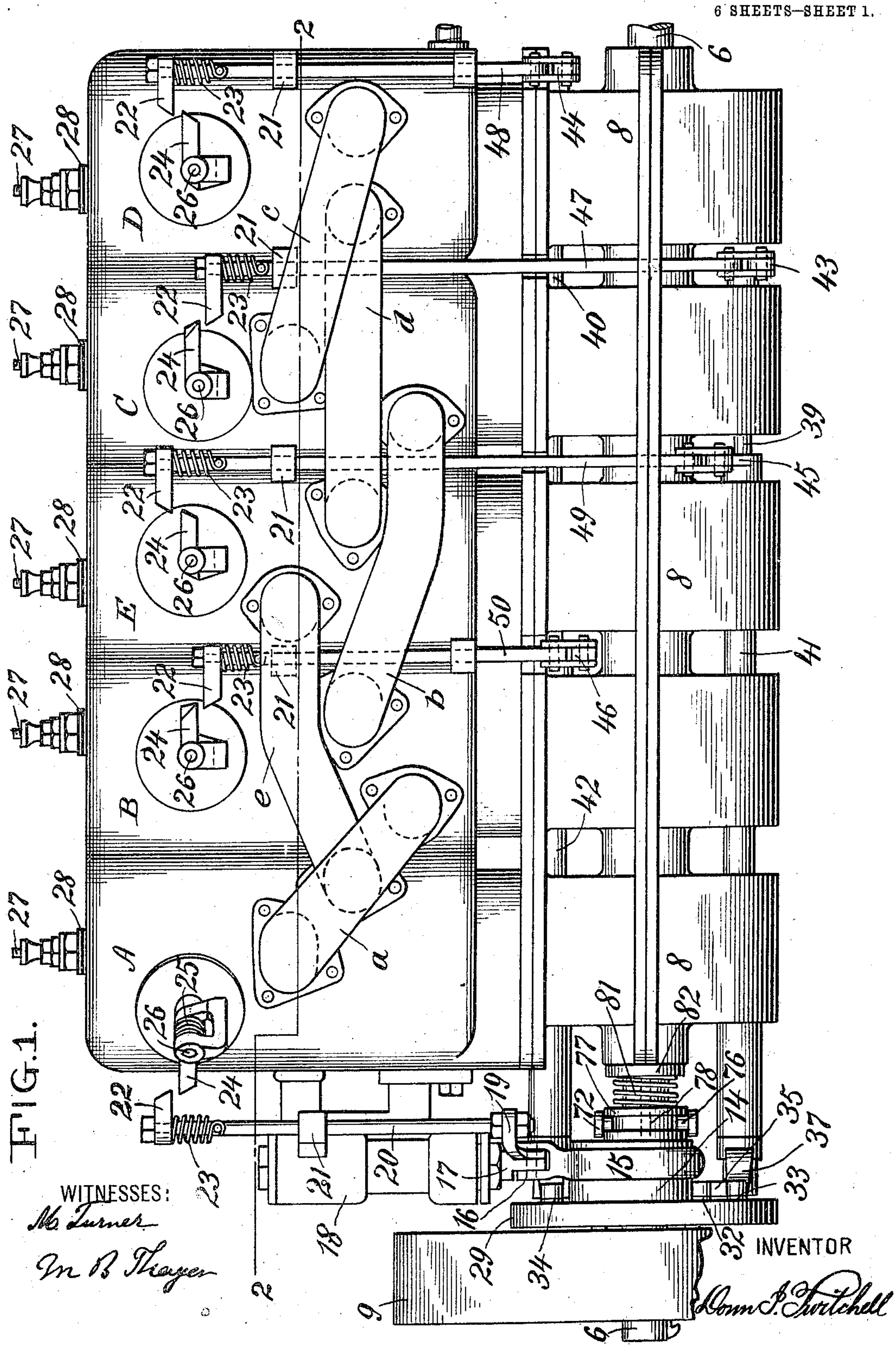
TWO-CYCLE INTERNAL COMBUSTION ENGINE.

APPLICATION FILED AUG. 10, 1905.

981,331.

Patented Jan. 10, 1911.

6 SHEETS—SHEET 1.



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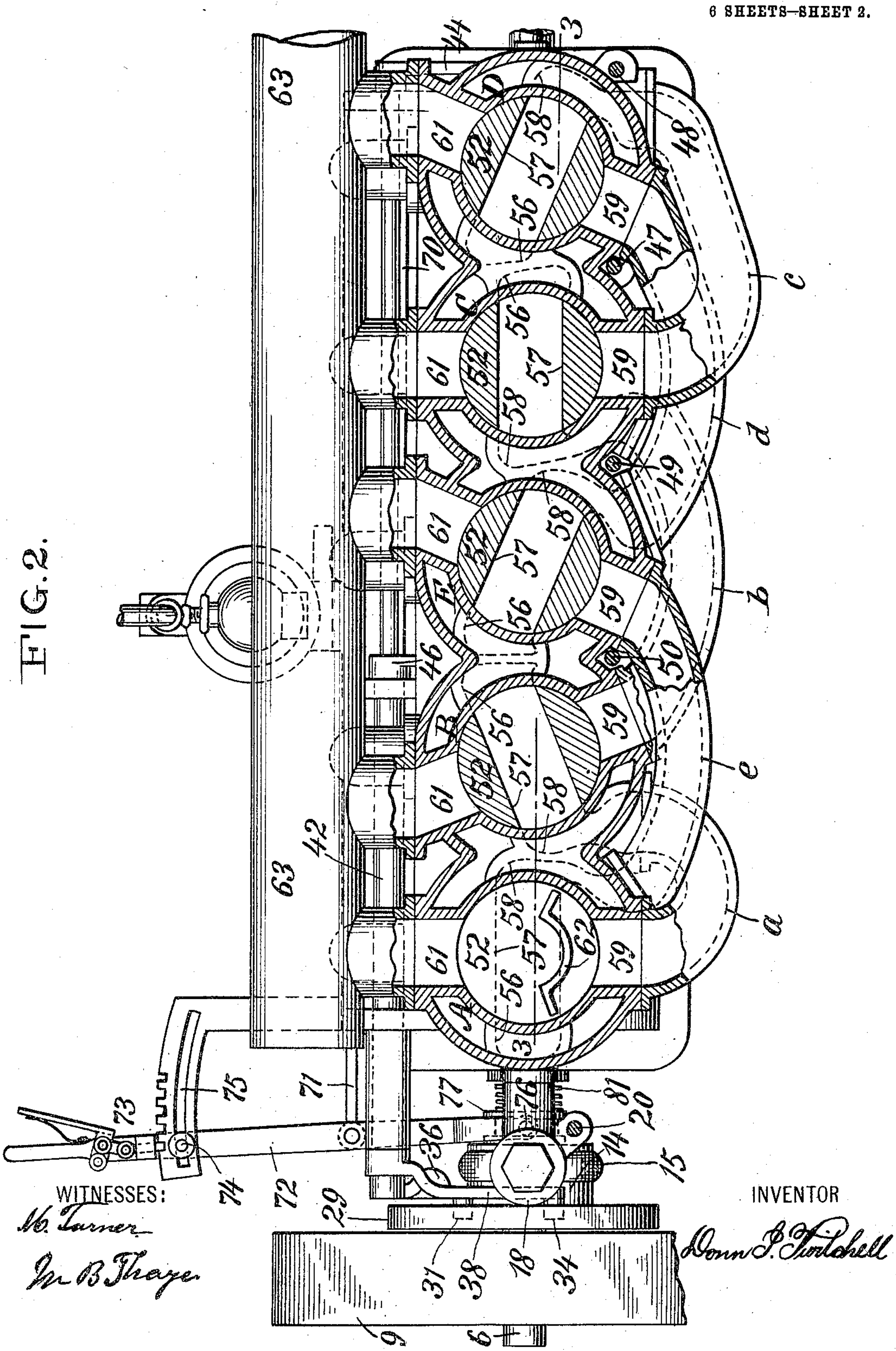

FIG. 2.

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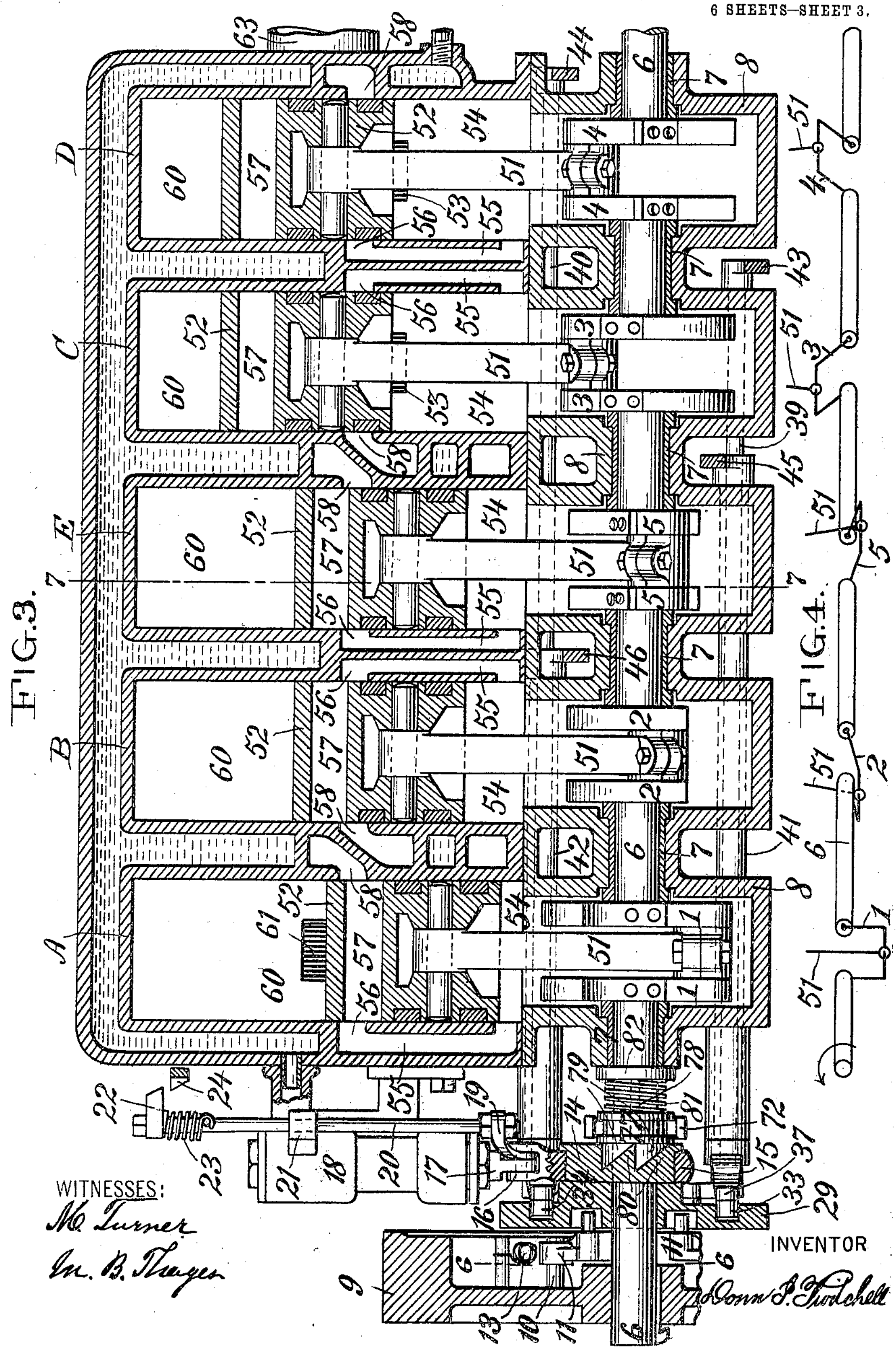

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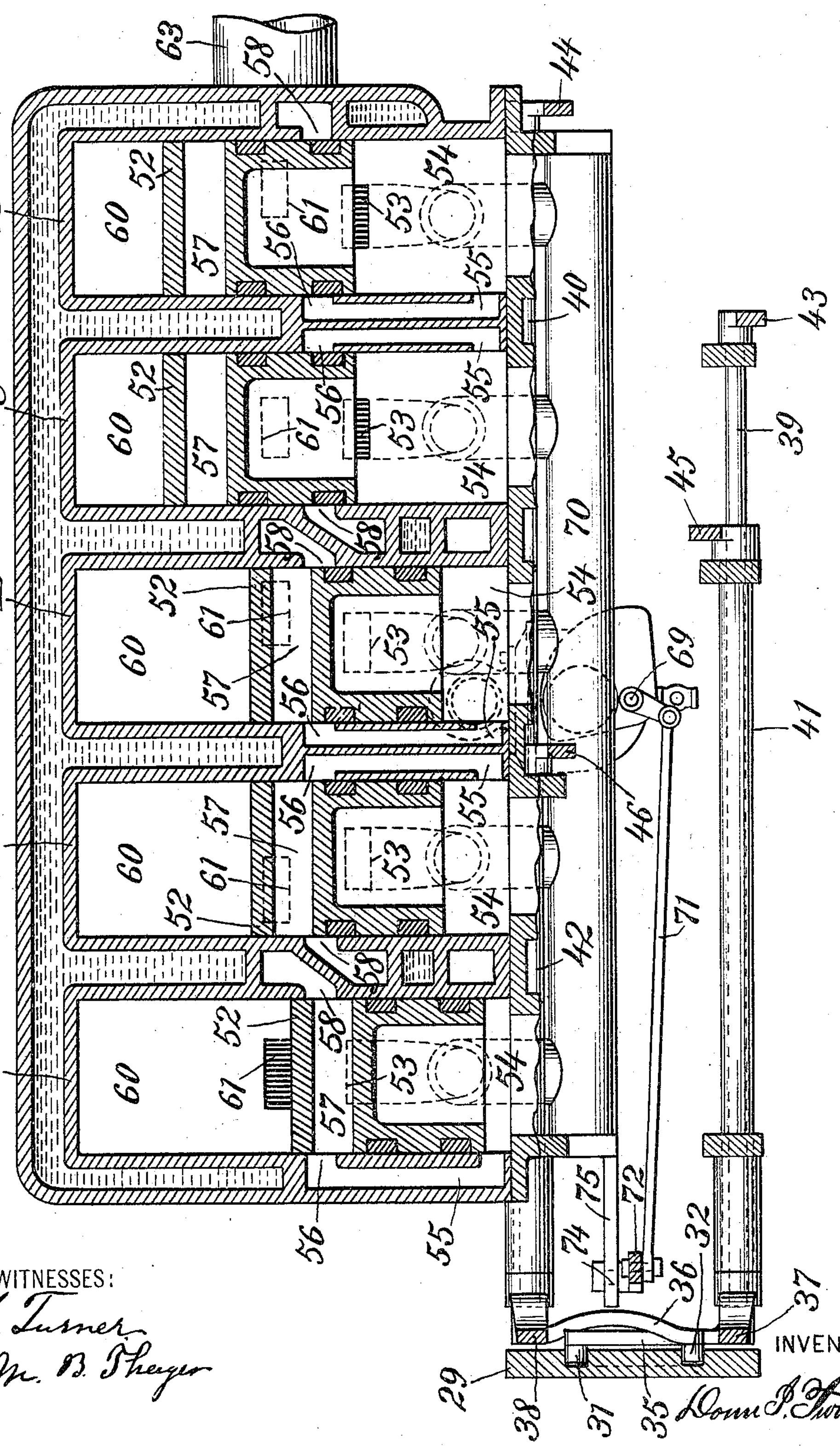
6 SHEETS—SHEET 4.

FIG.5.



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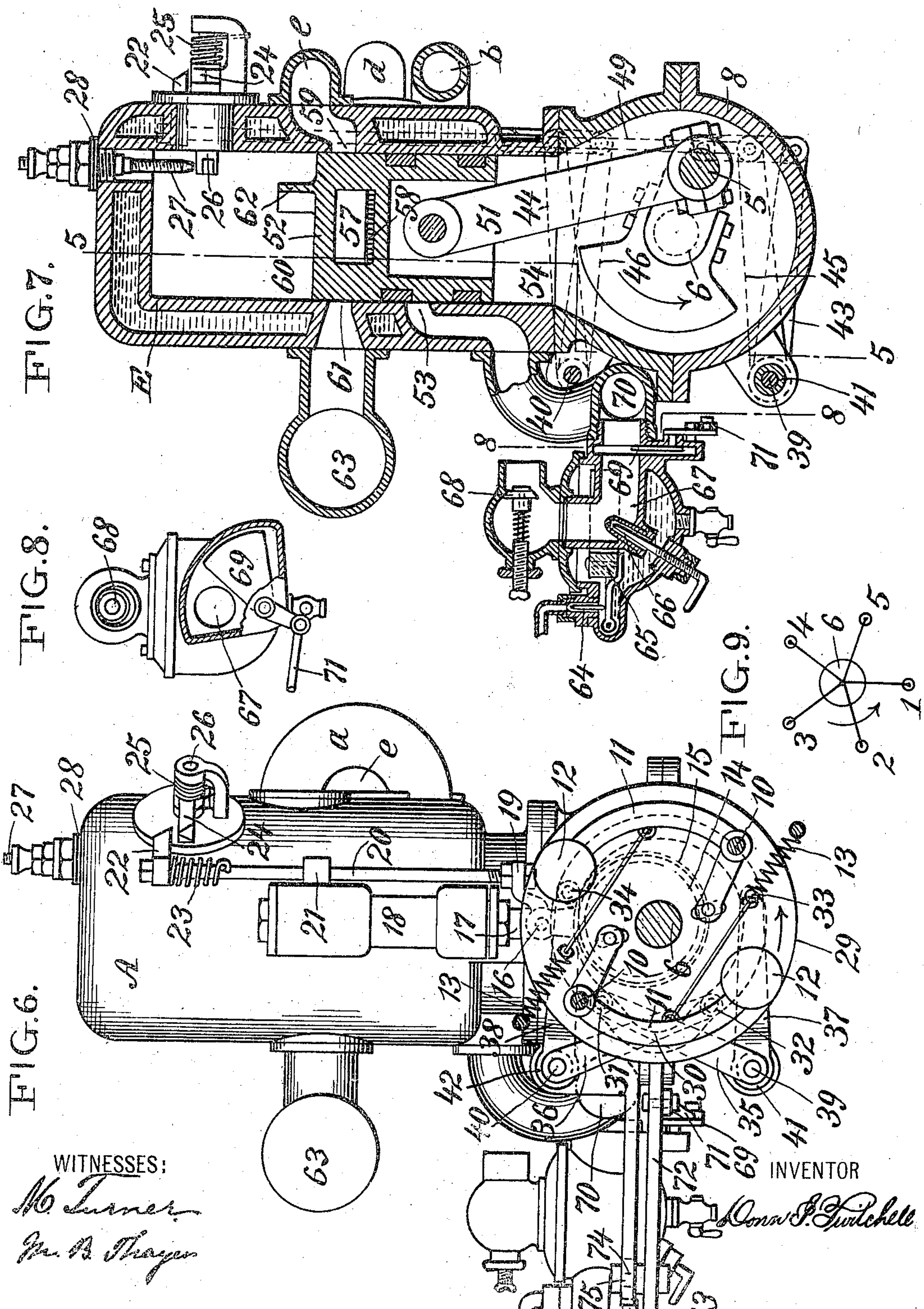

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6 SHEETS—SHEET 6.

FIG. 10.

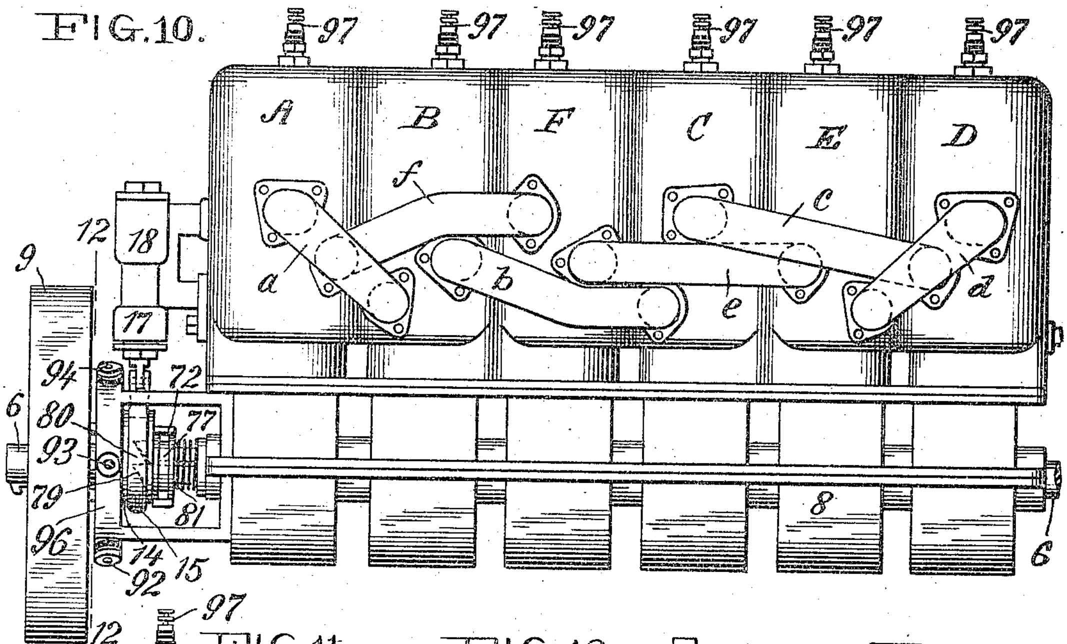


FIG. 11.

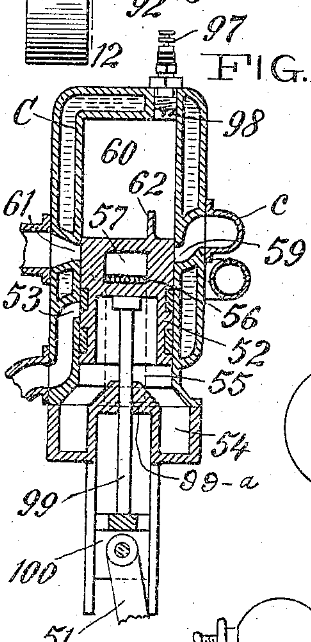


FIG. 12.

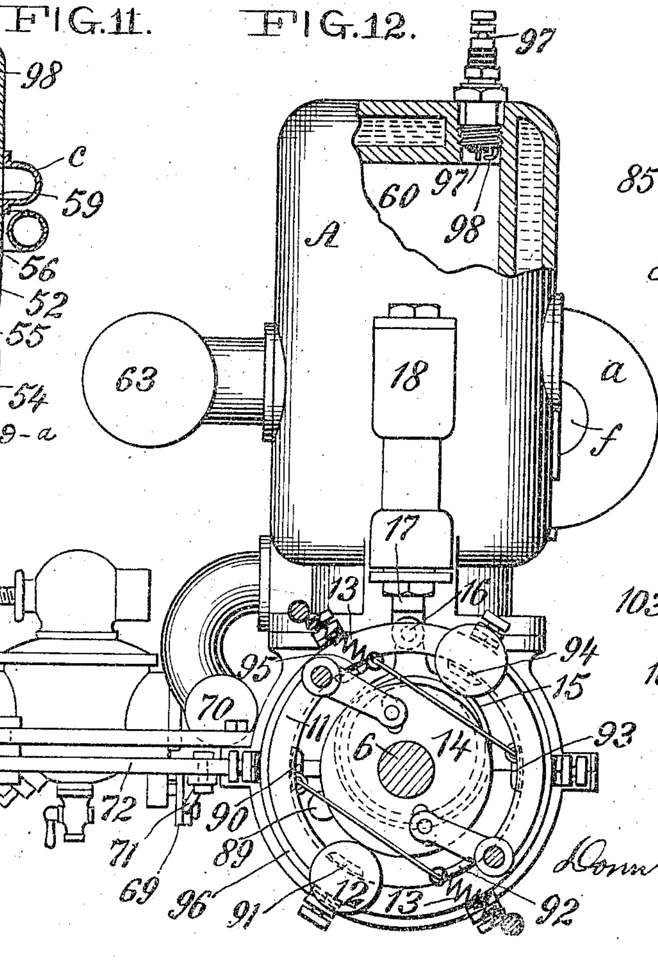


FIG. 13.

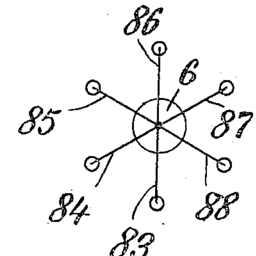
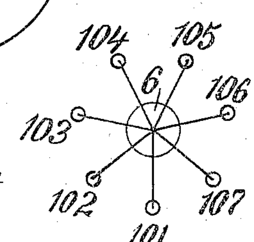


FIG. 14



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UNITED STATES PATENT OFFICE.

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TWO-CYCLE INTERNAL-COMBUSTION ENGINE.

981,331. Specification of Letters Patent. **Patented Jan. 10, 1911.**

Application filed August 10, 1905. Serial No. 273,578.

To all whom it may concern:

Be it known that I, DONN IRVING TWITCHELL, a citizen of the United States, and a resident of New York city, in the county of New York and State of New York, have invented certain new and useful Improvements in Two-Cycle 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 number of similar engines are placed alongside each other, and having their pistons connected to a common crank shaft.

The object of the invention is to provide a means whereby the full opening of the inlet ports can be delayed until after each of the pistons has reached the end of its working stroke, and the exhaust port has been opened; and to provide a means for supplying pressure for introducing the new charge.

A further object is to avoid the use of valves for opening the inlet ports. This is accomplished by the movement of the pistons themselves, each piston serving to open the inlet ports of an adjacent engine.

In the accompanying drawings Figure 1, is a side elevation of a series of five upright two-cycle engines, embodying my invention. Fig. 2 is a sectional plan view on the line 2—2 of Fig. 1. Fig. 3 is a vertical longitudinal section on the line 3—3 of Fig. 2. Fig. 4 is a perspective view in diagram of the crank shaft. Fig. 5 is a vertical longitudinal section on the line 5—5 of Fig. 7. Fig. 6 is a sectional end elevation on the line 6—6 of Fig. 3. Fig. 7 is a sectional elevation on the line 7—7 of Fig. 3. Fig. 8 is a detail sectional view on the line 8—8 of Fig. 7. Fig. 9 is a diagram representing the five cranks of the crank shaft. Fig. 10 is a side elevation of a modification of my invention, showing a series of six upright two-cycle engines. Fig. 11 is a sectional elevation of a modification in the construction of one of the series of engines. Fig. 12 is a sectional elevation on the line 12—12 of Fig. 10. Fig. 13 is a diagram representing a crank shaft having six cranks. Fig. 14 is a similar view representing seven cranks.

Referring to Figs. 1 to 9, five similar engines A, B, C, D and E are placed alongside each other, each having communication with some other through supply pipes *a*, *b*, *c*, *d* and *e*. Said supply pipes are opened for each engine by movement of the piston of some other engine, in such a manner that supply for each engine comes from some other engine.

The pistons of each engine are connected to cranks 1, 2, 3, 4 and 5 on crank shaft 6, and the cranks have such a relation to each other, as to cause the pistons to have play with reference to each other and to the supply pipes *a*, *b*, *c*, *d*, and *e*, to produce the result above referred to. Crank shaft 6 rotates in bearings 7 mounted in a casing 8.

A fly wheel 9 is secured to shaft 6, and upon the fly wheel are studs 10 on which are pivoted bell-crank levers 11. The long arm of the bell-cranks extends concentric with the studs 10 through an arc of the fly wheel and has a weight 12 upon its outer end, and a spring 13 is connected to the long arm of the bell crank and to the fly wheel, which acts to keep the weight concentric with stud 10. As the fly wheel revolves, weight 12 swings outward causing the short arm of the bell crank to turn the collar 14 which has an eccentric forming part of it, upon which is a strap 15 pivoted at 16 to the plunger 17 of the water circulating pump 18. Connected at 16 is an arm 19 adjustably secured to a vertical rod 20 riding in a guide 21. Upon the upper end of the rod 20 is pivoted an arm 22 which swings horizontally and is held by means of a spring 23 in line with an arm 24 which is held horizontal by means of a spring 25. Arm 24 is secured to a horizontal shaft 26 which extends into engine A and upon the inner end is secured an arm adapted to make electric contact with a terminal 27, which, when broken, produces an electric spark for igniting the charge. Terminal 27 extends vertically out from the cylinder through the insulation 28 and is provided with means for making connection with an electric battery (not shown), the other terminal of the battery being connected to the engine and passing through shaft 26. As no invention is claimed in the igniting device, a lengthy description is not considered necessary.

When the piston of engine A moves upward, eccentric collar 14 moves rod 20 and pivoted arm 22 downward, so that, when the piston has reached its uppermost position, electric contact will be made and broken and the charge ignited.

Forming part of eccentric collar 14 is a cam disk 29 provided with a groove concentric through four-fifths of a circle, the remaining one-fifth having a cam 30. Riding in the groove of cam disk 29 are four rollers 31, 32, 33 and 34, attached to four arms 35, 36, 37 and 38 secured to four shafts 39, 40, 41 and 42 to which are secured four arms 43, 44, 45 and 46 connected to four vertical rods 47, 48, 49 and 50, which operate the arm 24 of igniters for engines B, C, D and E. The four rollers 31, 32, 33 and 34 are so placed that the cam 30 shall act upon one of the rollers, and thus ignite a charge for every fifth of a revolution; there being one-fifth during which no roller will be acted upon by the cam 30. It is at this time that the eccentric collar 14 causes the igniter of engine A to ignite its charge. When eccentric collar 14 and cam disk 29 are turned on the shaft by movement of weighted bell crank 11, the time when the ignition takes place will be charged correspondingly for all the engines.

Cranks 1, 2, 3, 4 and 5 extend radially from the crank shaft 6, at five equal distances apart as shown by diagram in Figs. 4 and 9, so that if the crank of engine A occupies the position shown in Figs. 3 and 4, the shaft rotating in the direction indicated by the arrow, crank 2 of engine B will be one-fifth of a circle in the rear of crank 1 of engine A, crank 3 of C will be one-fifth in rear of crank 2 of B, crank 4 of D, one-fifth in rear of crank 3 of C, crank 5 of E one-fifth in rear of crank 4 of D, and crank 1 of A one-fifth in rear of crank 5 of E. Cranks 1, 2, 3, 4 and 5 are respectively connected by means of pitmen 51 to pistons 52 of engines A, B, C, D, and E.

All of the engines being constructed alike, a description of one will answer for all.

At the end of the up or return stroke, piston 52 opens a supply port 53 into a chamber 54 beneath the piston; port 53 being closed and the charge compressed by the down or working stroke of the piston. A duct 55 connects chamber 54 with a port 56 which is opened by means of a passage 57 formed in piston 52 to a port 58 which is connected to one end of a supply pipe *a*, *b*, *c*, *d*, or *e*, the other end of said supply pipe being connected to inlet port 59 of combustion chamber 60 of some other engine.

The engine operates as two-cycle engines are usually operated. Upward movement of piston 52 compresses the charge which being ignited by the igniting device described, forces the piston downward; exhaust port 61 and inlet port 59 are opened by the piston at the end of its downward movement, and the supply, entering through port 59 and striking deflector 62, is forced upward, displacing the burned gases which are forced out through exhaust port 61, into main exhaust pipe 63.

The fuel is supplied by a carbureter of any suitable design; that shown has a gasolene supply valve 64 controlled by a float 65, outlet for the gasolene being regulated by the needle valve 66. The gasolene enters an air passage 67 having an air inlet controlled by a valve 68 and an outlet for the mixture controlled by a throttle valve 69. The mixture enters a pipe 70, which is in communication with the inlet ports 53 of each of the compressing chambers 54 of the five engines.

Throttle valve 69 is connected by means of a rod 71 to a throttle lever 72, one end of which can be moved by the operator and locked by the device 73, so as to admit any desired amount of mixture to the engines. Lever 72 has a pin 74 which rides in a guide 75. The other end of the lever 72 is forked and provided with rollers 76, which ride in a grooved collar 77, mounted on the crank shaft 6 and held from turning by means of a spline 78. Collar 77 is provided with inclined teeth 79 which fit against corresponding teeth 80 formed on eccentric collar 14. A spring 81 between a collar 82 fixed to the shaft and collar 77, serves to keep teeth 79 against teeth 80 and also by means of groove in collar 77 to hold one end of throttle lever 72 in place. When eccentric collar 14 is turned by the action of weighted bell cranks 11, inclined teeth 80 taking against inclined teeth 79 on sliding collar 77, move the sliding collar endwise, and by means of the groove formed on the collar, move one end of lever 72, the other end of the lever hinging on the locking device 73. Such movement of lever 72 acts on rod 71 to close throttle valve 69, and thus reduce the supply. When the operator moves one end of lever 72, the other end hinges on rollers 76 which ride in the grooved sliding collar 77.

The operation is as follows:—With the pistons 52 occupying the positions shown in the drawings, piston of engine A has reached the end of its working stroke, exhaust port 61 is open to exhaust pipe 63, inlet port 59 is also open to supply pipe *a*, port 58 of which in engine B is nearly closed by piston 52 of engine B, further downward movement of piston of engine B will fully open port 58 to port 56 by means of passage 57 formed in the piston, and the compressed charge beneath the piston of engine B, will then pass through duct 55, port 56, passage 57, port 58, supply pipe *a*, and inlet port 59, into combustion chamber 60 of engine A before the upward or return movement of piston of engine A has cut off its exhaust port 61, and inlet port 59.

In the drawings, port 58 of engine B is

shown slightly open, when the piston of engine A is on a line with the dead center, for the reason that while the crank 1 is crossing the dead center, there is a wide margin between just before and just after; in which very little, if any, movement of the piston occurs. It will be seen that the piston in engine A practically reaches the end of its reciprocating movement before the crank 1 reaches the dead center and that considerable movement of the cranks 1 and 2 will take place after the piston in engine A practically reaches the end of its movement. The piston in engine B connected to crank 2, will, however, be moving rapidly during this trifling movement of the piston in engine A, so that the slight opening of port 58, shown in the drawing corresponds with the position of the pistons after the piston in engine A practically reaches the end of its movement, although the piston in engine B was just on the point of opening port 58 before the crank 1, to which the piston in engine A is connected reached the dead center. By thus causing the piston in engine B to start to open the port 58 after the piston in engine A practically completed its working stroke, but before the crank 1, to which it is connected, reaches the dead center, an increased amount of time is given for the combustible charge to be forced into the combustion chamber of engine A, before the piston closes the exhaust port 61, and inlet port 59. It will therefore be understood that the completion of the working stroke of the piston, implies the practical end of the piston's movement, although the crank to which it is connected may not have reached the dead center line.

It will be seen that the supply is not fully open until after the exhaust has been opened by the final downward movement of the piston of engine A, and that when the supply is opened by means of the piston of engine B, the charge is forced by its downward movement out from beneath the piston of engine B, into the combustion chamber of engine A.

Piston of engine B being at the end of its working stroke, exhaust port 61 of engine B will be open to the exhaust pipe 63, inlet port 59 will be open to supply pipe *b*, port 58 in engine C being nearly closed by the piston of engine C, downward movement of piston of engine C will open port 58, permitting the charge to pass into combustion chamber 60 of engine B before the upward movement of piston of engine B has cut off ports 61 and 59. Piston of engine C being at the end of its working stroke, downward movement of piston of engine D will force the charge through supply pipe C into combustion chamber 60 of engine C. Piston of engine D being at the end of its working stroke, downward movement of piston of engine E will force the charge through supply pipe *d* into combustion chamber 60 of engine D. Piston of engine E being at the end of its working stroke, downward movement of piston of engine A will force the charge through supply pipe *e* into combustion chamber 60 of engine E, making the cycle complete through engines A, B, C, D and E.

It will be noticed that by delaying the opening of the supply ports until after each of the pistons has reached the end of its working stroke the pressure of the burned gases will be reduced by entering exhaust pipe, and time will be allowed for complete combustion before the new charge is introduced. By placing the supply during the return movement of the piston, the supply is more thoroughly separated from the exhaust, which lessens the chance of the new charge finding its way into the exhaust, or coming in contact with flame, which would cause lighting back.

The pistons occupying the position shown in the drawings, cam 30 has acted upon roller 31, arm 35, shaft 39, arm 43, and rod 47 moving it upward, causing arm 22 to act upon arm 24 and turn shaft 26 to make and break electric current with contact 27, thus igniting the charge in engine C. Cam 30 will next act upon roller 32, arm 36, shaft 40, arm 44, and rod 48 moving it downward to operate the igniter for engine D. Cam 30 will next act upon roller 33, arm 37, hollow shaft 41, arm 45 and rod 49, moving it downward to operate the igniter for engine F. In the interval between roller 33 and roller 34, cam 30 does not act, eccentric 14 however acts upon rod 20 moving it downward to operate the igniter for engine A. Cam 30 will next act upon roller 34, arm 38, hollow shaft 42, arm 46 and rod 50, moving it upward to operate the igniter for engine B. Cam 30 will next act upon roller 31, thus completing the cycle of actuation of the igniters through the engine C, D, E, A and B.

In Figs. 10, 12 and 13 is shown a modification in which six engines A, B, C, D, E and F are used, connected by supply pipes *a*, *b*, *c*, *d*, *e*, and *f*, similar to that described and shown in Figs. 1 to 9. Engine A receives its supply through pipe *a* from engine B, engine B receives its supply through pipe *b* from engine C, engine D through pipe *d* from E, engine E through pipe *e* from F, engine F through pipe *f* from A, thus completing the cycle through six engines.

As shown in Fig. 13, cranks 83, 84, 85, 86, 87 and 88 coöperate with corresponding engines A, B, C, D, E and F in a manner similar to that described and shown in Figs. 1 to 9.

A modification of the igniting device is shown in Figs. 10 and 12, a jump spark system being used. Mounted on eccentric collar 14, which is operated as shown in Figs. 1 to 9, is a contact 89 adapted to make electric contact as the shaft 6 revolves, with insulated contacts 90, 91, 92, 93, 94 and 95, secured to a stationary ring 96. When contact 89 makes contact with the contacts on stationary ring 96, a primary electric circuit is closed and opened which acting upon a secondary electric circuit connected to contacts 97 and 98 insulated from each other, causes a spark in each of the engines A, B, C, D, E and F in a manner well known in the operation of a jump spark system of ignition.

In Fig. 11 is shown a modification of the invention in which the piston 52 is secured to a rod 99 which extends through the closed end or head 99ª of the cylinder, the head 99ª forming part of the compressing chamber 54. Rod 99 is attached to a cross-head 100 to which the piston 51 is connected.

As shown in Fig. 14, seven cranks 101, 102, 103, 104, 105, 106 and 107 coöperate with corresponding engines in a manner similar to that described and shown in Figs. 1 to 9. More can be used limited only by the question whether the piston which forces the supply into the combustion chamber 60 of some other engine, has downward movement, before ports 59 and 61 are closed by the upward movement of the piston in the engine which receives the supply.

By reference to Figs. 3 and 4, it will be seen that when the piston connected to crank 4 is moving upward and opening the inlet port 53, the piston connected to crank 2 is moving downward and opening the port 58, which communicates with the combustion chamber of cylinder E. It will be evident that during rotation of the different cranks, a like position will occur for the pistons in two other cylinders, for example, when the piston connected to crank 5 is moving upward and opening the inlet port 53 of engine E, the piston connected to crank 3 is moving downward and opening the port 58, which communicates with the combustion chamber of cylinder D.

It will be seen by reference to Fig. 1 that none of the ducts connecting the different cylinders extend beyond the space required for one intervening cylinder, and by reference to Fig. 10 it will be seen that although the number of cylinders has been increased, the ducts have not been made longer. By this means the ducts are all made as short as possible, and uniformity in the action of the combustible charges maintained in the different cylinders.

It will be understood that the engine is so constructed that the ducts have a proper relation to the cranks to which the pistons are connected, to cause coöperation in accordance with the foregoing description.

Having described my invention, what I claim and desire to secure by Letters Patent is:—

1. An internal combustion engine having multiple cylinders, each cylinder having a combustion chamber, a compressing chamber and a piston having reciprocating movement in said chambers, an outlet duct from each one of said compressing chambers connected to the combustion chamber of another of said cylinders, said duct being controlled by the piston in said compressing chamber; said pistons arranged to reciprocate in a manner to cause the piston in any one of said compressing chambers to close the outlet duct, during the working stroke of the piston in the combustion chamber connected to said duct, and to cause the piston in said compressing chamber at the conclusion of its working stroke, to fully open said duct after the conclusion of the working stroke of the piston in said combustion chamber.

2. An internal combustion engine having multiple cylinders, each cylinder having a combustion chamber, a compressing chamber, and a piston having reciprocating movement in said chambers, an outlet duct from each of said compressing chambers and a port in each of said combustion chambers, said ducts and said ports being controlled by the pistons, the outlet duct from the compressing chamber of each one of said cylinders being connected with the combustion chamber port of another of said cylinders, said pistons arranged to reciprocate in a manner to cause the piston in any one of said compressing chambers to close the outlet duct, during the working stroke of the piston in the combustion chamber connected to said duct, and to cause the piston in said compressing chamber at the conclusion of its working stroke to coöperate with the piston in said combustion chamber to fully open said duct after the conclusion of the working stroke of the piston in said combustion chamber.

3. An internal combustion engine having multiple cylinders, each cylinder having a combustion chamber, a compressing chamber, and a piston having reciprocating movement in said chambers, an outlet duct from each compressing chamber, an exhaust and an inlet port in each combustion chamber, the exhaust port of each combustion chamber being opened by the piston therein at the end of a working stroke, the outlet duct from the compressing chamber of each one of said cylinders, being connected with the combustion chamber inlet port of another of said cylinders, said ducts and said inlet ports being controlled by the pistons, said pistons arranged to reciprocate in a manner to cause the piston in any one of said compressing chambers to close the outlet duct during the working stroke of the piston in the combustion chamber connected to said

duct, and to cause the piston in said compressing chamber at the conclusion of its working stroke to coöperate with the piston in said combustion chamber to cause said duct and said inlet port to be fully opened after the conclusion of the working stroke of the piston in said combustion chamber.

4. An internal combustion engine having multiple cylinders, each cylinder having a combustion chamber, a compressing chamber, and a piston having reciprocating movement in said chambers, each combustion chamber having an exhaust and an inlet port which are opened by the piston at the end of a working stroke and closed by the return stroke, an outlet duct from each one of said compressing chambers connected to the combustion chamber inlet port of another of said cylinders, said duct being partially controlled by the piston in said compressing chamber, the piston in said compressing chamber and the piston in said combustion chamber arranged to reciprocate in such manner that they coöperate to open said duct after the piston in said combustion chamber has opened said exhaust and inlet ports, and coöperate to maintain said duct open until said exhaust and inlet ports are closed by return movement of the piston in said combustion chamber.

5. An internal combustion engine having multiple cylinders, each cylinder having a combustion chamber, a compressing chamber, and a piston having reciprocating movement in said chambers, an outlet duct from the compressing chamber of each one of said cylinders in communication with the combustion chamber of another of said cylinders, a port in each compressing chamber, each piston having a passage coöperating with one of said compressing chamber ports and with one of said ducts for connecting the combustion chamber of each one of said cylinders with the compressing chamber of another of said cylinders, said pistons arranged to reciprocate in a manner to cause the piston in any one of said compressing chambers to close the duct during the working stroke of the piston in the combustion chamber connected to said duct, and to cause said passage in the piston, at the conclusion of the working stroke of said piston in the compressing chamber, to fully open said duct after the piston in said combustion chamber has begun a return stroke.

6. An internal combustion engine having multiple cylinders, each cylinder having a combustion chamber, a compressing chamber, and a piston having reciprocating movement in said chambers, a duct for effecting communication between the combustion chamber of each one of said cylinders and the compressing chamber of another of said cylinders; one end of said duct being controlled by the piston in said combustion chamber and the other end controlled by the piston in said compressing chamber said pistons arranged to reciprocate in a manner to cause the piston in any one of said compressing chambers to close the duct during the working stroke of the piston in the combustion chamber connected to said duct and to cause the piston in said compressing chamber at the conclusion of its working stroke to fully open said duct after the conclusion of the working stroke of the piston in said combustion chamber, and also to cause the piston in said combustion chamber to close said duct at the conclusion of the working stroke of the piston in said compressing chamber.

7. An internal combustion engine having multiple cylinders, each cylinder having a combustion chamber, a compressing chamber, and a piston having reciprocating movement in said chambers, a duct for effecting communication between the combustion chamber of each one of said cylinders and the compressing chamber of another of said cylinders, said duct being controlled by the piston in said compressing chamber an exhaust port in each of said combustion chambers which is opened by the piston at the end of a working stroke and closed by the return stroke, said pistons arranged to reciprocate in a manner to cause the piston in any one of said compressing chambers to close the duct during the working stroke of the piston in the combustion chamber connected to said duct, and to cause the piston in said compressing chamber to open said duct before return movement of the piston in said combustion chamber closes the exhaust port.

8. An internal combustion engine having multiple cylinders, each cylinder having a combustion chamber, a compressing chamber, and a piston having reciprocating movement in said chambers, an outlet duct from each of said compressing chambers, and a port in each of said combustion chambers, said ducts and said ports being opened by the pistons at the end of a working stroke of each piston, the outlet duct from the compressing chamber of each one of said cylinders being connected with the combustion chamber port of another of said cylinders, the pistons being connected to cranks on one crank shaft, said cranks having angular relation to each other to cause the outlet duct from any one of said compressing chambers to remain closed, until opened by the piston in said compressing chamber after the conclusion of the working stroke of the piston in the combustion chamber connected to said duct.

9. An internal combustion engine having multiple cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston and a compressing

chamber on the opposite side, an outlet duct from each of said compressing chambers and a port in each of said combustion chambers, said ducts and said ports being opened by the pistons at the end of a working stroke of each piston, the outlet duct from the compressing chamber of each one of said cylinders being connected with the combustion chamber port of another of said cylinders, an inlet port for each of said compressing chambers, said inlet port being opened by the piston at the end of a return stroke, said pistons arranged to reciprocate in a manner to cause the piston in any one of said compressing chambers to close the outlet duct, while the piston in the combustion chamber connected to said duct concludes its working stroke, and to cause the piston in said compressing chamber to finally open said duct, substantially as described.

10. An internal combustion engine having multiple cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston and a compressing chamber on the opposite side, an exhaust and an inlet port in each combustion chamber, an outlet duct from each compressing chamber, said exhaust and inlet ports, and said duct being opened by the piston at the end of a working stroke and closed by the return stroke, the outlet duct from the compressing chamber of each one of said cylinders being connected with the combustion chamber inlet port of another of said cylinders, an inlet port for each of said compressing chambers, said compressing chamber inlet port being opened by the piston at the end of a return stroke, said pistons arranged to reciprocate in a manner to cause the piston in any of said compressing chambers to close said duct, while the piston in the combustion chamber connected to said duct concludes its working stroke and to cause the piston in said compressing chamber to open said duct before the piston in said combustion chamber has closed the exhaust port.

11. An internal combustion engine comprising a reciprocating piston in a cylinder having a combustion chamber, and inlet and exhaust ports in the cylinder which are opened by said piston at the end of a working stroke and closed by the return stroke, a similar piston in another cylinder having a compressing chamber, means whereby said compressing chamber is supplied with a mixture of gas and air, a duct for effecting communication between said inlet port and said compressing chamber, said duct being controlled by the piston in said compressing chamber, said pistons arranged to reciprocate in a manner to cause the piston in said compressing chamber to close said duct, while the piston in said combustion chamber concludes its working stroke, and to cause the piston in said compressing chamber at the conclusion of its working stroke to open said duct before the piston in said combustion chamber has closed the exhaust port.

12. An internal combustion engine, comprising a series of cylinders, each cylinder having a reciprocating piston, a compressing chamber on one side of the piston, a combustion chamber on the opposite side, an outlet duct from the compressing chamber and an inlet port in the combustion chamber, said duct and said port being opened by the piston at the end of a working stroke, the outlet duct from the compressing chamber of one of said cylinders being connected with the combustion chamber inlet port of a second cylinder, the combustion chamber inlet port of the first cylinder being connected with the outlet duct from the compressing chamber of a third cylinder, the outlet duct from the compressing chamber of the second cylinder being connected with the combustion chamber inlet port of a fourth cylinder, the combustion chamber inlet port of the third cylinder being connected with the outlet duct from the compressing chamber of a fifth cylinder, and the outlet duct from the compressing chamber of the fourth cylinder being connected with the combustion chamber inlet port of the fifth cylinder, substantially as described.

13. An internal combustion engine having multiple cylinders, each cylinder having a reciprocating piston, and inlet and exhaust passages which are opened by said piston at the end of a working stroke and closed by the return stroke, the inlet passage of each cylinder being also opened by the piston of another cylinder at the end of its working stroke, said pistons arranged to reciprocate in such manner that they cooperate to cause the inlet passage of one cylinder to be closed while its exhaust passage is being opened by its piston, and to cause said inlet passage to be opened at the beginning of return movement of said piston which opened the exhaust passage.

14. An internal combustion engine having multiple cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston, a compressing chamber on the opposite side, the combustion chamber of each of said cylinders having exhaust and inlet ports which are opened by the piston, an outlet duct from each compressing chamber communicating with the combustion chamber inlet port of another cylinder; and a passage in each piston adapted to open said outlet duct; said exhaust and inlet ports of the combustion chamber of any one of said cylinders, and said outlet duct from the compressing chamber of said cylinder being opened by the piston thereof at the end of its working stroke.

15. The combination with a series of cyl-

inders, each cylinder having a reciprocating piston, a compressing chamber on one side of the piston and a combustion chamber on the opposite side, an outlet duct from each compressing chamber, said duct being opened by the piston, at the end of a working stroke, each compressing chamber having an inlet port which is opened by the piston at the end of a return stroke, the outlet duct from the compressing chamber of any one of said cylinders being connected with the combustion chamber of a second cylinder of the series, the outlet duct from the compressing chamber of the last mentioned cylinder being connected to the combustion chamber of a third cylinder of the series, and so forth, the outlet duct from the compressing chamber of the last cylinder of the series being connected with the combustion chamber of the first cylinder of the series.

16. An internal combustion engine, comprising a series of cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston, and a compressing chamber on the opposite side, a port in each of said combustion chambers and a port in each of said compressing chambers, said ports being opened by the piston, an outlet duct from the compressing chamber of each one of said cylinders in communication with the combustion chamber port of another cylinder, each piston having a passage coöperating with one of said compressing chamber ports and with one of said ducts for placing the combustion chamber port of one of the cylinders in communication with the compressing chamber port of another cylinder, said pistons being connected to cranks on one crank shaft, the cranks having angular relation to each other to cause the pistons to coöperate to open a duct at the conclusion of a working stroke of the piston in a cylinder to the combustion chamber of which said duct is connected.

17. An internal combustion engine, comprising a series of cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston, and a compressing chamber on the opposite side, an outlet duct from each one of said compressing chambers connected to the combustion chamber of another of said cylinders, said duct being controlled by the piston in said compressing chamber, one of said ducts effecting communication between the combustion chamber of one of said cylinders and the compressing chamber of a second cylinder, another of said ducts effecting communication between the combustion chamber of the last mentioned cylinder and the compressing chamber of a third cylinder of the series, and so forth, the combustion chamber of the last cylinder of the series being in communication with the compressing chamber of the first cylinder of the series, said pistons being connected to cranks on one crank shaft, the cranks having angular relation to each other to cause the pistons to coöperate to open a duct at the conclusion of a working stroke of a piston in a cylinder to the combustion chamber of which said duct is connected, the cranks and ducts having relation to each other causing the pistons to open the ducts in the order named.

18. An internal combustion engine having four or more cylinders, each cylinder having a reciprocating piston, a compressing chamber on one side of the piston, a combustion chamber on the opposite side, an outlet passage from the compressing chamber of one of said cylinders, said passage being at times in communication with the combustion chamber of a second cylinder of the series, an outlet passage from the compressing chamber of the last mentioned cylinder, said passage being at times in communication with the combustion chamber of a third cylinder of the series, and so forth, an outlet passage from the compressing chamber of the last cylinder of the series, said passage being at times in communication with the combustion chamber of the first cylinder of the series, the engine being so constructed that the length of the passage for effecting communication between any two of said cylinders shall not exceed the length necessary to allow space for one intervening cylinder.

19. An internal combustion engine comprising a series of cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston and a compressing chamber on the opposite side, an outlet duct from the compressing chamber and an inlet port in the combustion chamber, said duct and said port being opened by the piston at the end of a working stroke, the compressing chamber having an inlet port which is opened by the piston at the end of a return stroke, the outlet duct from the compressing chamber of one of said cylinders being connected with the combustion chamber inlet port of a second cylinder of the series, the outlet duct from the compressing chamber of the last mentioned cylinder being connected to the combustion chamber inlet port of a third cylinder of the series, and so forth, the outlet duct from the compressing chamber of the last cylinder of the series being connected with the combustion chamber inlet port of the first cylinder of the series.

20. An internal combustion engine, comprising a series of cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston, and a compressing chamber on the opposite side,

each combustion chamber having an inlet passage in communication with the compressing chamber of another of said cylinders, said passage being opened by the piston in said compressing chamber, said pistons being connected to cranks, on one crank shaft, the cranks having angular relation to each other to cause the piston in any one of said cylinders to be at a different position at the time its inlet passage is opened from its position at the time such passage is closed.

21. An internal combustion engine, comprising a series of cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston and a compressing chamber on the opposite side, a port in each of said combustion chambers and a port in each of said compressing chambers, said ports being opened by the pistons, an outlet duct from the compressing chamber of each one of said cylinders in communication with the combustion chamber port of another cylinder, each piston having a passage coöperating with the port in one of said compressing chambers and with one of said ducts for placing the compressing chamber in communication with the combustion chamber port of another cylinder, the piston of each cylinder coöperating with the piston of some other cylinder to open one of the ducts, the pistons being connected to cranks on one crank shaft, the cranks having angular relation to each other to cause a duct to remain closed until the conclusion of the working stroke of the piston in the combustion chamber to which said duct is connected, and to be opened after the conclusion of said stroke.

22. An internal combustion engine comprising a series of internal combustion cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston and a compressing chamber on the opposite side, an inlet port for each compressing chamber, a duct connecting said inlet ports, a carbureter having a valve which controls a supply of gas and air, said carbureter being connected to said duct, said inlet ports being opened by the pistons at the end of movement in one direction, an outlet duct from each of said compressing chambers connecting with the combustion chamber of some other cylinder, each piston having a passage adapted to open said outlet duct at the end of movement of the piston in the opposite direction, and the several pistons being so connected that the piston in each cylinder shall reach a point controlling admission to a compressing chamber at the time another piston reaches a point controlling admission to a combustion chamber.

23. An internal combustion engine comprising a series of internal combustion cylinders, each cylinder having a reciprocating piston, a combustion chamber, a compressing chamber, an inlet port for each compressing chamber, said inlet ports being opened by the pistons at the end of movement in one direction, and an outlet duct from each of said compressing chambers, each one of said ducts being connected to the combustion chamber of another cylinder, each of said pistons being adapted to open said outlet duct at the end of movement in the opposite direction; and the several pistons being so connected that they shall reach points controlling admission to their respective compression chambers at different times.

24. An internal combustion engine having multiple cylinders, each cylinder having a reciprocating piston, and inlet and exhaust ports which are opened by said piston at the end of a working stroke and closed by the return stroke, the inlet passage of each cylinder being also controlled by the piston of another cylinder, and the engine having means for actuating the pistons whereby the inlet passage of one cylinder is held closed by the piston of another cylinder while the exhaust passage of the first mentioned cylinder is being opened by its piston, said actuating means causing the piston of said other cylinder to open the inlet passage of the first mentioned cylinder at the beginning of return movement of the piston in the first mentioned cylinder.

25. An internal combustion engine comprising a series of cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston and a compressing chamber on the opposite side; each of said combustion chambers having a port which is opened by the piston, a series of ducts, any one of said ducts being connected to said port of one of said combustion chambers and effecting communication between said combustion chamber and the compressing chamber of another cylinder, said duct being controlled by the piston in said compressing chamber, said pistons arranged to reciprocate in a manner to cause the piston in said compressing chamber to coöperate with the piston in said combustion chamber to open the duct effecting communication between said combustion chamber and said compressing chamber, the ducts being so arranged that said port of one cylinder is connected to the compressing chamber of a second cylinder of the series, said port of the last mentioned cylinder being connected to the compressing chamber of a third cylinder of the series, and so forth, said port of the last cylinder of the series being connected with the compressing chamber of the first cylinder of the series, said pistons being connected to cranks having angular relation to each other to cause the pistons to open the ducts in the order named.

26. An internal combustion engine, comprising a reciprocating piston in a cylinder

having a combustion chamber, and inlet and exhaust passages in the cylinder which are opened by said piston at the end of a working stroke and closed by the return stroke, a similar piston in another cylinder having a compressing chamber, said pistons being connected to cranks having angular relation to each other on one crank shaft, a duct for effecting communication between said inlet passage and said compressing chamber, said duct being opened by the last mentioned piston at the conclusion of a working stroke, the last mentioned piston being connected to a crank which follows less than 90 degrees behind the movement of the crank to which the first mentioned piston is connected.

27. An internal combustion engine having multiple cylinders, each cylinder having a reciprocating piston and inlet and exhaust passages which are opened by said piston at the end of a working stroke and closed by the return stroke, said inlet passage being also controlled by the piston of another cylinder, and the engine having means for actuating the pistons, whereby the inlet passage of one cylinder is held closed by the piston of another cylinder while the piston of the first mentioned cylinder concludes its working stroke, said actuating means causing the piston of said other cylinder, at the end of its working stroke, to open the inlet passage of the first mentioned cylinder before the piston of the first mentioned cylinder has closed the exhaust port.

28. An explosive engine having at least two cylinders, a piston in each cylinder, and a supply connection for the explosion chamber of each cylinder controlled by the movement of the piston in another cylinder, said pistons being so connected that the piston in each cylinder shall reach its dead points at times different from the times at which the piston in said other cylinder from which the first named cylinder is to be supplied reaches its dead points, substantially as described.

29. An explosive engine having at least two cylinders, a piston in each cylinder, and a supply connection for the explosion chamber of each cylinder controlled by the movement of the piston in another cylinder, said pistons being connected to cranks set at an angle to each other on a common shaft, substantially as described.

30. In an explosive engine, a plurality of cylinders having crank cases, a supply connection for the crank case of each cylinder, a passage connecting the crank case of each cylinder with the explosion chamber of another cylinder, and a piston in each cylinder having a port arranged to control the passage to another cylinder, the several pistons being so connected that the piston in each cylinder shall reach its dead points at times different from the times at which the piston in the cylinder which controls the supply to the first named cylinder reaches its dead points, substantially as described.

31. An explosive engine having multiple cylinders, and pistons therein, and inlet passages, the inlet passage for the explosion chamber of each cylinder being controlled by the piston of another cylinder, the engine also having means for operating said pistons in such a manner that the piston in any cylinder shall be nearer the admission end of the cylinder when the inlet passage to that cylinder opens than when said inlet passage closes, substantially as described.

32. An explosive engine having multiple cylinders, an inlet passage for each cylinder, and a piston in each cylinder, the inlet passage of each cylinder being controlled by the piston in another cylinder, and the engine having means for operating the pistons in such a manner that the piston in any cylinder shall be at a different position at the time its inlet passage is opened from its position at the time such passage is closed, substantially as described.

33. An internal combustion engine having multiple cylinders, each cylinder having a reciprocating piston, a compressing chamber on one side of the piston, a combustion chamber on the opposite side, an outlet duct from the compressing chamber, an exhaust and an inlet port in the combustion chamber, said duct and said exhaust and inlet ports being opened by the piston at the end of a working stroke and closed by the return stroke, the outlet duct from the compressing chamber of one of said cylinders being connected with the combustion chamber inlet port of a second cylinder, the combustion chamber inlet port of the first cylinder being connected with the outlet duct from the compressing chamber of a third cylinder, the outlet duct from the compressing chamber of the second cylinder being connected with the combustion chamber inlet port of a fourth cylinder, the combustion chamber inlet port of the third cylinder being connected with the outlet duct from the compressing chamber of a fifth cylinder, and the outlet duct from the compressing chamber of the fourth cylinder being connected with the combustion chamber inlet port of the fifth cylinder, said pistons being connected to cranks on one crank shaft, the cranks having angular relation to each other to cause the pistons to coöperate to open said ducts as follows: the first mentioned connected duct being opened by the piston in the first cylinder before return movement of the piston in the second cylinder closes the exhaust port therein, the second connected duct being opened by the piston in the third cylinder before return movement of the piston in the first cylinder closes the exhaust port there-

in, the third connected duct being opened by the piston in the second cylinder before return movement of the piston in the fourth cylinder closes the exhaust port therein, the fourth connected duct being opened by the piston in the fifth cylinder before return movement of the piston in the third cylinder closes the exhaust port therein, and the fifth connected duct being opened by the piston in the fourth cylinder before return movement of the piston in the fifth cylinder closes the exhaust port therein.

34. An internal combustion engine comprising a series of cylinders, each cylinder having a reciprocating piston, a combustion chamber on one side of the piston and a compressing chamber on the opposite side, an outlet duct from the compressing chamber, an exhaust and an inlet port in the combustion chamber, said duct and said port being opened by the piston at the end of a working stroke and closed by the return stroke, the compressing chamber having an inlet port which is opened by the piston at the end of a return stroke, the outlet duct from the compressing chamber of each one of said cylinders being connected with the combustion chamber inlet port of another of said cylinders, said pistons being connected to cranks having angular relation to each other on one crank shaft, the piston in any one of said compressing chambers being connected to a crank which follows less than 90 degrees behind the movement of the crank connected to the piston in the combustion chamber which communicates at times with the outlet duct from said compressing chamber whereby a combustible charge admitted to said compressing chamber and compressed by movement of the piston therein until said outlet duct opens, is transferred to said combustion chamber by displacing action of said piston while completing its working stroke simultaneous with said return movement of the piston in said combustion chamber, which finally closes said exhaust and inlet ports therein.

Signed at New York city in the county of New York and State of New York this 9th day of August A. D. 1905.

DONN IRVING TWITCHELL.

Witnesses:

M. TURNER,

M. B. THAYER.